Appendix 7-I: San Jose Creek Water Reclamation Plan East Process Optimization Project Supporting Documents

BLS
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NEWS RELEASE

WEST INFORMATION OFFICE
San Francisco, Calif.

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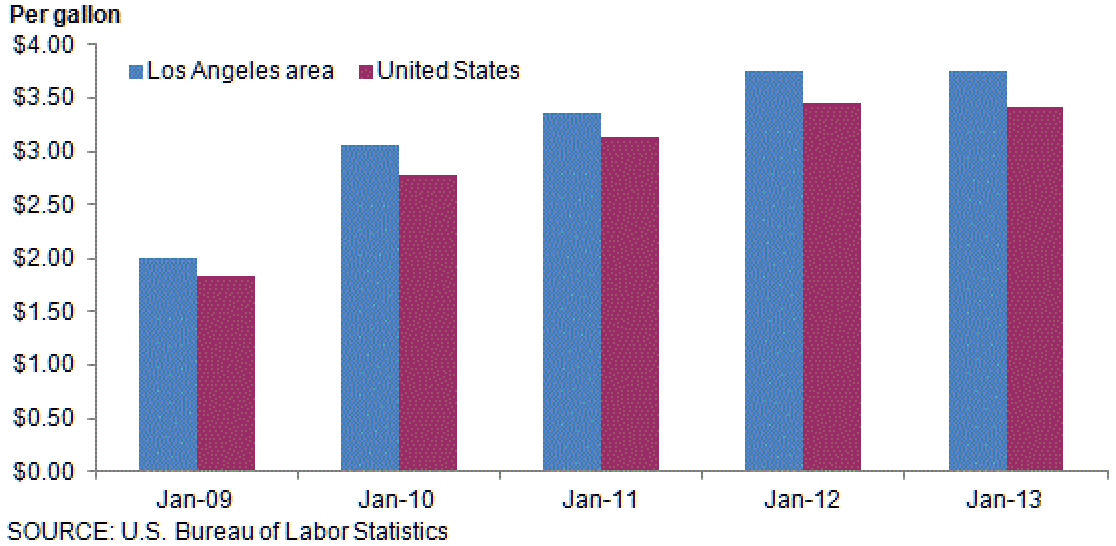
AVERAGE ENERGY PRICES, LOS ANGELES AREA–JANUARY 2013

Gasoline prices averaged $3.749 a gallon in the Los Angeles area in January 2013, the U.S. Bureau of Labor Statistics reported today. Regional Commissioner Richard J. Holden noted that area gasoline prices were similar to last January when they averaged $3.747 per gallon. Los Angeles area households paid an average of 23.2 cents per kilowatt hour (kWh) of electricity in January 2013, up from 20.4 cents per kWh in January 2012. The average cost of utility (piped) gas at $1.013 per therm in January was similar to the $0.996 per therm spent last year. (Data in this release are not seasonally adjusted; accordingly, over-the-year-analysis is used throughout.)

At $3.749 a gallon, Los Angeles area consumers paid 10.0 percent more than the $3.407 national average in January 2013. A year earlier, consumers in the Los Angeles area paid 8.7 percent more than the national average for a gallon of gasoline. The local price of a gallon of gasoline has exceeded the national average by more than six percent in the month of January in each of the past five years. (See chart 1.)

Chart 1. Average prices for gasoline, Los Angeles-Riverside-Orange County and the United States, 2009-2013 (as of January)



SOURCE: U.S. Bureau of Labor Statistics

The 23.2 cents per kWh Los Angeles households paid for electricity in January 2013 was 79.8 percent more than the nationwide average of 12.9 cents per kWh. Last January, electricity costs were 59.4 percent higher in Los Angeles compared to the nation. In the past five years, prices paid by Los Angeles area consumers for electricity exceeded the U.S. average by more than 42 percent in the month of January. (See chart 2.)

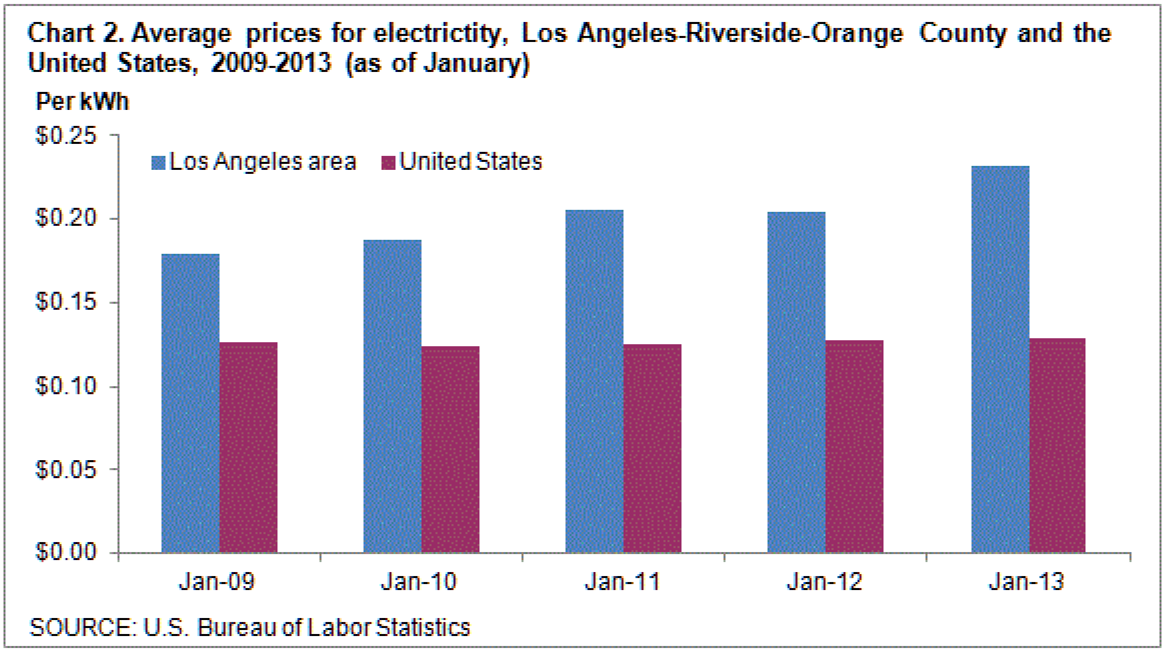


Chart 2. Average prices for electrictity, Los Angeles-Riverside-Orange County and the United States, 2009-2013 (as of January)

SOURCE: U.S. Bureau of Labor Statistics

Prices paid by Los Angeles area consumers for utility (piped) gas, commonly referred to as natural gas, were $1.013 per therm, similar to the national average in January 2013 ($0.996 per therm). A year earlier, area consumers also paid close to the same price per therm for natural gas compared to the nation. In three of the past five years, the per therm cost for natural gas in January in the Los Angeles area has been within three percent of the U.S. average. (See chart 3.)

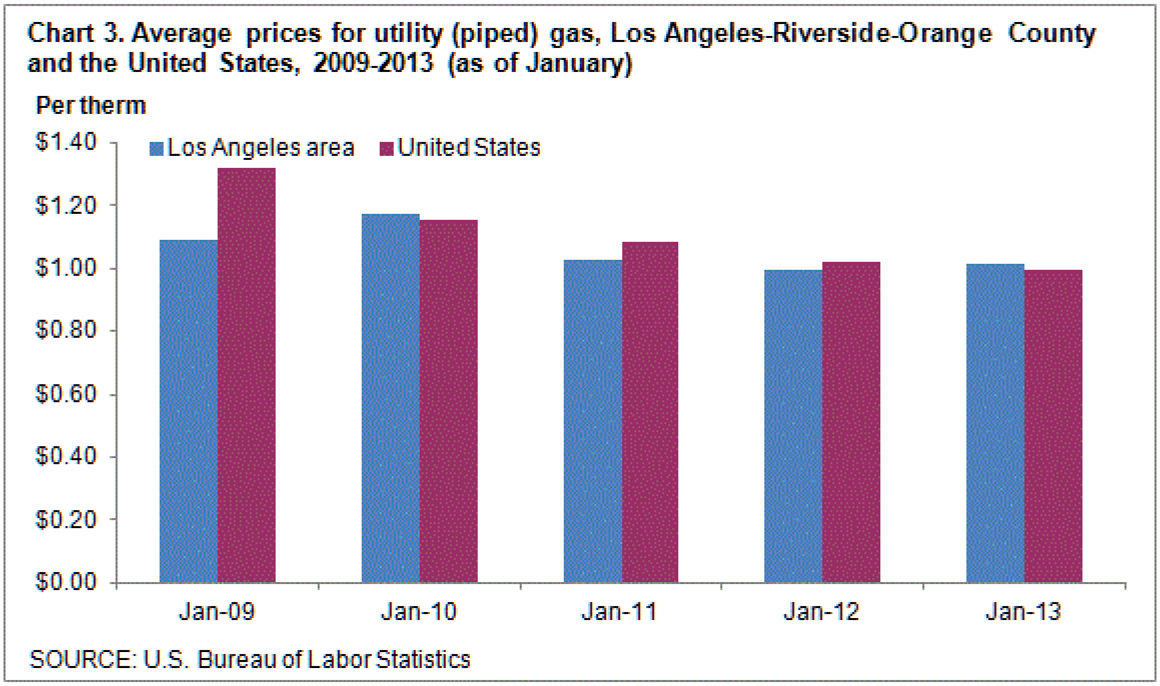


Chart 3. Average prices for utility (piped) gas, Los Angeles-Riverside-Orange County and the United States, 2009-2013 (as of January)

SOURCE: U.S. Bureau of Labor Statistics

The Los Angeles-Riverside-Orange County, Calif. metropolitan area consists of Los Angeles, Orange, Riverside, San Bernardino and Ventura Counties in California.

Technical Note

Average prices are estimated from Consumer Price Index (CPI) data for selected commodity series to support the research and analytic needs of CPI data users. Average prices for electricity, utility (piped) gas, and gasoline are published monthly for the U.S. city average, the 4 regions, the 3 population size classes, 10 region/size-class cross-classifications, and the 14 largest local index areas. For electricity, average prices per kilowatt-hour (kWh) and per 500 kWh are published. For utility (piped) gas, average prices per therm, per 40 therms, and per 100 therms are published. For gasoline, the average price per gallon is published. Average prices for commonly available grades of gasoline are published as well as the average price across all grades.

Price quotes for 40 therms and 100 therms of utility (piped) gas and for 500 kWh of electricity are collected in sample outlets for use in the average price programs only. Since they are for specified consumption amounts, they are not used in the CPI. All other price quotes used for average price estimation are regular CPI data.

With the exception of the 40 therms, 100 therms, and 500 kWh price quotes, all eligible prices are converted to a price per normalized quantity. These prices are then used to estimate a price for a defined fixed quantity.

The average price per kilowatt-hour represents the total bill divided by the kilowatt-hour usage. The total bill is the sum of all items applicable to all consumers appearing on an electricity bill including, but not limited to, variable rates per kWh, fixed costs, taxes, surcharges, and credits. This calculation also applies to the average price per therm for utility (piped) gas.

Information from this release will be made available to sensory impaired individuals upon request. Voice phone: 202-691-5200, Federal Relay Services: 800-877-8339.

Table 1. Average prices for gasoline, electricty, and utility (piped) gas, Los Angeles-Riverside-Orange County and the United States, January 2012-January 2013, not seasonally adjusted

Year and month	Gasoline per gallon		Electricity per kWh		Utillity (piped) gas per therm	
	Los Angeles area	United States	Los Angeles area	United States	Los Angeles area	United States
2012						
January	$3.747	$3.447	$0.204	$0.128	$0.996	$1.021
February	4.013	3.622	0.204	0.128	0.931	0.986
March	4.394	3.918	0.204	0.127	0.931	0.978
April	4.257	3.976	0.204	0.127	0.883	0.951
May	4.333	3.839	0.204	0.129	0.978	0.907
June	4.037	3.602	0.193	0.135	1.054	0.927
July	3.800	3.502	0.193	0.133	1.053	0.943
August	4.073	3.759	0.193	0.133	1.072	0.960
September	4.175	3.908	0.193	0.133	1.027	0.953
October	4.499	3.839	0.211	0.128	1.052	0.962
November	3.924	3.542	0.211	0.127	0.995	0.994
December	3.677	3.386	0.211	0.127	1.042	1.004
2013						
January	3.749	3.407	0.232	0.129	1.013	0.996

The State Water Project

Final Delivery Reliability Report

2011

June 2012

State of California
Natural Resources Agency
Department of Water Resources

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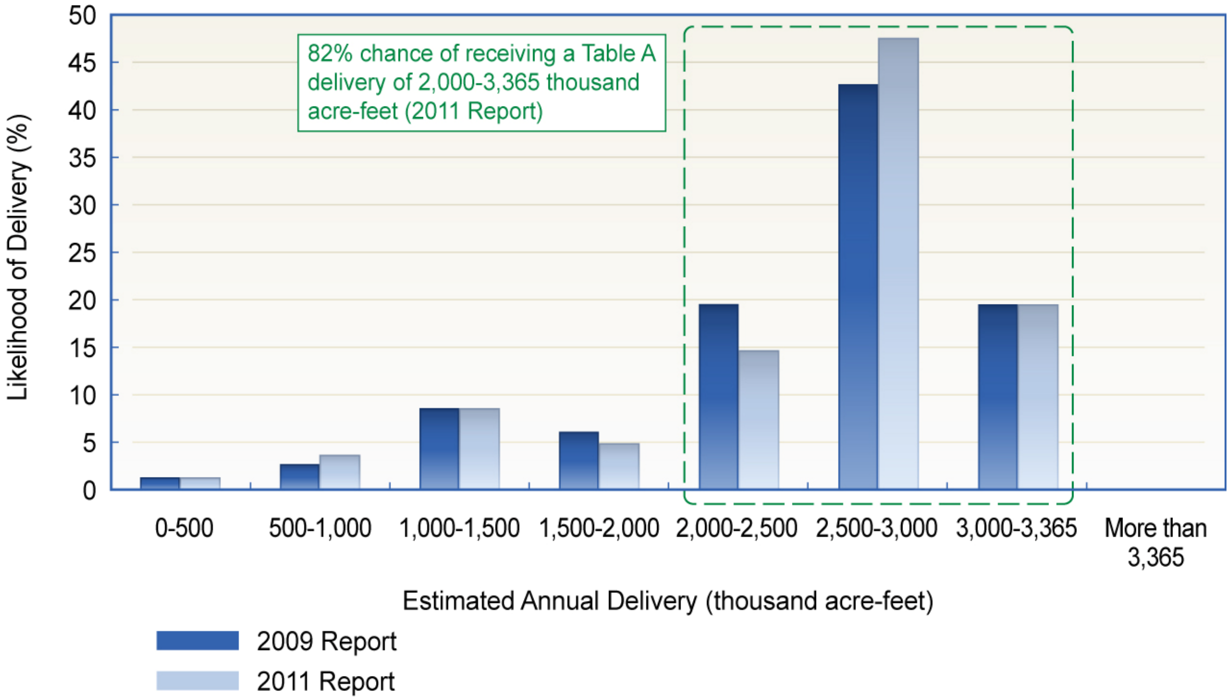

Figure 6-4. Estimated Likelihood of SWP Table A Water Deliveries (Existing Conditions)

Table 6-3. Estimated Average and Dry-Period Deliveries of SWP Table A Water (Existing Conditions), in Thousand Acre-Feet (Percent of Maximum SWP Table A Amount, 4,133 taf/year)

	Long-term Average	Single Dry Year (1977)	2-Year Drought (1976–1977)	4- Year Drought (1931–1934)	6-Year Drought (1987–1992)	6-Year Drought (1929–1934)
2009 Report	2,483 (60%)	302 (7%)	1,496 (36%)	1,402 (34%)	1,444 (35%)	1,398 (34%)
2011 Report	2,524 (61%)	380 (9%)	1,573 (38%)	1,454 (35%)	1,462 (35%)	1,433 (35%)

Table 6-4. Estimated Average and Wet-Period Deliveries of SWP Table A Water (Existing Conditions), in Thousand Acre-Feet (Percent of Maximum SWP Table A Amount, 4,133 taf/year)

	Long-term Average	Single Wet Year (1983)	2-Year Wet (1982–1983)	4-Year Wet (1980–1983)	6-Year Wet (1978–1983)	10-Year Wet (1978–1987)
2009 Report	2,483 (60%)	2,813 (68%)	2,935 (71%)	2,817 (68%)	2,817 (68%)	2,872 (67%)
2011 Report	2,524 (61%)	2,886 (70%)	2,958 (72%)	2,872 (69%)	2,873 (70%)	2,833 (69%)

Analysis of the Energy Intensity of Water Supplies for West Basin Municipal Water District

March, 2007

Robert C. Wilkinson, Ph.D.

Note to Readers

This report for West Basin Municipal Water District is an update and revision of an analysis and report by Robert Wilkinson, Fawzi Karajeh, and Julie Mottin (Hannah) conducted in April 2005. The earlier report, *Water Sources "Powering" Southern California: Imported Water, Recycled Water, Ground Water, and Desalinated Water*, was undertaken with support from the California Department of Water Resources, and it examined the energy intensity of water supply sources for both West Basin and Central Basin Municipal Water Districts. This analysis focuses exclusively on West Basin, and it includes new data for ocean desalination based on new engineering developments that have occurred over the past year and a half.

Principal Investigator: Robert C. Wilkinson, Ph.D.

Dr. Wilkinson is Director of the Water Policy Program at the Donald Bren School of Environmental Science and Management, and Lecturer in the Environmental Studies Program, at the University of California, Santa Barbara. His teaching, research, and consulting focuses on water policy, climate change, and environmental policy issues. Dr. Wilkinson advises private sector entities and government agencies in the U.S. and internationally. He currently served on the public advisory committee for California's 2005 State Water Plan, and he represented the University of California on the Governor's Task Force on Desalination.
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West Basin
Municipal Water District

West Basin Municipal Water District

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Overview

Southern California relies on imported and local water supplies for both potable and non-potable uses. Imported water travels great distances and over significant elevation gains through both the California State Water Project (SWP) and Colorado River Aqueduct (CRA) before arriving in Southern California, consuming a large amount of energy in the process. Local sources of water often require less energy to provide a sustainable supply of water. Three water source alternatives which are found or produced locally and could reduce the amount of imported water are desalinated ocean water, groundwater, and recycled water. Groundwater and recycled water are significantly less energy intensive than imports, while ocean desalination is getting close to the energy intensity of imports.

Energy requirements vary considerably between these four water sources. All water sources require pumping, treatment, and distribution. Differences in energy requirements arise from the varying processes needed to produce water to meet appropriate standards. This study examines the energy needed to complete each process for the waters supplied by West Basin Municipal Water District (West Basin).

Specific elements of energy inputs examined in this study for each water source are as follows:

- Energy required to **import water** includes three processes: pumping California SWP and CRA supplies to water providers; treating water to applicable standards; and distributing it to customers.
- **Desalination of ocean water** includes three basic processes: 1) pumping water from the ocean or intermediate source (e.g. a powerplant) to the desalination plant; 2) pre-treating and then desalting water including discharge of concentrate; and 3) distributing water from the desalination plant to customers.
- **Groundwater** usage requires energy for three processes: pumping groundwater from local aquifers to treatment facilities; treating water to applicable standards; and distributing water from the treatment plant to customers. Additional injection energy is sometimes needed for groundwater replenishment.
- Energy required to **recycle water** includes three processes: pumping water from secondary treatment plants to tertiary treatment plants; tertiary treatment of the water, and distributing water from the treatment plant to customers.

The energy intensity results of this study are summarized in the table on the following page. They indicate that recycled water is among the least energy-intensive supply options available, followed by groundwater that is naturally recharged and recharged with recycled water. Imported water and ocean desalination are the most energy intensive water supply options in California. East Branch State Water Project water is close in energy intensity to desalination figures based on current technology, and at some points along the system, SWP supplies exceed estimated ocean desalination energy intensity. The following table identifies energy inputs to each of the water supplies including estimated energy requirements for desalination. Details describing the West Basin system operations are included in the water source sections. Note that the Title 22 recycled water energy figure reflects only the *marginal* energy required to treat secondary effluent wastewater which has been processed to meet legal discharge requirements, along with the energy to convey it to user

Energy Intensity of Water Supplies for West Basin Municipal Water District

	af/yr	Percentage of Total Source Type	kWh/af Conveyance Pumping	kWh/af MWD Treatment	kWh/af Recycled Treatment	kWh/af Groundwater Pumping	kWh/af Groundwater Treatment	kWh/af Desalination	kWh/af WBMWD Distribution	Total kWh/af	Total kWh/year
Imported Deliveries											
State Water Project (SWP) [1]	57,559	43%	3,000	44	NA	NA	NA	NA	0	3,044	175,209,596
Colorado River Aqueduct (CRA) [1] (other that replenishment water)	76,300	57%	2,000	44	NA	NA	NA	NA	0	2,044	155,957,200
Groundwater[2]											
natural recharge	19,720	40%	NA	NA	NA	350	0	NA	0	350	6,902,030
replenished with (injected) SWP water [1]	9,367	19%	3,000	44	NA	350	0	NA	0	3,394	31,791,598
replenished with (injected) CRA water [1]	11,831	24%	2,000	44	NA	350	0	NA	0	2,394	28,323,432
replenished with (injected) recycled water	8,381	17%	205	0	790	350	0	NA	220	1,565	13,116,278
Recycled Water											
West Basin Treatment, Title 22	21,506	60%	205	NA	0	NA	NA	NA	285	490	10,537,940
West Basin Treatment, RO	14,337	40%	205	NA	790	NA	NA	NA	285	1,280	18,351,360
Ocean Desalination	20,000	100%	200	NA	NA	NA	NA	3,027	460	3,687	82,588,800

Notes:

NA Not applicable

[1] Imported water based on percentage of CRA and SWP water MWD received, averaged over an 11-year period. Note that the figures for imports do not include an accounting for system losses due to evaporation and other factors. These losses clearly exist, and an estimate of 5% or more may be reasonable. The figures for imports above should therefore be understood to be conservative (that is, the actual energy intensity is in fact higher for imported supplies than indicated by the figures).

[2] Groundwater values include entire basin, West Basin service area covers approximately 86% of the basin. Groundwater values are specific to aquifer characteristics, including depth, within the basin.

Energy Intensity of Water

Water treatment and delivery systems in California, including extraction of "raw water" supplies from natural sources, conveyance, treatment and distribution, end-use, and wastewater collection and treatment, account for one of the largest energy uses in the state.[1] The California Energy Commission estimated in its 2005 Integrated Energy Policy Report that approximately 19% of California's electricity is used for water related purposes including delivery, end-uses, and wastewater treatment.[2] The total energy embodied in a unit of water (that is, the amount of energy required to transport, treat, and process a given amount of water) varies with location, source, and use within the state. In many areas, the energy intensity may increase in the future due to limits on water resource extraction, and regulatory requirements for water quality, and other factors.[3] Technology improvements may offset this trend to some extent.

Energy intensity is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.

The Water-Energy Nexus

Water and energy systems are interconnected in several important ways in California. Water systems both provide energy – through hydropower – and consume large amounts of energy, mainly through pumping. Critical elements of California's water infrastructure are highly energy-intensive. Moving large quantities of water long distances and over significant elevation gains, treating and distributing it within the state's communities and rural areas, using it for various purposes, and treating the resulting wastewater, accounts for one of the largest uses of electrical energy in the state.[4]

Improving the efficiency with which water is used provides an important opportunity to increase related energy efficiency. ("*Efficiency*" as used here describes the useful work or service provided by a given amount of water.) Significant potential economic as well as environmental benefits can be cost-effectively achieved in the energy sector through efficiency improvements in the state's water systems and through shifting to less energy intensive local sources. The California Public Utilities Commission is currently planning to include water efficiency improvements as a means of achieving energy efficiency benefits for the state.[5]

Overview of Energy Inputs to Water Systems

There are four principle energy elements in water systems:

1. primary water extraction and supply delivery (imported and local)
2. treatment and distribution within service areas
3. on-site water pumping, treatment, and thermal inputs (heating and cooling)

4. wastewater collection, treatment, and discharge

Pumping water in each of these four stages is energy-intensive. Other important components of embedded energy in water include groundwater pumping, treatment and pressurization of water supply systems, treatment and thermal energy (heating and cooling) applications at the point of end-use, and wastewater pumping and treatment.[6]

1. Primary water extraction and supply delivery

Moving water from near sea-level in the Sacramento-San Joaquin Delta to the San Joaquin-Tulare Lake Basin, the Central Coast, and Southern California, and from the Colorado River to metropolitan Southern California, is highly energy intensive. Approximately 3,236 kWh is required to pump one acre-foot of SWP water to the end of the East Branch in Southern California, and 2,580 kWh for the West Branch. About 2,000 kWh is required to pump one acre foot of water through the CRA to southern California.[7] Groundwater pumping also requires significant amounts of energy depending on the depth of the source. (Data on groundwater is incomplete and difficult to obtain because California does not systematically manage groundwater resources.)

2. Treatment and distribution within service areas

Within local service areas, water is treated, pumped, and pressurized for distribution. Local conditions and sources determine both the treatment requirements and the energy required for pumping and pressurization.

3. On-site water pumping, treatment, and thermal inputs

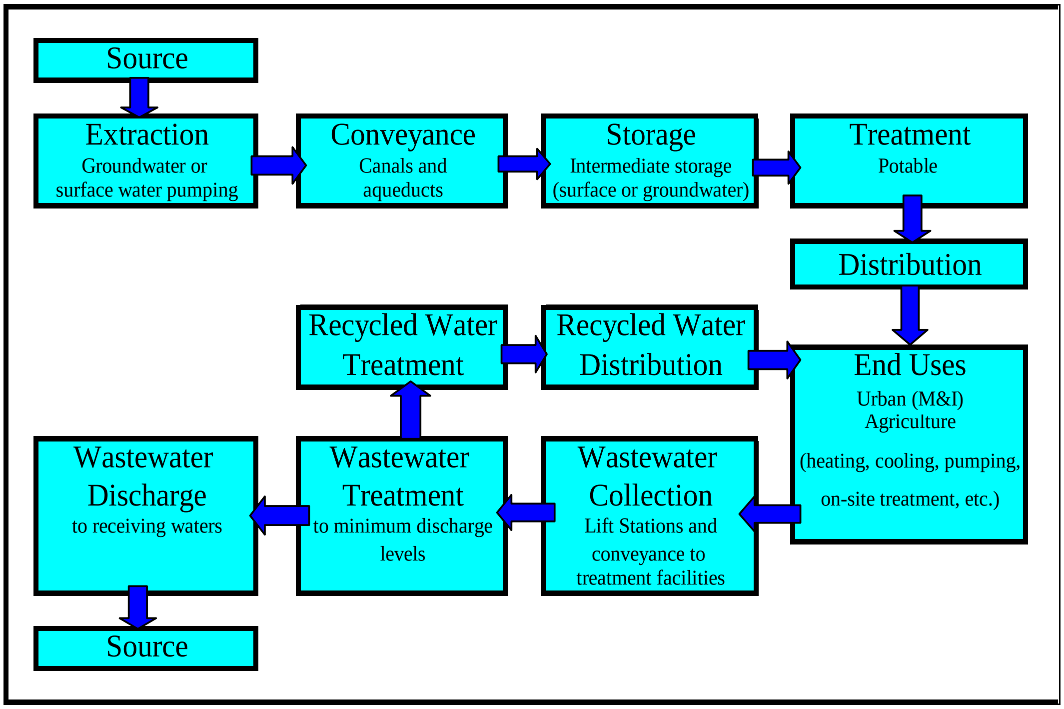
Individual water users use energy to further treat water supplies (e.g. softeners, filters, etc.), circulate and pressurize water supplies (e.g. building circulation pumps), and heat and cool water for various purposes.

4. Wastewater collection, treatment, and discharge

Finally, wastewater is collected and treated by a wastewater authority (unless a septic system or other alternative is being used). Wastewater is often pumped to treatment facilities where gravity flow is not possible, and standard treatment processes require energy for pumping, aeration, and other processes. (In cases where water is reclaimed and re-used, the calculation of total energy intensity is adjusted to account for wastewater as a *source* of water supply. The energy intensity generally includes the additional energy for treatment processes beyond the level required for wastewater discharge, plus distribution.)

The simplified flow chart below illustrates the steps in the water system process. A spreadsheet computer model is available to allow cumulative calculations of the energy inputs embedded at each stage of the process. This methodology is consistent with that applied by the California Energy Commission in its analysis of the energy intensity of water.

Simplified Flow Diagram of Energy Inputs to Water Systems



Source: Robert Wilkinson, UCSB[8]

Calculating Energy Intensity

Total energy intensity, or the amount of energy required to facilitate the use of a given amount of water in a specific location, may be calculated by accounting for the summing the energy requirements for the following factors:

- imported supplies
- local supplies
- regional distribution
- treatment
- local distribution
- on-site thermal (heating or cooling)
- on-site pumping
- wastewater collection
- wastewater treatment

Water pumping, and specifically the long-distance transport of water in conveyance systems, is a major element of California’s total demand for electricity as noted above. Water use (based on embedded energy) is the next largest consumer of electricity in a typical Southern California home after refrigerators and air conditioners. Electricity required to support water service in the typical home in Southern California is estimated at between 14% to 19% of total residential energy demand.[9] If air conditioning is not a factor the figure is even higher. Nearly three quarters of this energy demand is for pumping imported water.

Interbasin Transfers

Some of California’s water systems are uniquely energy-intensive, relative to national averages, due to the pumping requirements of major conveyance systems which move large volumes of water long distances and over thousands of feet in elevation lift. Some of the interbasin transfer systems (systems that move water from one watershed to another) are net energy producers, such as the San Francisco and Los Angeles aqueducts. Others, such as the SWP and the CRA require large amounts of electrical energy to convey water. On *average*, approximately 3,000 kWh is necessary to pump one AF of SWP water to southern California,[10] and 2,000 kWh is required to pump one AF of water through the CRA to southern California.[11]

Total energy savings for reducing the full embedded energy of *marginal* (e.g. imported) supplies of water used indoors in Southern California is estimated at about 3,500 kWh/af.[12] Conveyance over long distances and over mountain ranges accounts for this high marginal energy intensity. In addition to avoiding the energy and other costs of pumping additional water supplies, there are environmental benefits through reduced extractions from stressed ecosystems such as the delta.

Imported Water:
The State Water Project and the Colorado River Aqueduct

Water diversion, conveyance, and storage systems developed in California in the 20th century are remarkable engineering accomplishments. These water works move millions of AF of water around the state annually. The state’s 1,200-plus reservoirs have a total storage capacity of more than 42.7 million acre feet (maf).[13] West Basin receives imported water from Northern California through the State Water Project and Colorado River water via the Colorado River Aqueduct. The Metropolitan Water District of Southern California delivers both of these imported water supplies to the West Basin.

California’s Major Interbasin Water Projects

The State Water Project

The State Water Project (SWP) is a state-owned system. It was built and is managed by the California Department of Water Resources (DWR). The SWP provides supplemental water for agricultural and urban uses.[14] SWP facilities include 28 dams and reservoirs, 22 pumping and generating plants, and nearly 660 miles of aqueducts.[15] Lake Oroville on the Feather River, the project’s largest storage facility, has a total capacity of about 3.5 maf.[16] Oroville Dam is the tallest and one of the largest earth-fill dams in the United States.[17]

Water is pumped out of the delta for the SWP at two locations. In the northern Delta, Barker Slough Pumping Plant diverts water for delivery to Napa and Solano counties through the North Bay

Aqueduct.[18] Further south at the Clifton Court Forebay, water is pumped into Bethany Reservoir by the Banks Pumping Plant. From Bethany Reservoir, the majority of the water is conveyed south in the 444-mile-long Governor Edmund G. Brown California Aqueduct to agricultural users in the San Joaquin Valley and to urban users in Southern California. The South Bay Pumping Plant also lifts water from the Bethany Reservoir into the South Bay Aqueduct. [19]

The State Water Project is the largest consumer of electrical energy in the state, requiring an average of 5,000 GWh per year.[20] The energy required to operate the SWP is provided by a combination of DWR’s own hydroelectric and other generation plants and power purchased from other utilities. The project’s eight hydroelectric power plants, including three pumping-generating plants, and a coal-fired plant produce enough electricity in a normal year to supply about two-thirds of the project's necessary power.

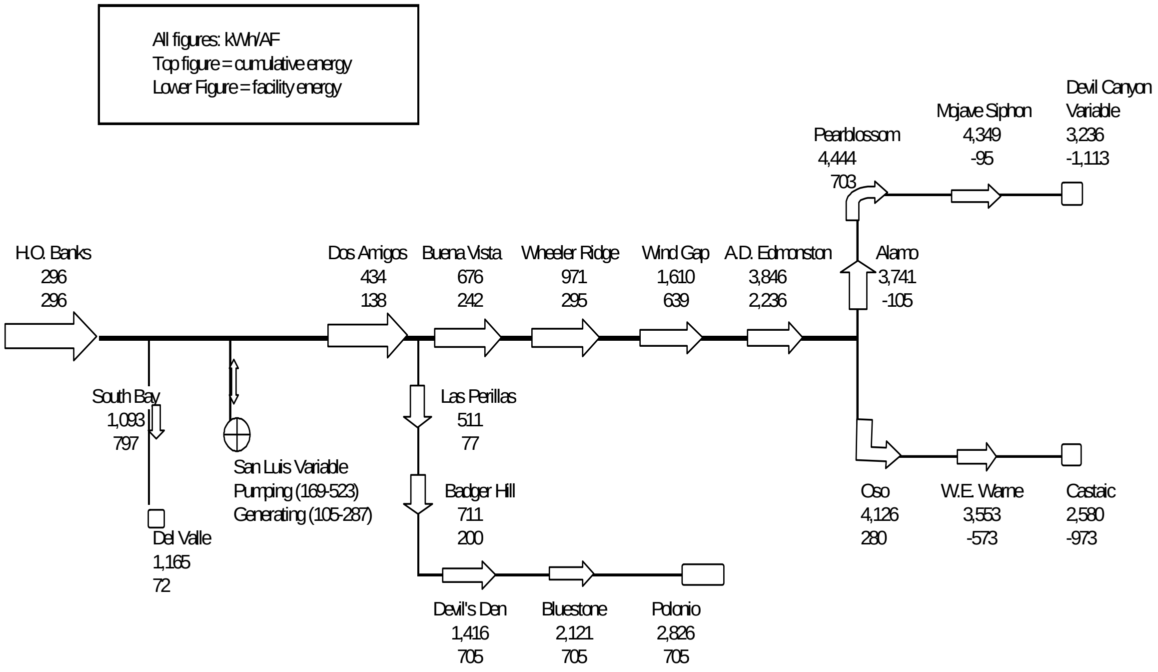
Energy requirements would be considerably higher if the SWP was delivering full contract volumes of water. The project delivered an average of approximately 2.0 mafy, or half its contracted volumes, throughout the 1980s and 1990s.[21] Since 2000 the volumes of imported water have generally increased.

The following map indicates the location of the pumping and power generation facilities on the SWP.

Names and Locations of Primary State Water Delivery Facilities

The following schematic shows each individual pumping unit on the State Water Project, along with data for both the individual and cumulative energy required to deliver an AF of water to that point in the system. Note that the figures include energy recovery in the system, but they do not account for losses due to evaporation and other factors. These losses may be in the range of 5% or more. While more study of this issue is in order, it is important to observe that the energy intensity numbers are conservative (e.g. low) in that they assume that all of the water originally pumped from the delta reaches the ends of the system without loss.

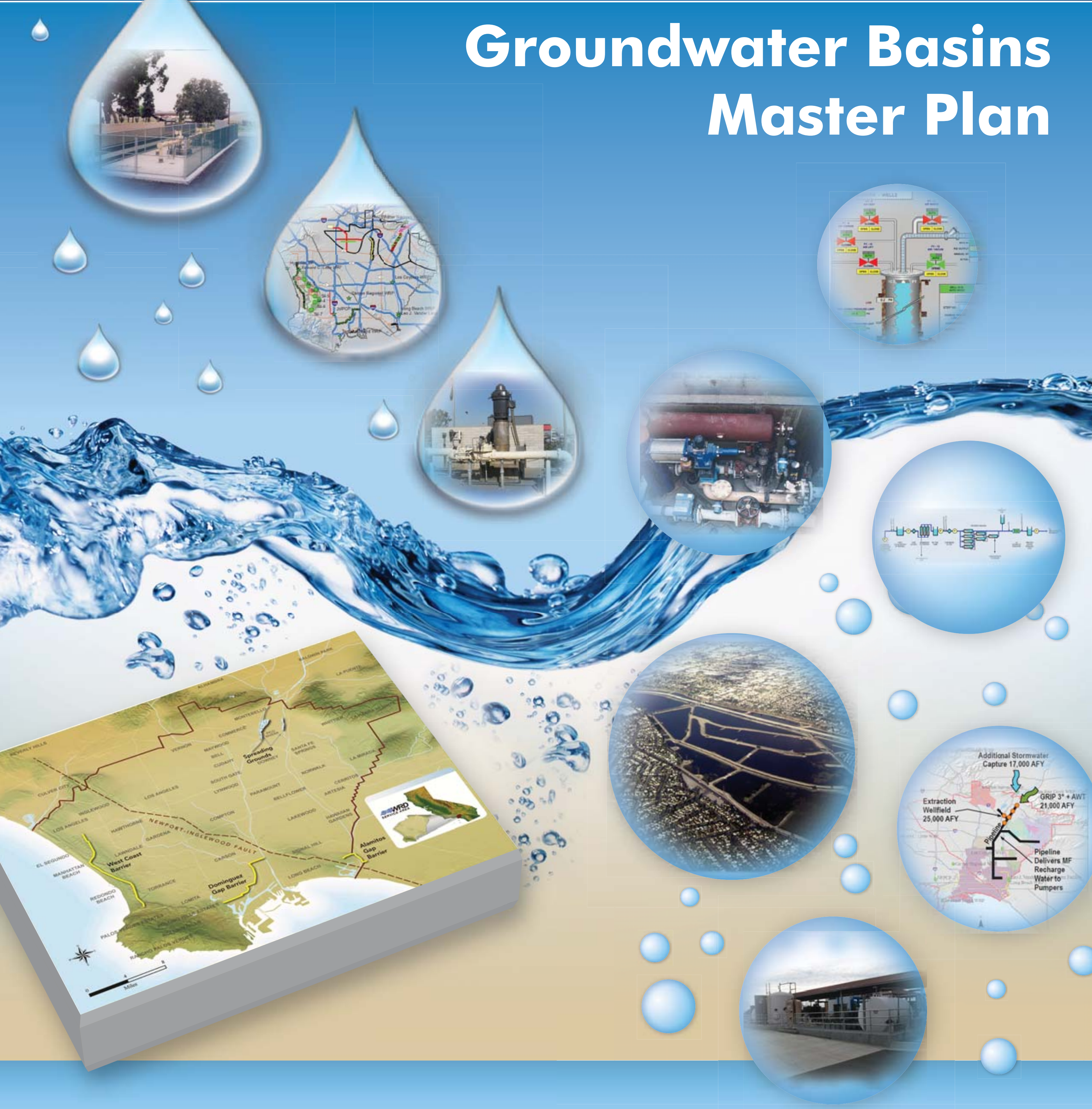
State Water Project
Kilowatt-Hours per Acre Foot Pumped
(Includes Transmission Losses)



Source: Wilkinson, based on data from: California Department of Water Resources, State Water Project Analysis Office, Division of Operations and Maintenance, *Bulletin 132-97*, 4/25/97.

Draft Report

Groundwater Basins Master Plan



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Water and Environment

Prepared for

WRD
Water Replenishment District of Southern California

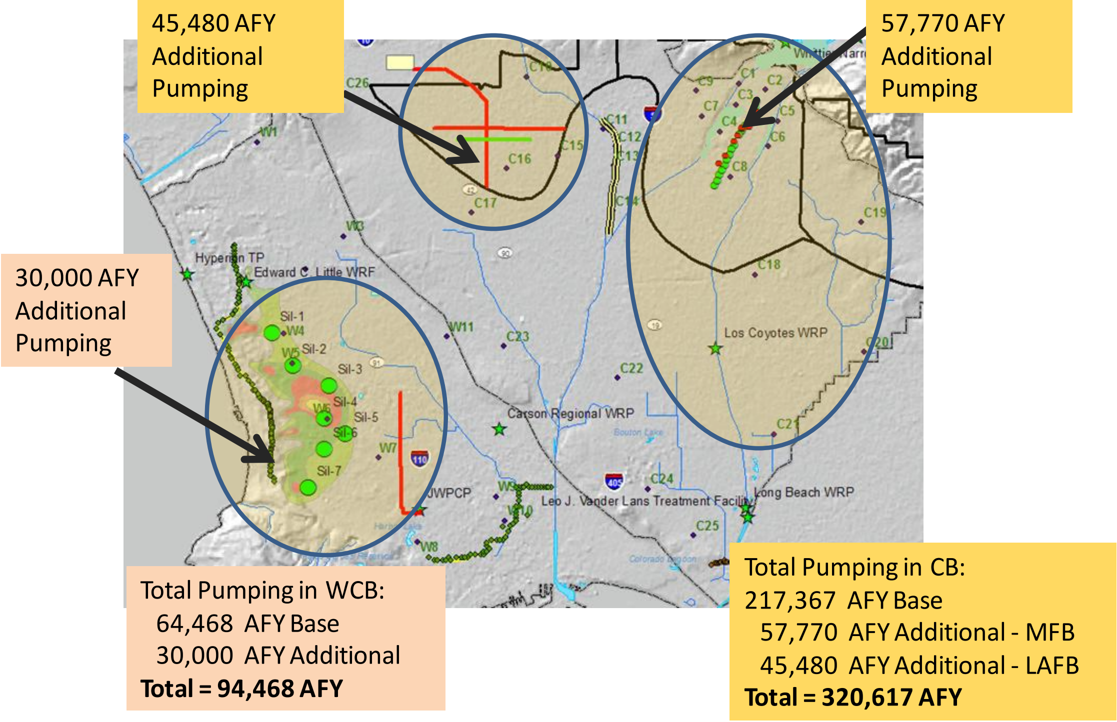
July 2012

Executive Summary

The Water Replenishment District of Southern California (WRD), in coordination with other basin stakeholders, has developed this Draft Groundwater Basins Master Plan (GBMP). The intent of this plan is to provide a single reference document for parties operating within and maintaining the West Coast and Central groundwater basins. This GBMP complements the efforts of the **W**ater **I** ndependence **N**ow (WIN) program by identifying projects and programs to enhance basin replenishment, increase the reliability of groundwater resources, improve and protect groundwater quality, and ensure that the groundwater supplies are suitable for beneficial uses.

This GBMP identifies opportunities to develop supplemental replenishment water supplies to further utilize the West Coast and Central Basins. The key objective for creating additional replenishment water supply is to significantly reduce imported water use by providing for increased pumping from these basins. This GBMP focuses on developing concepts to generate additional water supply of as much as 1) 30,000 acre-feet per year (AFY) above the current water rights in the West Coast Basin for a total annual pumping quantity of 94,468 AFY, and 2) 103,250 AFY above the current Central Basin Allowed Pumping Allocation (APA), or a total annual pumping quantity of 320,617 AFY (Figure ES-1). Note that the current pumping in both the basins is below the adjudicated and allowable limits. The increases in water supplies were considered as a stepwise process, first assuming the pumping matches the adjudicated and allowable limits and then adding supplies in order to allow increased pumping above the adjudicated and allowable limits in both basins. The stepwise increase in water supplies approach considered the use of low-cost water supplies first, and then the use of more costly water supplies to further increase replenishment, thus allowing increased pumping. Provided below is a detailed conceptual approach used for the development of scenarios and alternatives (developed in coordination with stakeholders), and testing of scenarios using an updated WRD/U.S. Geological Survey (USGS) MODFLOW groundwater flow model, which led to the goal of maximizing the development of the groundwater supplies.

FIGURE ES-1
Conceptualization of Water Supplies for Pumping with Increased Utilization of the West Coast and Central Basins



Notes:

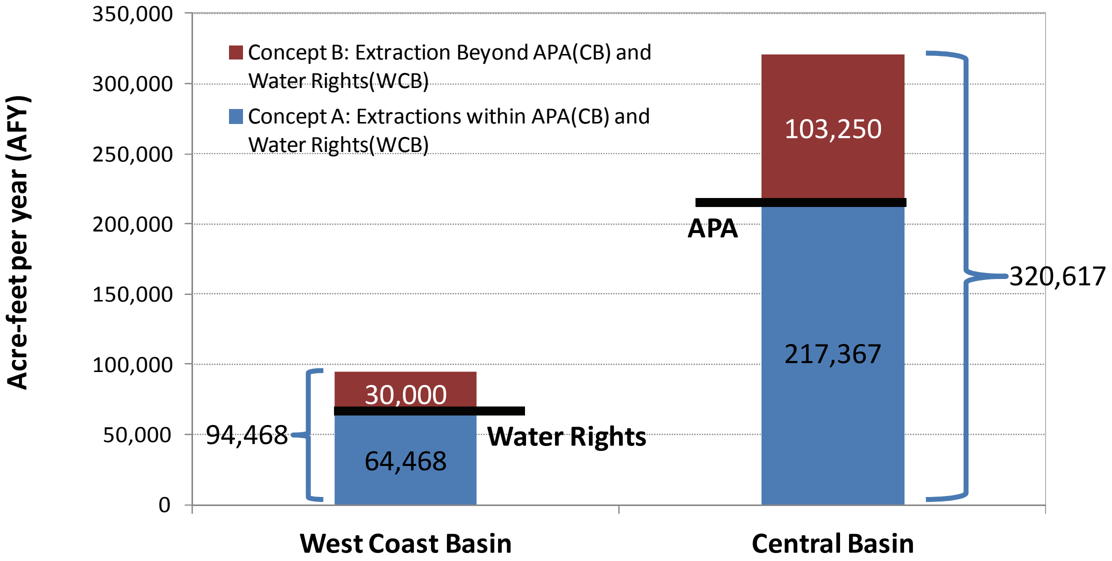
CB = Central Basin
MFB = Montebello Forebay
LAFB = Los Angeles Forebay
WCB = West Coast Basin

The development of the GBMP followed a phased approach. Phase 1 of the study began with the focus on the West Coast Basin in March 2010 and Central Basin in November 2010. Stakeholder workshops were held with the West Coast Basin and Central Basin stakeholders and pumpers to discuss the baseline operating conditions, increased utilization of the groundwater basins, and proposed management alternatives to develop initial concepts. The initial concepts were further refined based on stakeholder feedback. With the concepts established, Phase 2 detailed analyses of the West Coast Basin and Central Basin alternatives commenced, including groundwater modeling and cost evaluations. The basin stakeholders that have been engaged in this process include water purveyors and pumpers with water rights (including local refineries), water wholesalers (Metropolitan Water District of Southern California member agencies), and recycled water providers.

To meet the overall goal of the GBMP, Concepts A and B were defined as described below:

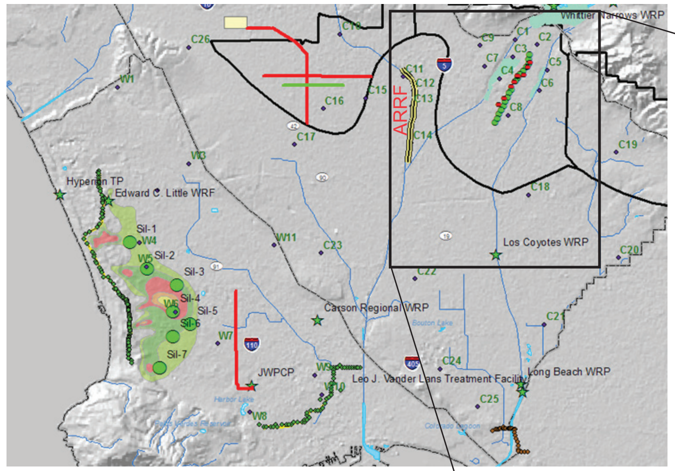
Concept A: This concept is based on increased pumping from the current pumping levels up to the total adjudicated and allowable limits in both basins (Figure ES-2), which is 64,468 AFY in the West Coast Basin and an APA of 217,367 AFY in the Central Basin.

FIGURE ES-2
Conceptualization of Concepts A and B in the West Coast and Central Basins



Concept B: This concept, as shown in Figure ES-2, is based on increased pumping for up to 30,000 AFY above the current West Coast Basin water rights, or 94,468 AFY. Under this concept, pumping in the Central Basin is increased up to 103,250 AFY above the current APA, or a total supply of 320,617 AFY to offset nearly the entire imported water use in this basin.

Figures ES-3 through ES-5 provide schematic representations of how the West Coast and Central Basins could be further developed to increase use of local supplies and reduce dependence on imported water. As shown in Figure ES-3, additional stormwater and recycled water could be developed in the Montebello Forebay. Additional stormwater could be captured from the San Gabriel River through increased recharge at the Montebello Forebay Spreading Grounds (MFSG). However, as this increased recharge causes mounding of groundwater, which limits recharge, it is necessary to add additional groundwater extraction to limit the rise of groundwater levels from this increased recharge. The Forebay Increased Extraction-Intrabasin Transfer (FIX-IT) project is proposed to provide for 25,000 AFY of extraction and a pipeline to deliver water to participating pumpers as far south as Long Beach, which will allow for the increased stormwater capture. In addition, approximately 5,000 AFY of stormwater could be captured from the Los Angeles River through an Aquifer Recharge and Recovery Project (ARRF), which is a unique facility to capture stormwater, provide for soil aquifer treatment (SAT) and injection into the Central Basin aquifers for recovery by participating pumpers. In summary, up to 22,000 AFY of stormwater could potentially be developed as part of the GBMP.



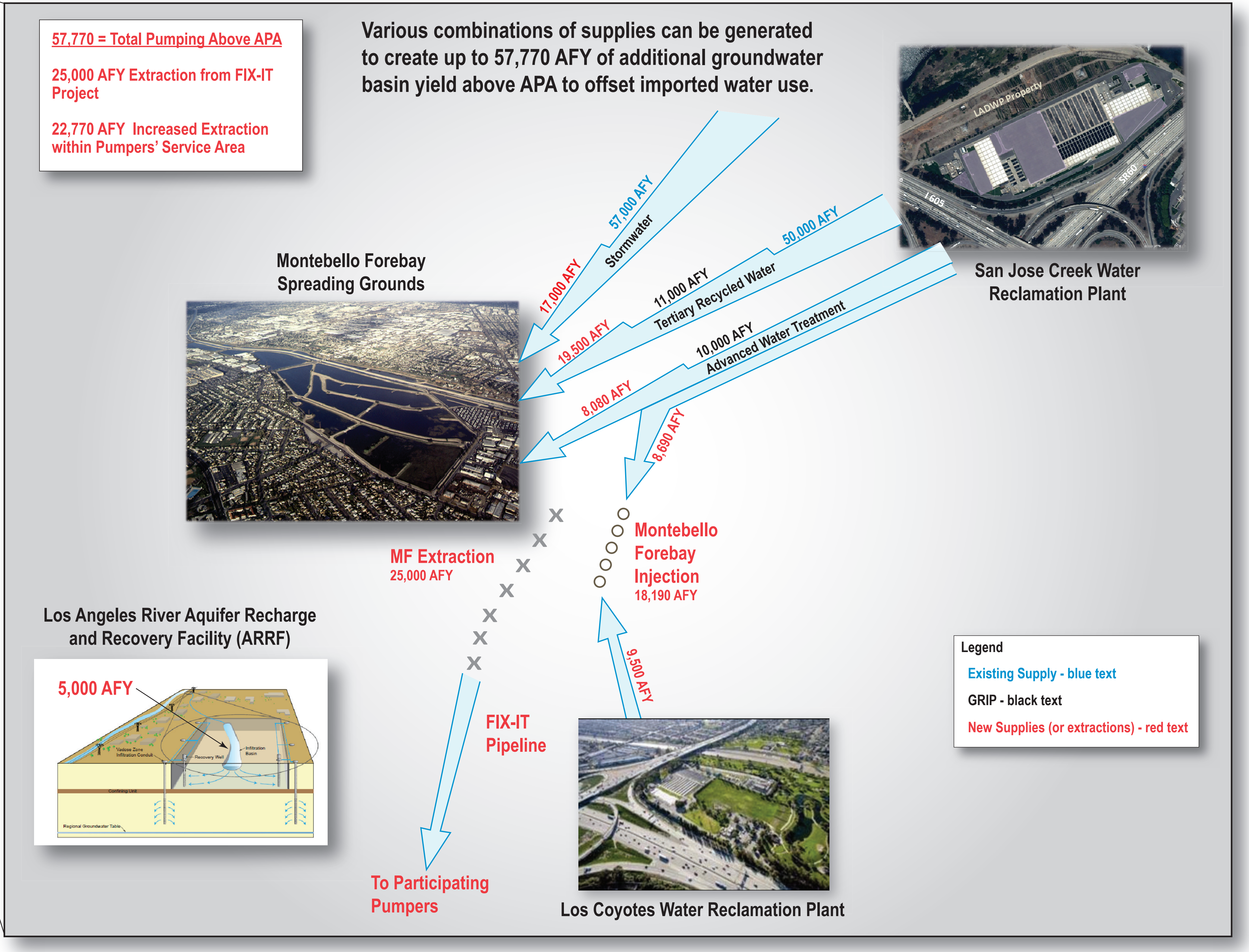
Alternative combinations of available stormwater, tertiary recycled water and advanced treated recycled water supplies are described in this GBMP. Ultimately 57,770 AFY of additional groundwater production could be developed from these supplies which can be pumped to offset imported water demands.

Potential New Supplies	
17,000	AFY stormwater
19,500	AFY tertiary
16,770	AFY (8,690 + 8,080) advanced
9,500	AFY Advanced
5,000	AFY (ARRF)
67,770	AFY
-10,000	AFY
57,770	AFY

Replenishment to provide for 217,367 AFY of APA pumping

57,000	AFY surface water
50,000	AFY tertiary
11,000	AFY GRIP tertiary
10,000	AFY GRIP advanced
10,000	AFY
138,000	AFY

57,770 AFY	Additional Pumping yield to offset imported water demand
25,000 AFY	FIX-IT Project Pumping to prevent mounding at spreading grounds
22,770 AFY	Increased Extraction within pumpers' service areas



57,770 = Total Pumping Above APA

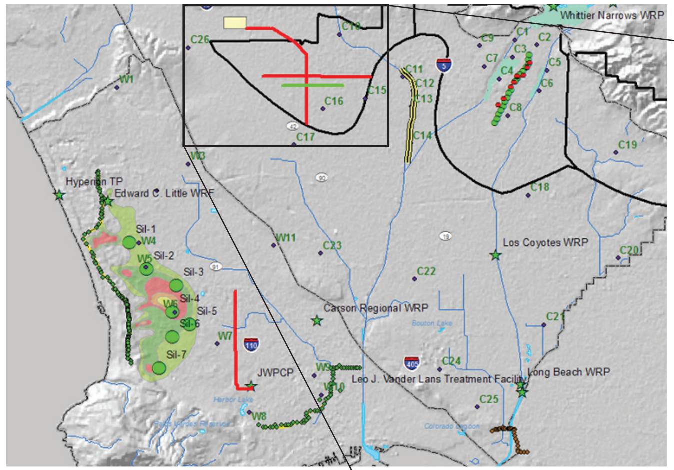
25,000 AFY Extraction from FIX-IT Project

22,770 AFY Increased Extraction within Pumpers' Service Area

Various combinations of supplies can be generated to create up to 57,770 AFY of additional groundwater basin yield above APA to offset imported water use.

FIGURE ES-3
Potential Development of Montebello Forebay to provide for full utilization of Central Basin APA and to expand beyond APA by 57,770 AFY.
Groundwater Basins Master Plan

CH2MHILL.



Sewer flows going to the City of Los Angeles' Hyperion Treatment Plant could be intercepted and treated by a newly constructed advanced water treatment facility (AWTF). This high quality recycled water could be injected in the Los Angeles' Forebay for replenishment of the Central Basin. 50 new injection wells could be constructed to inject the recycled water. 21 new extraction wells could extract 29,000 AFY for delivery to the City of Los Angeles and participating pumpers could extract the remaining 16,480 AFY to offset imported water demands.

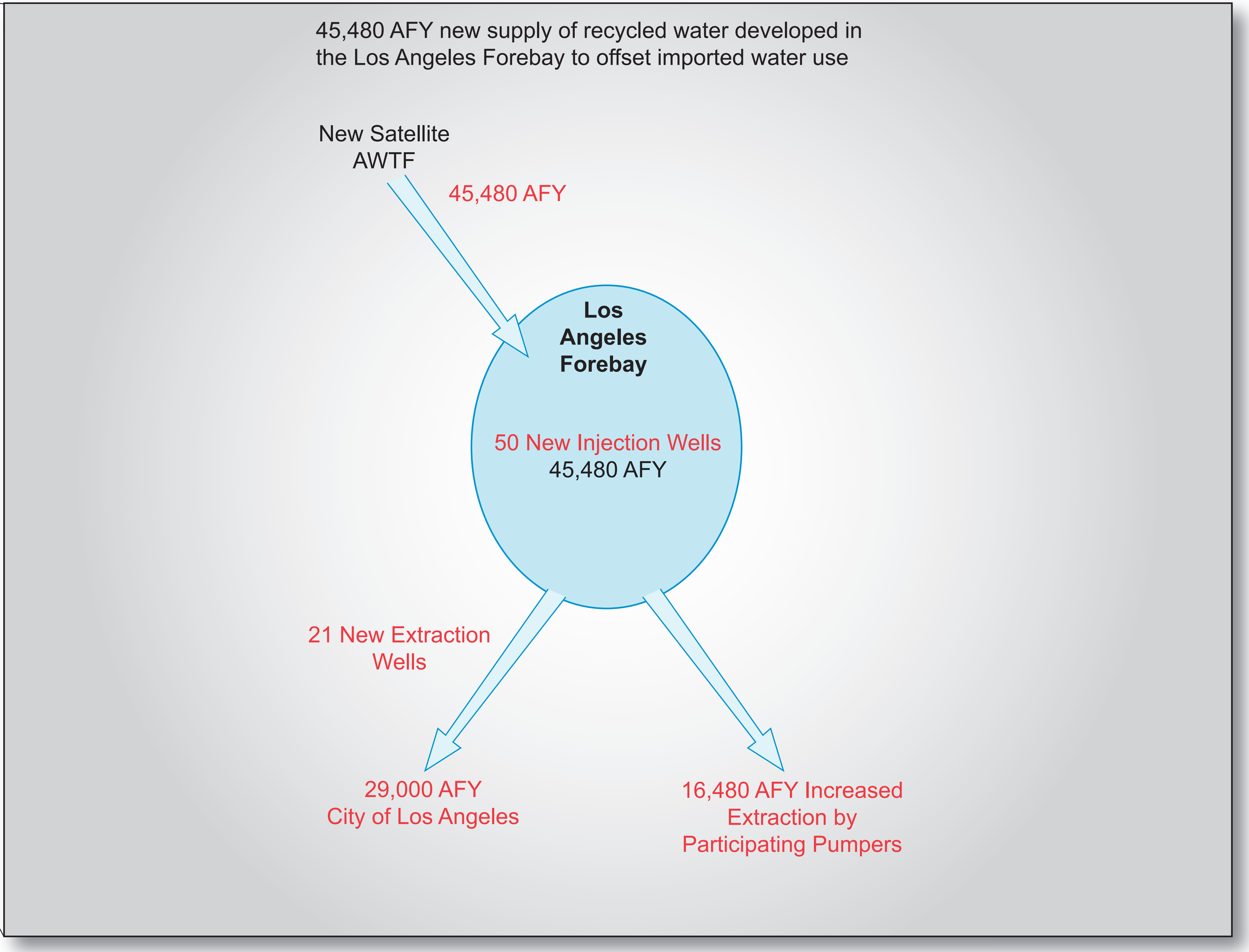
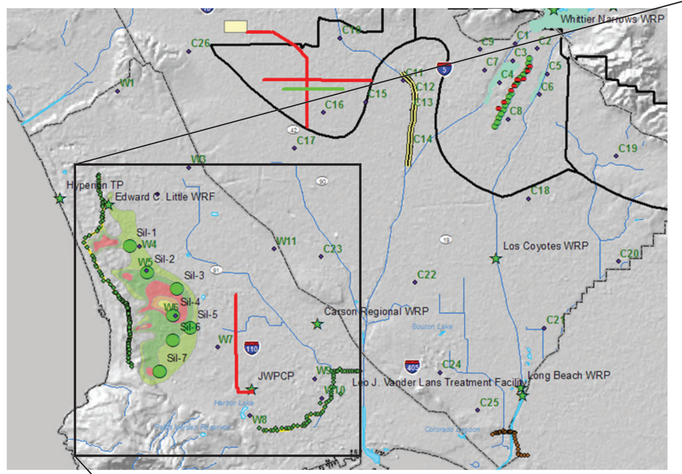


FIGURE ES-4
Potential Development of Los Angeles Forebay Area to Provide for Expanded Pumping Beyond APA by up to 45,480 AFY
Groundwater Basins Master Plan



In the West Coast Basin, recycled water supplies are available from the City of Los Angeles' Hyperion Treatment Plant and Terminal Island Water Reclamation Plant, and the Los Angeles County Sanitation Districts Joint Water Pollution Control Plant. These supplies can be used for injection to first meet replenishment requirements for pumping water rights (WR), then expanded to provide up to 30,000 AFY of pumping above water rights of 64,468 AFY as follows:

Potential New Supplies

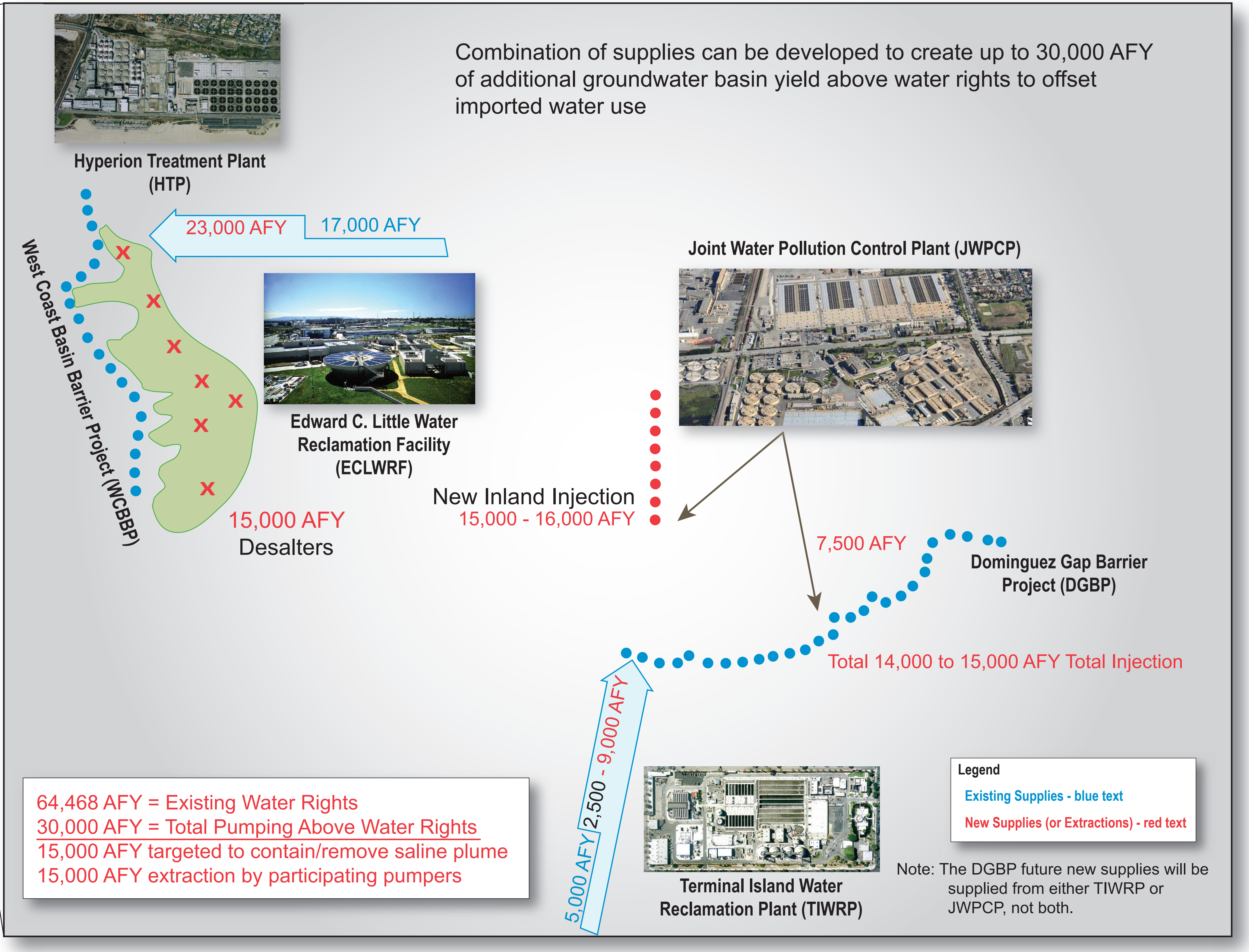
23,000	23,000 AFY	HTP/ECLWRF
22,500	16,000 AFY	JWPCP
2,500*	9,000 AFY	TIWRP
48,000	48,000 AFY	
-18,000	-18,000 AFY	
30,000	30,000 AFY	

Replenishment Required to Meet WR

17,000 AFY	HTP/ECLWRF
5,000 AFY	TIWRP
18,000 AFY	
40,000 AFY	

30,000 AFY	Additional Pumping Yield Above Water Rights
15,000 AFY	Desalters targeted to remove salts
15,000 AFY	Increased extraction to participating pumpers

* Currently Planned



Combination of supplies can be developed to create up to 30,000 AFY of additional groundwater basin yield above water rights to offset imported water use

Hyperion Treatment Plant (HTP)

23,000 AFY

17,000 AFY

West Coast Basin Barrier Project (WCBBP)

Edward C. Little Water Reclamation Facility (ECLWRF)

15,000 AFY
Desalters

New Inland Injection
15,000 - 16,000 AFY

Joint Water Pollution Control Plant (JWPCP)

7,500 AFY

Dominguez Gap Barrier Project (DGBP)

Total 14,000 to 15,000 AFY Total Injection

5,000 AFY

2,500 - 9,000 AFY

Terminal Island Water Reclamation Plant (TIWRP)

64,468 AFY = Existing Water Rights
30,000 AFY = Total Pumping Above Water Rights
15,000 AFY targeted to contain/remove saline plume
15,000 AFY extraction by participating pumpers

Legend
Existing Supplies - blue text
New Supplies (or Extractions) - red text

Note: The DGBP future new supplies will be supplied from either TIWRP or JWPCP, not both.

FIGURE ES-5
Potential Development of West Coast Basin to Provide for Full Use of Water Rights and to Expand Beyond Water Rights by up to 30,000 AFY
Groundwater Basins Master Plan

Also shown in Figure ES-3 is the development of additional recycled water from the Los Angeles County Sanitation Districts' (LACSD) San Jose Creek Water Reclamation Plant (SJCWRP) and Los Coyotes Water Reclamation Plant (LCWRP). WRD is already working with LACSD on the Groundwater Reliability Improvement Project (GRIP), which is a project to replace 21,000 AFY of imported water for replenishment with recycled water. The source of the recycled water is the SJCWRP. GRIP may include all tertiary recycled water or some combination of tertiary and advanced treated recycled water (note that a split between tertiary and advanced treated water is shown in Figure ES-3, but this is subject to change as the project is further developed). WRD is also in the process of expanding the Leo J. Vander Lans Water Treatment Facility to 8,000 AFY, which currently treats recycled water produced by LACSD's Long Beach Water Reclamation Plant and may by supplemented by source water from the LCWRP, for injection into the Alamitos Barrier Project. Full utilization of SJCWRP and LCWRP flows could provide up to an additional 66,800 AFY of recycled water for replenishment (which includes GRIP) through surface spreading and injection in the Montebello Forebay. Development of these available supplies and additional replenishment, through multiple possible combinations of projects as described herein, could provide the replenishment required to meet pumping levels up to the Central Basin APA, and to as much as 57,770 AFY beyond the APA.

Figure ES-4 shows potential development of replenishment in the Los Angeles Forebay. Opportunities were considered to intercept sewer flows to the Hyperion Treatment Plant (HTP), consistent with the City of Los Angeles' Recycled Water Master Plan. As shown in Figure ES-4, a new satellite advanced water treatment facility (AWTF) could be constructed to produce high quality recycled water for injection into the Los Angeles Forebay using 50 new injection wells. Approximately 21 extraction wells would extract 29,000 AFY for delivery to the City of Los Angeles' potable water distribution system and participating pumpers would extract an additional 16,480 AFY within their service areas. This 45,480 AFY of additional replenishment and pumping, combined with the water resources development in the Montebello Forebay described above, could largely offset imported water use in the Central Basin.

Figure ES-5 shows opportunities to use available recycled water supplies from the City of Los Angeles' HTP and Terminal Island Water Reclamation Plant (TIWRP), as well as LACSD's Joint Water Pollution Control Plant (JWPCP). Expansion of West Basin Municipal Water District's (WBMWD) Edward C. Little Water Reclamation Facility (ECLWRF) could meet the injection requirements into the West Coast Basin Barrier Project (WCBBP). These supplies are sufficient to replenish the West Coast Basin through injection, as necessary, to allow for pumping up to the basin water rights of 64,468 AFY, and beyond by as much as 30,000 AFY for a total of 94,468 AFY. The existing injection barriers have sufficient capacity to meet replenishment needs up to the basin's water rights; however, additional injection capacity will likely be needed to allow pumping beyond water rights levels. Figure ES-3 shows a new line of inland injection wells to provide 15,000 to 16,000 AFY from the JWPCP. In addition, up to seven desalters could be constructed to contain/remove saline to brackish groundwater in the Silverado Aquifer in order to restore groundwater quality of this principal aquifer used for municipal and industrial supplies. As a part of this overall water resource plan, oil refineries would reduce their use of groundwater substantially, and transfer this use to municipalities such as the City of Los Angeles, by replacing their groundwater supplies with recycled water supplies.

Consistent with Concepts A and B, GBMP planning scenarios, which represent a range of basin operating conditions (extraction/replenishment), were developed for each basin. The conceptualization of scenarios was based on a supply mix for basin replenishment and pumping schemes (such as pumping locations and changes to current pumping patterns for some of the purveyors) for each basin as presented below.

West Coast Basin:

- **Approach:** Shifted oil companies' non-potable demands from groundwater use to recycled water and shifted this groundwater pumping to municipal purveyors.
- **Overall Goal:** Contained/removed the saline plume. Scenarios were developed with increased injection into the Silverado aquifer, and decreasing or eliminating injection into the San Pedro aquifer while increasing extractions from Silverado aquifer to pump up to the adjudicated water rights. Scenarios that were found to increase seawater intrusion significantly into the Lower San Pedro aquifer, and even somewhat into the

Silverado aquifer, were deemed too risky and/or ineffective and thus, were not considered for further modeling and analysis.

- **Water Supply Sources for Replenishment:** Additional sources of groundwater replenishment supply considered were recycled water supplied by HTP with advanced treatment provided either at HTP or at WBMWD's ECLWRF, expansion of the TIWRP, and advanced treatment of effluent from LACSD's JWPCP. Because the West Coast Basin aquifers are largely confined, stormwater infiltration is not a viable source of basin replenishment. (Seawater desalination projects, such as those currently being considered by WBMWD and others in the region, would be delivered directly into the potable water distribution system rather than serve as a groundwater replenishment supply. As such, seawater desalination is not a supply component of the GBMP alternatives.)
- **Extraction and Replenishment Conditions:** Groundwater injection using the existing barriers (WCBBP and Dominguez Gap Barrier Project [DGBP]), as well as new inland injection wells, are utilized for the West Coast Basin scenarios. Table ES-1 describes scenarios considered and evaluated under Concept A. Table ES-2 describes the pumping and injection conditions evaluated in the Concept A and B planning scenarios for the West Coast Basin.

TABLE ES-1
Locations of Extraction and Injection under West Coast Basin – Concept A Scenarios

Concept A Scenarios	Silverado Aquifer		Lower San Pedro Aquifer	
	Injection[a]	Silverado Extraction	Injection	Extraction
Scenario WCB-A1 (A1a, A1b, A1c)	Increased beyond current plans	Increased to adjudicated rights; pump from saline plume	No change to current level of protection	None
Scenario WCB-A2	Same as in Scenario WCB-A1	Same as in Scenario WCB-A1, and also moved Lower San Pedro pumping to this aquifer	Eliminated injection and shift pumping to Silverado	None
Scenario WCB-A3	Same as in Scenario WCB-A1	Same as in Scenario WCB-A1	Eliminated injection unless surplus imported water is available	None
Scenario WCB-A4	Same as in Scenario WCB-A1	Same as in Scenario WCB-A1	Eliminated injection	Considered extraction and treatment of brackish groundwater

[a] Injection considered at existing barriers only

TABLE ES-2
Injection and Extraction Conditions under West Coast Basin Planning Scenarios (Concepts A and B)

West Coast Basin Scenarios	Recharge	Pumping
Concept A Scenarios (Pumping within water rights): WCB-A1 (A1a, A1b, A1c), WCB-A2, WCB-A3, WCB-A4	Assumed recharge at the two existing injection barriers with 100 percent recycled water contribution at each barrier, sufficient to meet the adjudicated water rights.	It was assumed that all pumpers pumped their full water rights and that oil companies shifted their non-potable demands from groundwater to recycled water, and that these water rights are pumped by municipal purveyors; For Scenario WCB-A1c, three pumpers (that is, California Water Service Company (CWSC)–Hawthorne, City of Torrance, and City of Los Angeles) would use a total 15,000 AFY of desalinated groundwater. Thus, extraction for these three pumpers was shifted from their current well locations to seven new desalters (shown in Figure ES-5) in the Silverado aquifer.

TABLE ES-2
Injection and Extraction Conditions under West Coast Basin Planning Scenarios (Concepts A and B)

West Coast Basin Scenarios	Recharge	Pumping
Concept B Scenarios (Pumping above water rights): WCB-B1	In addition to increased recharge at the two existing injection barriers, replenishment included the use of a new, inland injection well system (shown in Figure ES-5).	Pumping of additional 30,000 AFY above water rights assumes that pumping was distributed to CWSC-Hawthorne, City of Torrance, and City of Los Angeles; otherwise all other pumping was the same as Scenario WCB-A1c.

Central Basin:

- **Approach**: Increased water supply in increments starting from the current groundwater replenishment level up to the APA, followed by an increase of 57,770 AFY in the Montebello Forebay and finally, an increase of 45,480 AFY in the Los Angeles Forebay.
- **Overall Goal:** Offset nearly all imported water supplies, including direct deliveries.
- **Water Supply Source for Replenishment:** Additional sources of groundwater replenishment in the Central Basin considered were stormwater and recycled water from LACSD's SJCWRP and LCWRP, as well as potentially from the City of Los Angeles. New advanced purification facilities would be constructed to treat wastewater and provide high quality water for replenishment. Stormwater from the San Gabriel River and Rio Hondo that currently bypasses the spreading grounds following large storm events could be used for recharge in the Montebello Forebay. Increased recharge capacity at the MFSG is provided by depressing nearby groundwater levels through shifting of pumping in the Montebello Forebay with the FIX-IT project. Storm flows from the Los Angeles River that are wasted to the ocean can be captured and used as a potential source for groundwater basin recharge. The Los Angeles River ARRF project (shown in Figure ES-3) is considered as a system that would first treat stormwater and then recover (pump) the treated water for subsequent injection through a vadose zone infiltration conduit into the groundwater basin for replenishment in the Los Angles Forebay.
- **Extraction and Replenishment Conditions:** Recharge of the basin would occur by increased spreading at the MFSG) and injection using the existing barrier (Alamito Barrier Project), as well as using a new inland injection wellfield to match the pumping. The additional available stormwater that could be diverted into the spreading basins and the spreading basin recharge capacity were evaluated based on historical operations. Table ES-3 provides a description of recharge and pumping conditions evaluated in the Concept A and B planning scenarios for the Central Basin.

TABLE ES-3
Extraction and Injection Conditions under CB – Concepts A and B Scenarios

Central Basin Scenarios	Recharge	Pumping
Concept A Scenarios (Pumping within APA):		
CB-A1	Increases extraction by water rights holders up to the APA basin by replenishing the basin through the spreading of an additional 31,000 AFY of recycled water from the SJCWRP at the MFSG.	Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with imported water usage.
CB-A2	Modifies Scenario CB-A1 by using recycled water from both the SJCWRP as well as the LCWRP.	Same as in Scenario CB-A1.
CB-A3	Modifies Scenario CB-A2 by injecting recycled water from the LCWRP.	Same as in Scenario CB-A1.

TABLE ES-3
Extraction and Injection Conditions under CB – Concepts A and B Scenarios

Central Basin Scenarios	Recharge	Pumping
CB-A4	Modifies Scenario CB-A1 by increasing the amount of stormwater that can be captured from the San Gabriel River and Rio Hondo and recharged in the MFSG.	Same as in Scenario CB-A1; however, pumping for City of Long Beach, Golden State Water Company, Paramount, and Santa Fe Springs shifted to the FIX-IT wellfield (Figure ES-3).
CB-A5	Modifies Scenario CB-A1 by increasing the amount of stormwater that can be captured from the Los Angeles River and recharged in the Los Angeles Forebay.	Same as in Scenario CB-A1.
Concept B Scenarios (Pumping above APA):		
CB-B1	Maximizing use of stormwater capture from the Rio Hondo and San Gabriel and Los Angeles Rivers (22,000 AFY) and available recycled water from SJCWRP and LCWRP (66,800 AFY) in the Montebello Forebay.	Extraction is increased beyond the APA by an additional 57,770 AFY in the Montebello Forebay.
CB-B2:	Injection of 45,480 AFY of FAT-treated effluent from new satellite AWTF at new line of extraction wells in the Los Angeles Forebay, in conjunction with maximizing stormwater capture and recycled water use (per Scenario CB-B1).	Extraction is increased in the Montebello and Los Angeles Forebays to a total of 103,250 AFY above the APA.

Note:
FAT = full-advanced treatment

The scenarios developed for each basin were combined for the purposes of groundwater modeling, conducted simultaneously for both basins. Several modeling combinations were generated by combining select West Coast Basin and Central Basin scenarios to evaluate basinwide groundwater conditions. Only feasible combinations of scenarios were used for conducting model simulations.

The WRD/USGS MODFLOW groundwater flow model of the West Coast and Central Basins, developed for the period of 1971 through 2000, was updated to include hydrologic data and basin operations from the 2000 through 2010 period into the existing model. The model was extended through water year 2050 by repeating the hydrology from 1971 through 2010 and refined to provide for monthly stress periods in order to better assess fluctuations in groundwater levels and storage. Groundwater modeling of various basin operational conditions was conducted to assess the overall water balance in the West Coast and Central Basins, considering hydrologic variations over a long-term (40-year) period. Pumping and replenishment were balanced so that groundwater storage levels ended at the same levels as they began over the simulation period. Scenarios that were simulated with the model included the following:

1. Pumping at APA levels in the Central Basin (Concept A) and at water rights levels in the West Coast Basin (Concept A), with sufficient replenishment to support these pumping conditions
2. Pumping above APA levels in the Central Basin (Concept B) and at water rights levels in the West Coast Basin (Concept A), with sufficient replenishment to support these pumping conditions
3. Pumping at APA levels in the Central Basin (Concept A) and above water rights levels in the West Coast Basin (Concept B), with sufficient replenishment to support these pumping conditions
4. Pumping above APA levels in the Central Basin (Concept B) and above water rights levels in the West Coast Basin (Concept B), with sufficient replenishment to support these pumping conditions

The modeling results were used to assess groundwater level fluctuations, identify trends in groundwater storage, and identify groundwater flow between adjacent groundwater basins and subareas within basins. Table ES-4 provides a summary of modeling combinations, including the GBMP planning scenarios that make up each combination, the replenishment and pumping quantities used for each model run, and modeling results.

TABLE ES-4
Summary of Modeling Conditions and Results

Modeling Scenarios	**Modeling Combinations** (GBMP Planning Scenarios[a])	**Pumping (AFY)**	**Replenishment (AFY)**	**Modeling Results**
WCB: Pumping within water rights CB: Pumping within APA	***Combination 1*** (WCB-A1a and CB-A1) ***Combination 2*** (WCB-A1a and CB-A4) ***Combination 3*** (WCB-A1c and CB-A1)	64,468 (WCB) +217,367 (CB) =281,835	186,001	Groundwater level hydrographs show an overall water balance in both the basins. The changes in the basinwide groundwater balance are within acceptable limits. Under Scenario WCB-A1a, the flow path lines show eastward advancement of the saline plume. Under Scenario WCB-A1c, modeling results indicate improvements in water quality.
WCB: Pumping within water rights CB: Pumping above APA	***Combination 4*** (WCB-A1a and CB-B1)	64,468 (WCB) +275,137 (CB) =339,605	243,423	Hydrographs in the Montebello Forebay show groundwater levels in wells near the Rio Hondo spreading grounds rise to and slightly above land surface during high-rate recharge events in wet years. Basins are balanced over the simulation period.
	Combination 5 (WCB-A1a and CB-B2)	64,468 (WCB) +320,617 (CB) =385,085	288,903	Groundwater levels in this model run were similar to Combination 4 results. Water budget indicated that the basins end with a significant surplus at the end of the simulation period. This surplus is largely contained in the Los Angeles Forebay, which indicates that replenishment is not equally balanced with pumping in this area.
WCB: Pumping above water rights CB: Pumping within APA	***Combination 6*** (WCB-B1 and CB-A1)	94,468 (WCB) + 217,367 (CB) = 311,835	318,890	Hydrographs are similar to Combination 1. Cumulative storage indicated that the basins are balanced over the simulation period. There is not a surplus or deficit in storage at the end of the period.
WCB: Pumping above water rights CB: Pumping above APA	***Combination 7*** (WCB-B1 and CB-B1)	94,468 (WCB) +275,137 (CB) =369,605	250,223	Same as Combination 6.

[a] Per Tables ES-1 and ES-2

Based on the planning concepts and viable scenarios for the West Coast and Central Basins, GBMP alternatives were developed for the purpose of comparative assessment. GBMP alternatives comprise specific projects consisting of supply, recharge, and extraction components to meet target supply yields corresponding to the basin planning scenarios. Formulating alternatives with consistent supply yields allowed for comparison of the alternatives with respect to the GBMP evaluation criteria, including costs. The costs for each of the alternatives were prepared by combining the individual project costs.

Table ES-5 shows the total extraction and recharge schemes for each of the West Coast Basin alternatives, and the amount of imported water shifted to groundwater for these alternatives is shown in Table ES-6.

TABLE ES-5
Total Extractions and Additional Recharge Beyond Current Levels Considered for West Coast Basin Alternatives

			Additional Recharge Needed to Meet Total Extraction			
			Recycled Water (Injection)			
Concept	Alternatives	Total Extraction (AFY)	WCBBP (AFY)	DGBP (AFY)	WCB-NEW (AFY)	Total (AFY)
A	WCB-A1	64,468	15,500	2500[a]	N/A	18,000
B	WCB-B1a	94,468	23,000	10,000	15,000	48,000
	WCB-B1b	94,468	23,000	9,000	16,000	48,000

[a] Expands recycled water production capacity to fully replace current imported water replenishment for 100 percent recycled water contribution (RWC).

Notes:

WCB-NEW = New barrier system in the West Coast Basin

N/A: not applicable

TABLE ES-6
Imported Water Replacement and Pumping Shifts Under West Coast Basin Alternatives

Concept	Alternatives	Total Extraction (AFY)	Quantity of Imported Water Shifted to Groundwater (AFY)	Number of Purveyors
A	WCB-A1	64,468	See footnote[a]	See footnote[b]
B	WCB-B1a	94,468	30,000	8
	WCB-B1b	94,468	30,000	8

[a] The difference between adjudicated rights and pumping over recent 10–year period (water years 2000/2001-2009/2010) averaged 22,500 AFY, indicating the amount of imported water use that would be replaced with groundwater pumping.

[b] Adjusted existing pumpers to reach their respective water rights

For the Central Basin alternatives, the total extraction and recharge schemes are shown in Table ES-7. The amount of imported water use replaced with groundwater pumping and the associated pumping shifts are shown in Table ES-8.

A summary of the major facilities included in the GBMP alternatives is provided on Figure ES-6.

TABLE ES-7
Total Extractions and Additional Recharge Beyond Current Levels Considered for Central Basin Alternatives

			Additional Recharge Needed to Meet Total Extraction						
			Stormwater (AFY)		AWT Injection (AFY)		Spreading (AFY)		
Concept	Alternatives	Total Extraction (AFY)	SGR	LAR	MFB	LAFB	Tertiary	AWT	Total (AFY)
A	Pumpers extract full APA	217,367					31,000		31,000
	CB-A1a-f							31,000	31,000
	CB-A2a						15,500	15,500	31,000
	CB-A2b							31,000	31,000
	CB-A3a						15,500	15,500	31,000
	CB-A3b							31,000	31,000
	CB-A4a	[a]	17,000				14,000		31,000
	CB-A4b	[a]	17,000					14,000	31,000
	CB-A5a			5,000			26,000		31,000
	CB-A5b			5,000				26,000	31,000
B	Pumpers extract above full APA	275,137 - 320,617							
	CB-B1a	275,137 [b]	17,000	5,000	18,190		48,600		88,770
	CB-B1b	275,137 [b]	17,000	5,000	18,190			48,570	88,770
	CB-B2a	320,617 [c]	17,000	5,000	18,190	45,480	48,600		134,250
	CB-B2b	320,617 [c]	17,000	5,000	18,190	45,480		48,570	134,250

Notes:

[a] Includes 25,000 AFY of extraction associated with the FIX-IT project in the Montebello Forebay

[b] Includes 57,770 AFY of extraction associated with the FIX-IT project in the Montebello Forebay

[c] Includes 29,000 AFY of extraction in the Los Angeles Forebay to serve the City of Los Angeles and 25,000 AFY of extraction associated with the FIX-IT project in the Montebello Forebay

SGR = San Gabriel River

LAR = Los Angeles River

TABLE ES-8
Imported Water Replacement and Pumping Shifts Under Central Basin Alternatives

Concept	Alternatives	Total Extraction (AFY)	Revised Pumping[a]	
			MFB (AFY)	LAFB (AFY)
A	Pumpers extract full APA	217,367		
	CB-A1a-f		[b]	[b]
	CB-A2a		[b]	[b]
	CB-A2b		[b]	[b]
	CB-A3a		[b]	[b]
	CB-A3b		[b]	[b]
	CB-A4a		[c]	[b]
	CB-A4b		[c]	[b]
	CB-A5a		[c]	[b]
	CB-A5b		[c]	[b]
B	Pumpers extract above full APA	275,137		
	CB-B1a		57,770	N/A
	CB-B1b		57,770	N/A
	Pumpers extract above full APA	320,617		
	CB-B2a		57,770	45,480[d]
	CB-B2b		57,770	45,480[d]

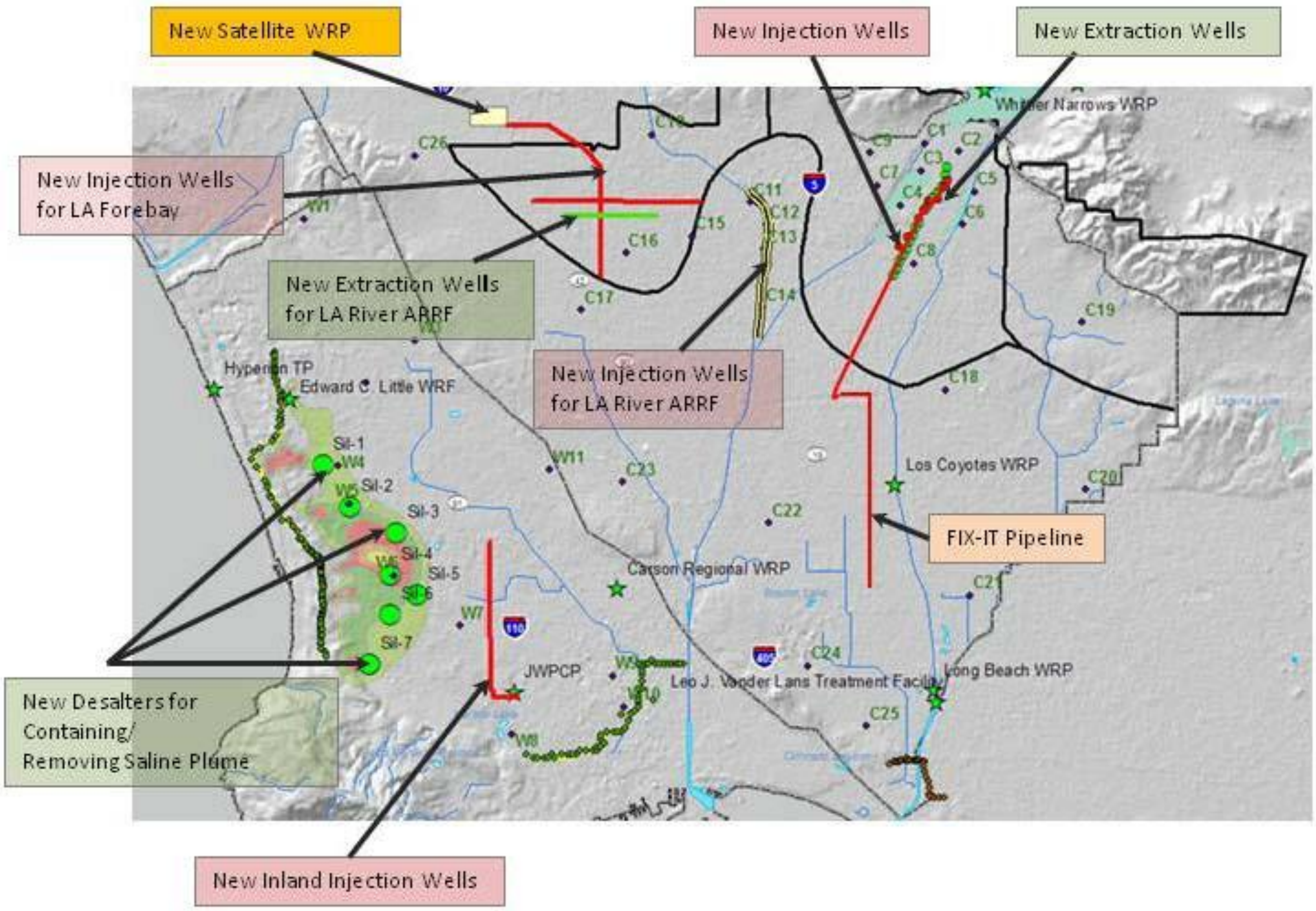
[a] Some pumping occurs outside the forebay limits.

[b] The difference between adjudicated rights and pumping over recent 10-year period (water years 2000/2001-2009/2010) averaged 22,000 AFY, indicating the amount of imported water that would be replaced by groundwater pumping.

[c] Shifted pumping of 25,000 AFY for four pumpers for the FIX-IT project

[d] Pumping includes 29,000 AFY for City of Los Angeles

FIGURE ES-6
Location of Major Facilities in the GBMP Alternatives for the West Coast and Central Basins



Figures ES-7 and ES-8 present annual yield and present value unit cost (dollars per acre-foot [$/AF]) for the West Coast and Central Basin alternatives, respectively. An analysis of the GBMP alternatives provides an assessment of the performance of the alternatives relative to evaluation criteria that can guide stakeholder decision making.

FIGURE ES-7
Annual Yield and Present Value Unit Cost for the West Coast Basin Alternatives

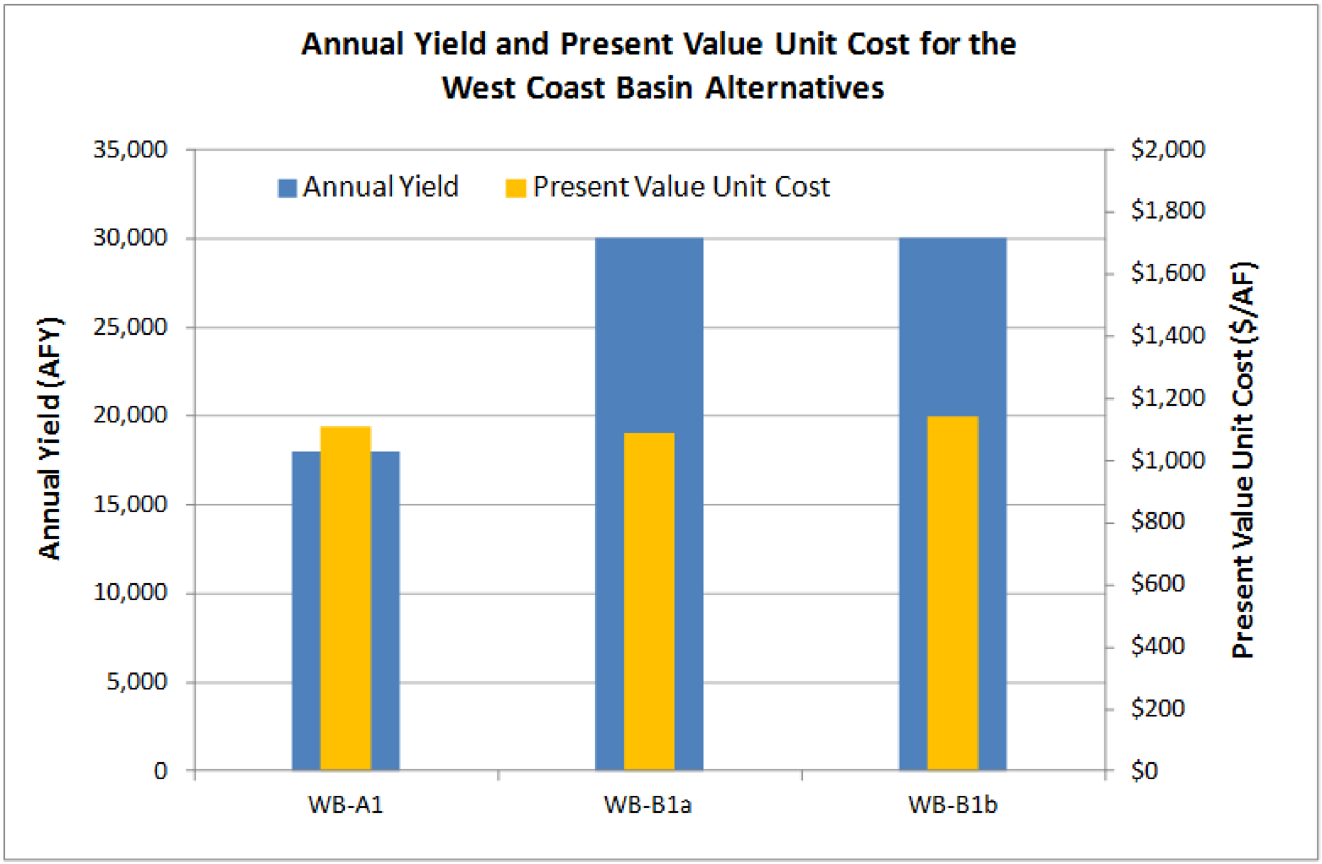
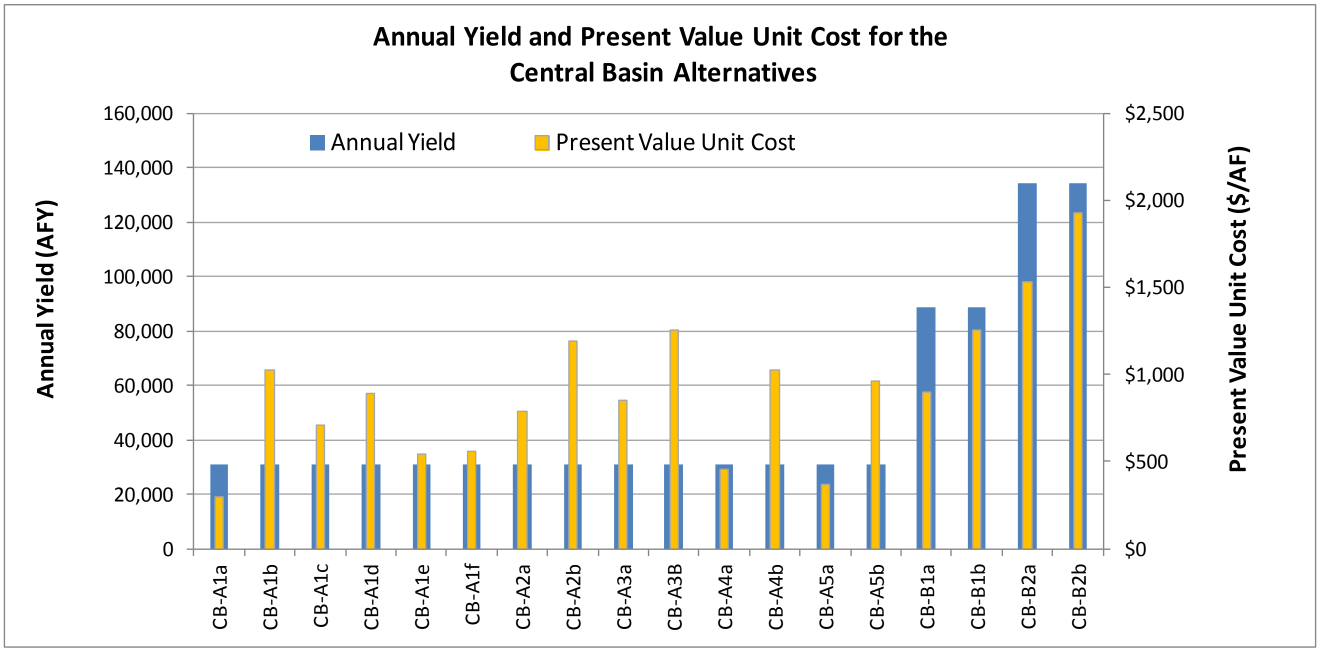


FIGURE ES-8
Annual Yield and Present Value Unit Cost for the Central Basin Alternatives



In addition to cost, the following criteria were also evaluated for each alternative: 1) water supply availability and reliability, 2) energy/greenhouse gas emissions, 3) environmental impacts, and 4) total dissolved solids (TDS) loading. These were compared against the No Project Alternative, in which imported water was used to provide additional replenishment to match basin pumping.

Key findings from the evaluation are:

- Lifecycle costs for alternatives using recycled water with FAT are more than twice the costs for tertiary alternatives.
- The lifecycle costs for tertiary alternatives could be even lower if the purchase price for tertiary effluent is reduced. These estimates assume a price of $300/AF for tertiary projects and a price of $100/AF for projects utilizing advanced water treatment processes.
- Energy demands and carbon dioxide (CO_2) emissions are significantly higher for the No Project Alternative due to pumping required for the conveyance of imported water.
- CO_2 emissions for FAT alternatives are approximately 60 percent less than the No Project Alternative.
- CO_2 emissions for tertiary alternatives are significantly lower than the No Project Alternative.
- FAT alternatives result in a TDS loading that is significantly lower than the No Project Alternative.

This Draft GBMP identifies a range of projects and opportunities to not only ensure that additional replenishment water will be supplied to meet the pumpers' use of groundwater for which they have rights, but also identifies opportunities to further reduce reliance on imported water through enhanced use of the vast groundwater storage of these basins. The projects have been defined sufficiently to estimate their broad cost implications and allow for comparison of the value of pursuing development of these various water sources. The implementation of projects and alternatives would require stakeholder coordination, regulatory and legal considerations, confirmation of availability of supplies for replenishment, validation of spreading ground capacity, and development/enhancement of the modeling framework to evaluate the impacts of changes to the water quantity and quality as an effect of these alternatives.

This Draft GBMP is not a capital improvement program, nor does it encourage or commit any party to a particular project or program. It does not address institutional issues, which are significant and critical to advancing any of the elements identified herein. While estimated planning-level costs are provided for specific projects and alternatives as a basis for comparison, no attempt has been made to analyze future Replenishment Assessment impacts, or to allocate potential benefits that may be realized from these projects or alternatives.

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Abbreviations

$/af	dollar(s) per acre-foot
$M	million dollars
AB	Assembly Bill
ABP	Alamitos Barrier Project
AF	acre-feet
AFM	acre-feet per month
AFY	acre-feet per year
AOP	advanced oxidation process
APA	Allowed Pumping Allocation
ARRF	Aquifer Recharge Recovery Facility
ASR	aquifer storage and recovery
AWT	advanced water treatment
AWTF	advanced water treatment facility
BAC	biological activated carbon
CDPH	California Department of Public Health
CO_2	carbon dioxide
CRWRF	Juanita Millender-McDonald Carson Regional Water Reclamation Facility
CWSC	California Water Services Company
DGB	Dominguez Gap Barrier
DGBP	Dominguez Gap Barrier Project
DWR	California Department of Water Resources
ECLWRF	Edward C. Little Water Reclamation Facility
EIR	environmental impact report
EIS	environmental impact statement
FAT	full-advanced treatment
FIX-IT	Forebay Infiltration and Extraction Intra-basin Transfer
ft	feet; foot
ft^3/s	cubic foot (feet) per second
GAC	granular activate carbon
GBMP	Groundwater Basins Master Plan
GHG	greenhouse gas
GRIP	Groundwater Reliability Improvement Project
GRRP	Groundwater Replenishment Reuse Project

GWR	groundwater recharge
GWV	Groundwater Vistas
hp	horsepower
HTP	Hyperion Treatment Plant
ID	identification number
IRP	Integrated Resources Plan
JOS	Joint Outfall System
JWPCP	Joint Water Pollution Control Plant
kWh	kilowatt-hour
LA RWMP	Los Angeles Recycled Water Master Plan
LACDPW	Los Angeles County Department of Public Works
LACSD	Los Angeles County Sanitation Districts
LADWP	Los Angeles Department of Water and Power
LBWRP	Long Beach Water Reclamation Plant
LCWRP	Los Coyotes Water Reclamation Plant
LVLWTF	Leo J. Vander Lans Water Treatment Facility
MBR	membrane bioreactor
MF	microfiltration
MFSG	Montebello Forebay Spreading Grounds
mg/L	milligram(s) per liter
mgd	million gallon(s) per day
MWD	Metropolitan Water District of Southern California
N/A	not applicable
NDMA	N-nitrosodimethylamine
NF	nanofiltration
NPR	non-potable reuse
O&M	operations and maintenance
OCWD	Orange County Water District
PEIR	Programmatic Environmental Impact Report
RA	replenishment assessment
Reclamation	Bureau of Reclamation
RO	reverse osmosis
RW	recycled water
RWC	recycled water contribution
RWQCB	Regional Water Quality Control Board
SAT	soil aquifer treatment

SJCWRP	San Jose Creek Water Reclamation Plant
SNMP	Salt and Nutrient Management Plan
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TIWRP	Terminal Island Water Reclamation Plant
TOC	total organic carbon
USGS	U.S. Geological Survey
UV	ultraviolet
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WBMWD	West Basin Municipal Water District
WCBBP	West Coast Basin Barrier Project
WIN	Water Independence Now
WIN BIGGR	Water Independence Now By Increasing Groundwater Recharge and Recovery
WRD	Water Replenishment District of Southern California
WRP	water reclamation plant
WWTP	wastewater treatment plant

SECTION 1.0

Introduction

1.1 Introduction

The Water Replenishment District of Southern California (WRD), in coordination with other basin stakeholders, has developed this Draft Groundwater Basins Master Plan (GBMP). The intent of this plan is to provide a single reference document for parties operating within and maintaining the West Coast and Central groundwater basins. This Draft GBMP presents a number of options for meeting replenishment requirements of the West Coast and Central Basins and options for expanding use of the basins' storage to increase reliability of area water supplies. While this Draft GBMP provides opportunities for increased use of these groundwater basins, realization of these opportunities will come from future actions of pumpers, the holders of water rights for these basins, and other basin stakeholders. WRD can and is willing to facilitate additional activities and partnerships to continue to move those options, or other similar options that might be identified, forward to improve reliability of local water supplies and continue protection of these important groundwater basins.

The water supply planning environment has changed dramatically in recent years—locally dry conditions have reduced local water supplies; reductions in Colorado River supplies due to hydrologic conditions have occurred; and significant reductions in State Water Project water supplies have occurred due to hydrologic and regulatory conditions. In addition, there has been much recent work on climate change and its impacts, including El Niño Southern Oscillation, Pacific Decadal Oscillation, and long-term climate changes, such as reduced snowpack in California and along the Colorado River Basin. Climate change impacts may include reduced inflows into reservoirs throughout the spring and summer; increase the frequency of short, high-intensity storms with high sediment loads that cannot be easily diverted into off-stream storage; and cause sea level rise that could affect State Water Project diversion facilities and saltwater intrusion into coastal aquifers. The vulnerability of Southern California to potential impacts of catastrophic events, such as earthquakes and Bay-Delta levee failures, has also prompted increased emphasis on reducing the region's dependence on imported water supplies and increasing the use of local water resources.

As a result of the uncertainties in imported water supplies and significant increases in the cost of imported water, local pumpers are revisiting their business plans to assess their alternatives to develop more local water. In recent years, nearly one-third of the adjudicated water rights in the West Coast Basin (approximately 20,000 acre-feet per year [AFY]), and a comparable amount (although only about 10 percent of the Allowed Pumping Allocation [APA]) in the Central Basin have not been pumped. This is principally because of the need to install relatively expensive wellhead treatment systems to address localized water quality issues. Groundwater production, including pumping, wellhead treatment, and replenishment, was not historically as cost effective as relying on imported water. However, given the rising costs of imported water, groundwater may become a much more competitive supply as long as the cost of replenishment water is affordable. Recycled water may prove to be the most affordable and reliable supply of replenishment and water augmentation.

To enhance and protect local water resources and facilities, WRD has partnered with pumpers and other local agencies such as the Los Angeles County Department of Public Works (LACDPW) who operates the existing seawater intrusion injection barriers and spreading grounds; oil companies who pump large quantities of water for oil refining; and suppliers of recycled water, including the West Basin Municipal Water District (WBMWD), the Los Angeles County Sanitation Districts (LACSD), and the City of Los Angeles. For example, programs are in place to reduce the use of potable groundwater and imported water for non-potable uses and switch those non-potable uses to recycled water supplies (for instance, oil refineries are switching some water demands to recycled water). In addition, several studies have been completed to assess the condition of the injection barrier facilities and wells, enhance the capacities of the existing spreading basins, and move to the use of recycled water for replenishment to reduce reliance on imported water. Several key planning programs by these agencies that are pertinent to this Draft GBMP are described in Appendix A.

Overlying agencies in the West Coast and Central Basins have initiated efforts to improve water supply reliability and protect local water resources, including the following:

- WRD's Water Independence Now (WIN) initiative
  - The WIN program is a network of local facilities and education efforts that could help the quality of life and economy of southern Los Angeles County if the imported water we depend upon becomes unavailable. WIN includes support of increased conservation, increased use of recycled water, storage of water in groundwater basins to protect against drought and emergency water supply interruptions, and protection of local groundwater resources.
- WBMWD Water Reliability 2020 program
  - The Water Reliability 2020 program is designed to reduce imported water use from 66 to 33 percent by the year 2020 by more than doubling efforts to recycle water, doubling conservation efforts, increasing educational programs about conservation, and developing an ocean water desalination program.
- WRD's ongoing assessments of the West Coast Basin saline plume and development of a Saline Plume Policy. The saline plume is a mass of brackish groundwater in the Torrance area created by seawater intrusion that was trapped inland of the West Coast Basin Barrier after the barrier was put into operation in the 1950s and 1960s.
- WRD's and WBMWD's development of recycled water supplies
- Water purveyors' expansion of recycled water uses within their service areas
- City of Los Angeles' development of their Integrated Resources Plan (IRP) and subsequent Recycled Water Master Plan (RWMP)
- Cooperative efforts by WRD and LACDPW to assess the condition of the existing injection barriers and enhance the capacity of the Montebello Forebay Spreading Basins
- LACDPW's extension of the Dominguez Gap Barrier Cooperative efforts between stakeholders to shift industrial water uses from groundwater and imported water to recycled water

Lastly, amendments are under consideration to the West Coast and Central Basin Judgments to allow for more flexibility in the use of these basins' storage capacity, including conjunctive use of the groundwater basins. If approved, these Judgment amendments will allow for increased optimization of the West Coast and Central Basin operations and provide for a more reliable and cost-effective water supply for the region.

This Draft GBMP is intended to be a starting point for basin-wide planning that will serve as the basis for a programmatic environmental review process. Complementing stakeholder outreach conducted during the preparation of the Draft GBMP, WRD intends to use the environmental impact report (EIR) process to formally vet the Draft GBMP alternatives and further open dialogue about these potential opportunities. The determination of the relative value of these opportunities will stem from such dialogue. WRD's intent is to facilitate these discussions with the preparation of this Draft GBMP. The Draft GBMP is not intended to be a capital improvement program, nor does it address any of the institutional, financial, regulatory, or legal issues that might be associated with implementation of any of the identified projects or alternatives. Rather, the Draft GBMP provides technical analysis of what might be possible to enhance utilization of the West Coast and Central groundwater basins for local and regional benefits.

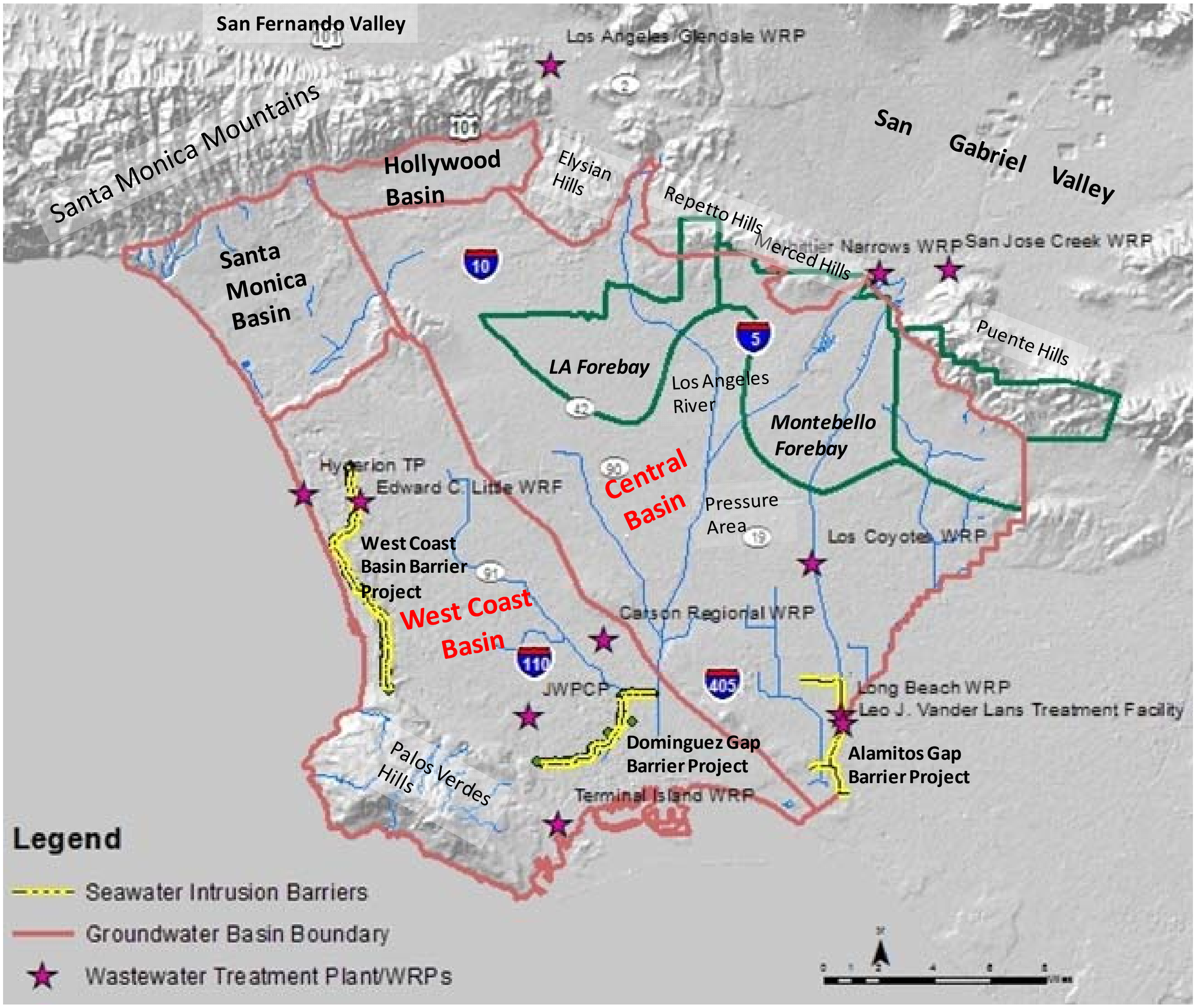
1.1.1 Background

The content of this Draft GBMP should be considered in light of the densely urban and geologically complex area of study, the historical use of the subject groundwater basins, and the role of WRD in both managing these basins and providing this analysis of potential long-term replenishment alternatives.

1.1.2 Description of Study Area

The Draft GBMP Study Area is located in the southern portion of Los Angeles County, in the WRD service area, shown in Figure 1-1, which overlays the West Coast and Central groundwater basins. Home to over 4 million people, the water supply reliability in this area is critical to the economic sustainability of water resources both locally and statewide through the Study Area's connection to imported water sources.

FIGURE 1-1
Water Replenishment District of Southern California Service Area



The Study Area is located in the Los Angeles Coastal Plain and is highly urbanized. The major land forms of the Coastal Plain consist of bordering highlands and foothills, older plains and hills, younger alluvial plains, rivers that drain the area, and offshore topography.

The Central Basin covers approximately 270 square miles and is bounded on the north by the Hollywood Basin and the Elysian, Repetto, Merced, and Puente Hills; to the east by the Los Angeles County/Orange County line; and to the south and west by the Newport-Inglewood Uplift, a series of discontinuous faults and folds that form a prominent line of northwest-trending hills including the Baldwin Hills, Dominguez Hills, and Signal Hill.

The West Coast Basin covers approximately 140 square miles and is bounded on the north by the Baldwin Hills and the Ballona Escarpment (a bluff just south of Ballona Creek), on the east by the Newport-Inglewood Uplift, to the south by San Pedro Bay and the Palos Verdes Hills, and to the west by Santa Monica Bay.

The Central Basin is divided into four sections—the Los Angeles Forebay, the Montebello Forebay, the Whittier Area, and the Pressure Area (California Department of Water Resources [DWR], 1961). The two forebays represent areas of unconfined (water table) aquifers that allow percolation of surface water down into the deeper production aquifers to replenish the rest of the basin. The Whittier Area and Pressure Area are confined aquifer systems that receive relatively minimal recharge from surface water, but are replenished from the upgradient forebay areas or other groundwater basins.

In the West Coast Basin, aquifers are generally confined and receive the majority of their natural replenishment from adjacent groundwater basins or from the Pacific Ocean (seawater intrusion). Both the Newport-Inglewood Uplift and the Charnock Fault (in the West Coast Basin) are partial barriers to groundwater flow, causing differences in water levels on opposite sides of each fault system. Groundwater flows between the West Coast and Central Basins based on the groundwater elevations on either side of the Newport-Inglewood Uplift. Most of the groundwater in the West Coast and Central Basins remains at an elevation below sea level due to historic overpumping, so maintaining the seawater barrier wells to keep out the intruding saltwater is of vital importance.(WRD, 2011a).

1.1.3 Groundwater Basins History

Prior to the adjudication of groundwater rights in the early 1960s, annual production (pumping) reached levels as high as 292,000 acre-feet (AF) in the Central Basin and 94,000 AF in the West Coast Basin. This was more than double the 173,400 AF of natural safe yield of the basins determined by DWR in 1962. The “natural safe yield” is the amount that can be withdrawn from the aquifer without adverse affect (DWR, 2009), assuming natural replenishment of the aquifer generally from runoff and precipitation. Due to this serious overdraft, water levels declined, groundwater was lost from storage, and seawater intruded into the coastal aquifers. To remedy this problem, the courts adjudicated the two basins to put a limit on pumping. The West Coast Basin adjudication was set at 64,468 AFY. The Central Basin adjudication was set at 267,900 AFY, although the Judgment set a lower APA of 217,367 AFY to impose stricter control. Therefore, the current amount allowed to be pumped from both basins is 281,835 AFY (WRD, 2011b).

The existing Judgments do not allow for use of currently unused storage space in the basins, estimated at a total of 450,000 AF in both basins (120,000 AF in the West Coast Basin and 330,000 AF in the Central Basin). In 2009, motions were filed in court to amend both Judgments to allow parties to the Judgments to store water for later extraction. The amendments would also include provisions for the interbasin transfer of storage rights between the West Coast and Central Basins, also not currently allowed. Most significantly, the implementation of water augmentation projects, wherein recharge and extraction volumes are matched within an established timeframe, would allow pumping beyond adjudicated rights, without using the allotted storage space described in the storage provisions. After several challenges to these motions, final decisions on the amendments are still pending (see Appendix B for more details regarding the proposed Judgment amendments).

1.1.4 Role of the Water Replenishment District of Southern California

WRD was formed by a vote of the people in 1959 for the purpose of protecting the groundwater resources of the West Coast and Central groundwater basins. WRD manages groundwater for nearly 4 million residents in 43 cities of southern Los Angeles County over a 420-square-mile service area, shown in Figure 1-1. WRD protects the basins through groundwater replenishment, deterrence of seawater intrusion, and groundwater quality monitoring of contamination through an assessment on water pumped from the WRD service area. WRD ensures that a reliable supply of high-quality groundwater is available through its clean water projects, water supply programs, and effective management principles.

The adjudicated pumping amounts described in Appendix B are greater than the natural replenishment of the groundwater basins, creating an annual deficit or annual overdraft. WRD is enabled under the California Water

Code to purchase and recharge additional water to make up the overdraft, which is known as artificial replenishment or managed aquifer recharge. WRD has the authority to levy a replenishment assessment on all pumping within the District to raise the monies necessary to purchase the artificial replenishment water and to fund projects and programs necessary for replenishment and groundwater quality activities (WRD, 2011b).

WRD initiated the preparation of the GBMP to facilitate long-term planning with basin stakeholders and identify sustainable, reliable sources of replenishment water to cost-effectively meet projected groundwater production demands.

1.2 Groundwater Basins Master Plan Objectives

As an element of WRD's WIN program, the GBMP establishes a framework in which projects recommended for further evaluation can be examined and considered within an open, transparent process. By considering regional, basin-wide needs and opportunities, the Draft GBMP offers stakeholders options that can satisfy individual water systems' interests and priorities while also providing broader basin benefits. Under the WIN program, WRD has been implementing projects and programs that enhance basin replenishment, increase the reliability of groundwater resources, improve and protect groundwater quality, and ensure that the groundwater supplies are suitable for beneficial uses. Offering a wide range of alternatives for the basin stakeholders to consider in advancing the WIN program goals is the primary objective of the GBMP.

Ultimately, implementation of any of these projects or programs beyond meeting replenishment obligations of WRD would result solely from the impetus of the basin stakeholders to invest in the development of additional replenishment water to more fully use the basins, and "WIN BIGGR" (**W**ater **I**ndependence **N**ow **B**y **I**ncreasing **G**roundwater **R**echarge and **R**ecovery). These are complex projects, some with lengthy implementation timeframes and numerous institutional challenges. This Draft GBMP makes no attempt to resolve these challenges; rather, it is intended to identify possibilities that may hold sufficient interest and support of the basin stakeholders to warrant further exploration.

This Draft GBMP is supported by the U.S. Department of the Interior's WaterSMART (**S**ustain and **M**anage **A**merica's **R**esources for **T**omorrow) program. WaterSMART provides funding for the bureaus of the Department, including the Bureau of Reclamation (Reclamation), to work with local government agencies such as WRD to pursue a sustainable water supply. Reclamation's WaterSMART System Optimization Review grant was awarded for this study and is intended to provide an analysis of system-wide efficiency that focuses on improving the effectiveness and operations of a delivery system, district, or watershed (Reclamation, 2012).

The following GBMP objectives thus address not only the interests of WRD and regional stakeholders, but national interests as well:

- Meet adjudicated pumping rights in each basin
- Provide sufficient supply to meet replenishment for adjudicated rights, and then to offset surface water deliveries of imported water via increased pumping beyond the adjudications (pending approval of the proposed Judgment amendments)
- Reduce reliance on imported water through increased usage of stormwater and recycled water
- Increase local supply production
- Remove contamination from key portions of the groundwater basins
- Maintain protections against seawater intrusion
- Protect existing water quality
- Identify opportunities for a coordinated energy strategy for new water supply projects in the Study Area, including the use of renewable energy where feasible and minimizing energy footprint
- Minimize the cost to the agencies that use groundwater and other stakeholders

- Expand use of supplies, developing lower costs supplies first, then progressively use more costly supplies
- Minimize impacts on the environment by progressive development
- Engage stakeholders in the planning and decision-making process

Development of this GBMP was initiated by WRD to provide the basin stakeholders with a roadmap for collaborative and strategic development of potential future projects and programs that will more effectively use the groundwater basins to increase water supply reliability. Applying a long-term planning perspective, this Draft GBMP identifies a range of projects and opportunities to not only ensure that additional replenishment water will be supplied to meet the pumpers use of groundwater for which they have rights, but also identifies opportunities to further reduce reliance on imported water through enhanced use of the vast groundwater storage of these basins. The projects have been defined sufficiently to estimate their broad cost implications and allow for comparison of the value of pursuing development of these various water sources.

1.3 Groundwater Basins Master Plan Content

This GBMP is organized to first present the GBMP planning process followed by development of conceptual options (Concepts A and B) in both basins. Based on these concepts, planning scenarios were developed for each basin to represent a range of basin operating conditions (extraction/replenishment). Scenarios for each basin were combined for the purposes of groundwater modeling, which was conducted simultaneously for both basins.

Based on the concepts and scenarios in the West Coast and Central Basins, GBMP alternatives were developed. Specific projects were identified which can be selected under GBMP alternatives to meet target supply yields corresponding to the basin planning scenarios. Formulating alternatives with consistent supply yields allowed for comparison of the alternatives with respect to evaluation criteria, including costs. Figure 1-2 shows the organization of this planning process in specific sections of this report.

Following this section which includes the introduction and GBMP objectives, the Draft GBMP consists of the following sections:

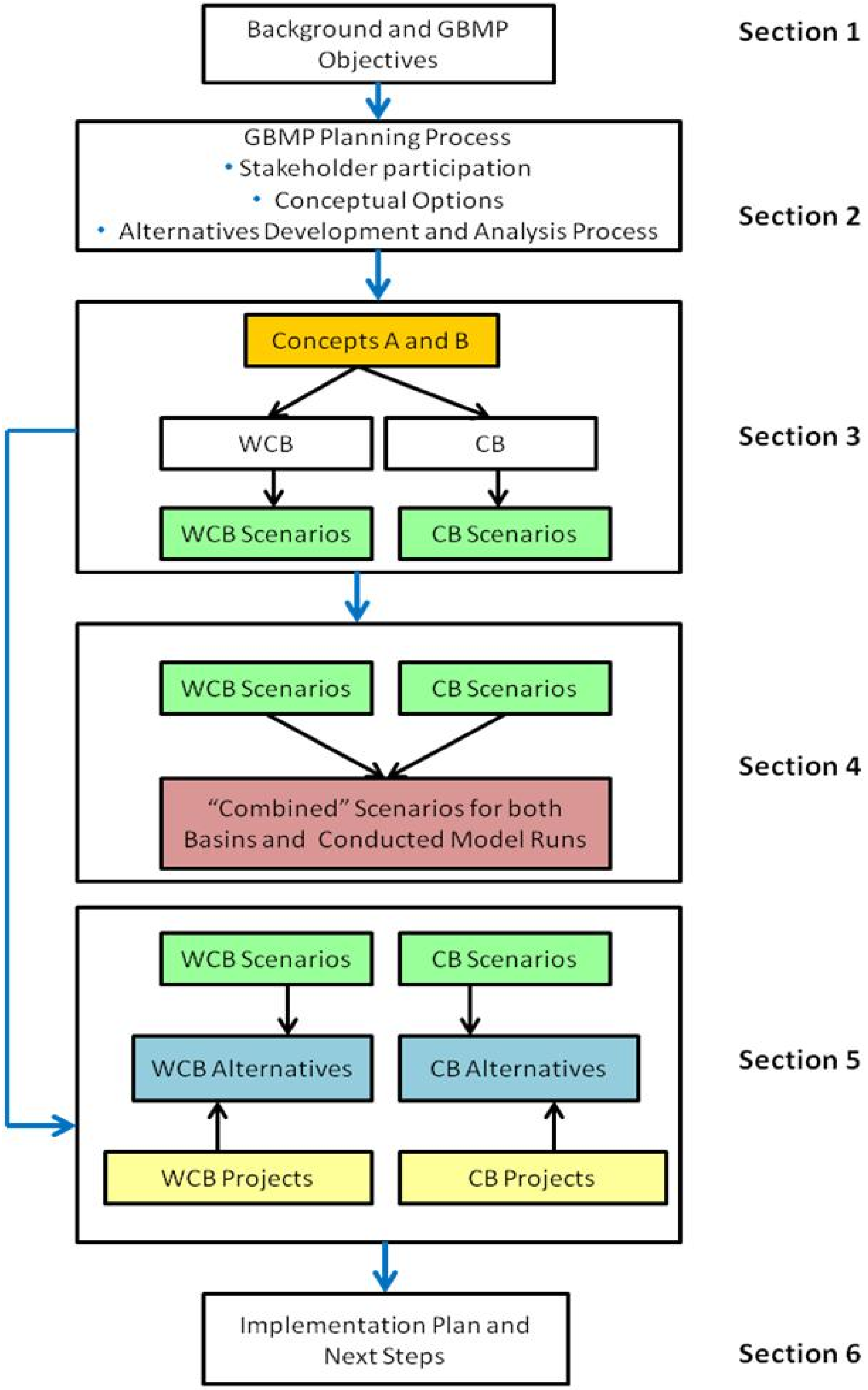
- Section 2.0: Draft GBMP Planning Process – This section describes the approach employed to define and develop conceptual options, scenarios, modeling combinations and alternatives for potential groundwater replenishment options for the West Coast and Central Basins.
- Section 3.0: Groundwater Basin Extraction/Replenishment Planning Scenarios – This section describes the broad planning scenarios for each groundwater basin that served as the basis for developing the GBMP alternatives. The planning scenarios were based on the Concept A (pumping within the adjudicated rights) and Concept B (pumping above the adjudicated rights) conceptual options for the West Coast and Central Basins. Concept A and Concept B scenarios were developed separately for both basins.
- Section 4.0: Groundwater Modeling Assessments of Basin Operating Conditions – This section summarizes groundwater modeling simulations conducted to evaluate the impacts of the GBMP planning scenarios. The West Coast and Central Basin scenarios developed in Section 3.0 were combined to generate groundwater basin-wide conditions. Various "combinations" were generated by combining the West Coast Basin and Central scenarios. Only feasible combinations of scenarios were used for conducting model simulations.
- Section 5.0: Formulation and Evaluation of Alternatives – This section identifies specific projects consisting of supply, recharge, and extraction components, which are ultimately combined into GBMP alternatives to satisfy the GBMP planning scenarios presented in Section 3.0 and evaluated in Section 4.0. The identified basin-specific projects were used to satisfy the groundwater yield needed for each of the scenarios identified in Section 3.0. The costs for each of the alternatives were prepared by combining the individual project costs. An analysis of the GBMP alternatives provides an assessment of the performance of the alternatives relative to evaluation criteria that can guide stakeholder decision making.

- Section 6.0: Implementation Plan – This section outlines the key considerations that must be addressed to advance the GBMP alternatives as well as next immediate steps for GBMP implementation. These issues include regulatory and legal issues, implementation of related projects and planning activities currently underway, the availability of replenishment water sources, spreading ground capacity, model development/enhancement, and consideration of impacts on the groundwater replenishment assessment.

As noted previously in Section 1.1, the Draft GBMP is not a capital improvement program, nor does it encourage or commit any party to a particular project or program. It does not address institutional issues, which are significant and critical to advancing any of the elements identified herein. While estimated planning-level costs are provided for specific projects and alternatives as a basis for comparison, no attempt has been made to analyze future RA impacts, or to allocate potential benefits that may be realized from these projects or alternatives.

The implementation plan included in Section 6.0 provides recommendations for further stakeholder consideration, and potential next steps to explore the identified projects more fully. It does not, however, lay out a specific plan, as that would require site-specific environmental review, further policy development, and resolution of institutional issues.

FIGURE 1-2
Report Section Organization of Planning Process Elements

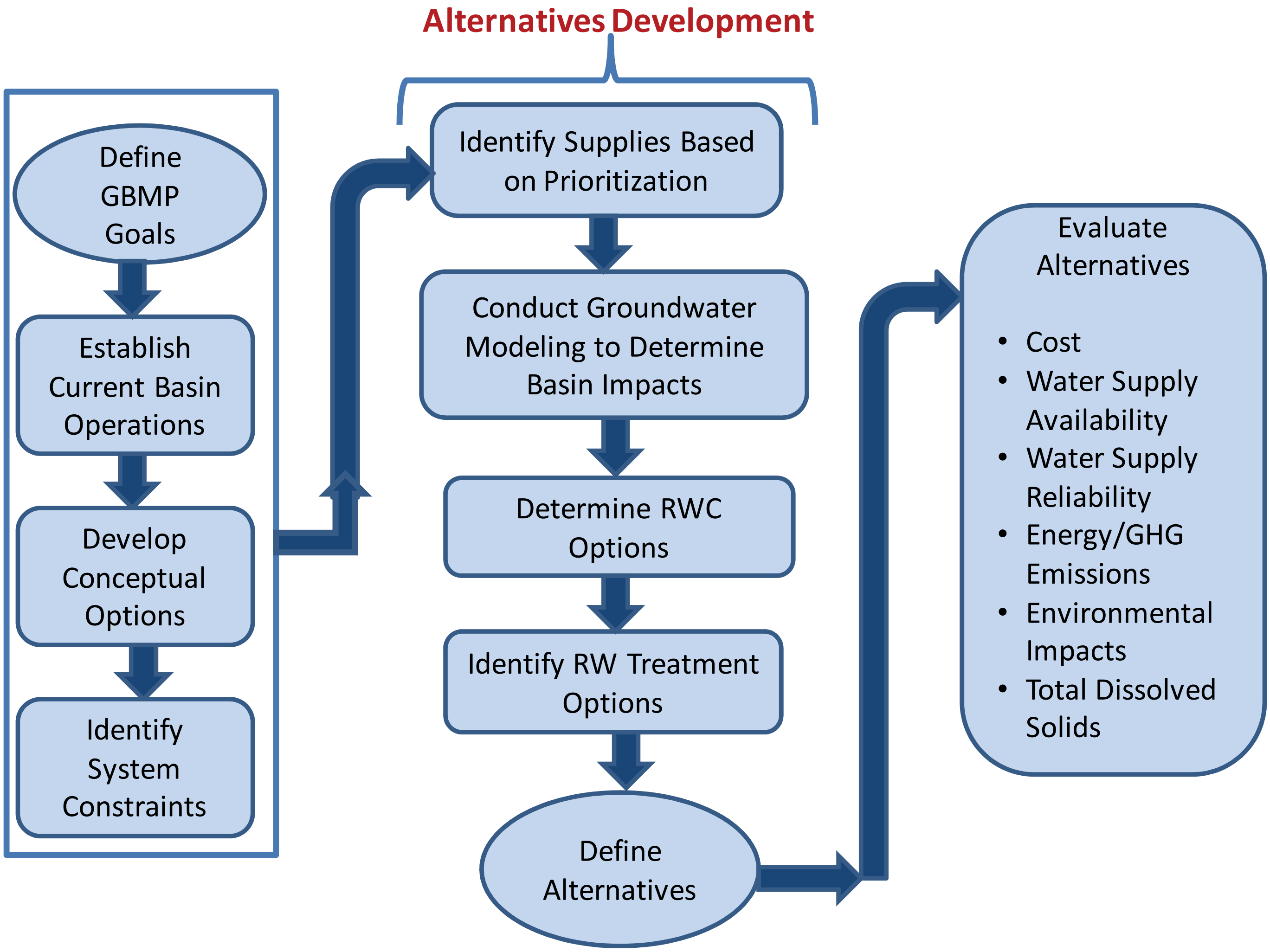


Draft Groundwater Basins Master Plan Planning Process

2.1 Planning Process

The process employed to develop alternatives for this Draft GBMP is described in this section and summarized in Figure 2-1.

FIGURE 2-1
GBMP Planning Process



Notes:

GHG = greenhouse gas
RW = recycled water
RWC = recycled water contribution

2.1.1 Overview

Planning for each of the two groundwater basins was conducted in two phases. Phase 1 consisted of study scoping and alternatives development, and Phase 2 consisted of detailed alternatives analysis, including groundwater modeling and economic comparisons. Basin stakeholders, primarily wholesale water agencies, water purveyors, pumpers, and recycled water providers were engaged throughout the process.

The Draft GBMP was developed with a “bottoms-up” perspective, both with respect to the groundwater basin operations and impacts, as well as with consideration—first and foremost—for the interests and drivers of the water rights holders. Programs and projects that can provide synergistic opportunities and benefits to basin stakeholders will naturally find support and be carried through to implementation. The relative costs and benefits of the alternatives evaluated, when measured against alternate water supply options such as the purchase of imported water for either direct use or replenishment, will drive implementation decisions by the stakeholders.

If the existing basin judgments are amended (as described in Appendix B) to allow for enhanced use of basin storage, extraction beyond the current adjudication limits can be considered through the development of water augmentation replenishment projects. Examples of such projects and their associated costs were developed for this report. Implementation of such projects would be a complex and protracted process, requiring extensive coordination across multiple institutions and potentially vast geographical expanse. The Draft GBMP provides a groundwater-focused framework within which to begin exploring such possibilities.

2.1.2 Stakeholder Participation

This Draft GBMP is being developed as a tool for the basin stakeholders to use as they plan for increased utilization of the groundwater basins. The basin stakeholders that have been engaged in the Draft GBMP development process include water purveyors and pumpers with water rights (including local refineries), water wholesalers (Metropolitan member agencies), and recycled water providers.

As the study began with the focus on the West Coast Basin on March 2, 2010 (less than 1 week after the project team kickoff meeting with WRD), West Coast Basin stakeholders were introduced to the initiation of the plan development process at the monthly meeting of the West Basin Water Association. Meeting participants were asked to identify points of contact within each representative organization with whom WRD could communicate regarding the plan development. Individual meetings followed in which pumper plans for future groundwater use were discussed so that the Draft GBMP could consider how to meet changing future groundwater demand patterns. In early September 2010, an initial workshop was held with West Coast Basin stakeholders to discuss the baseline operating conditions, and proposed alternative management concepts were initially presented. These initial concepts, described in Section 6.0, were further refined based on stakeholder feedback and discussed in a subsequent workshop in late September 2010. With the initial concepts established, Phase 2 detailed analyses of the West Coast Basin alternatives commenced, including groundwater modeling and cost evaluations.

In early November 2010, Phase 1 of the Central Basin portion of the study began. Due to the large number of Central Basin pumpers, three introductory workshops were held through early January 2011 to ensure that stakeholders interested in participating had ample opportunity to engage in the process. Follow-up one-on-one meetings with the Central Basin stakeholders were also held in the ensuing months as the Phase 1 concepts and alternatives were developed. In early May 2011, the Phase 1 work was discussed with the Central Basin Water Association and, later that month, a meeting of Metropolitan Water District member agencies from the Central Basin was held to discuss the planning approach and Phase 1 findings. In early August 2011, the projects and alternatives identified during Phase 1 were presented at the Central Basin Water Association seeking feedback, refinements, and consensus on proceeding with the Phase 2 technical and economic analyses.

The findings of the Phase 2 analyses were presented to the West Basin and Central Basin Water pumpers in March 2012.

2.2 GBMP Goals, Basin Operations, and Conceptual Options

The specific goals of the Draft GBMP stem from historical and current basin operations. Each year, WRD plans for the replenishment needs of the West Coast and Central Basins for the ensuing year. This is done by estimating anticipated groundwater production demands (based on 3-year historical averages) relative to monitored groundwater levels, and incorporating the effects of averages from a long-term (30-year) hydrologic record.

Sources of replenishment water currently include recycled water and imported water, as well as stormwater (primarily in the Central Basin). The cost of replenishing the basins with recycled water and imported water to match anticipated pumping demands is determined by the anticipated mix of water supplies expected to be available.

WRD is responsible for ensuring that the adjudicated water rights within each basin can be satisfied for the pumping community. Without sufficient planning, the development of projects that could potentially provide more reliable, cost-effective water supply sources than are currently available for replenishment may be delayed, and full utilization of these water rights will be contingent on the availability and value of imported water purchase. The objectives of the GBMP thus support the region's broader goals of increased water supply reliability through the use of local water resources in a cost-effective and environmentally sustainable manner.

2.2.1 Groundwater Basins Master Plan Goals

The primary goals of the GBMP alternatives include the following:

1. Replace the current use of imported water for basin replenishment.
2. Enhance utilization of the West Coast and Central Basins.

With the uncertain reliability and availability of imported water described previously, discounted, surplus replenishment water has decreased significantly in recent years and is no longer included in MWD's published rate sheets. Thus, increasing the availability of locally supplied and accessible groundwater, if relatively cost-effective replenishment can be provided, increases the ability of local water purveyors to plan for and control their water supply. An estimate of increasing imported water costs is provided in Figure 2-2. The information in this graph was developed for the *Groundwater Reliability Improvement Project (GRIP) Alternatives* Analysis study (RMC, 2011), and reflects the following assumptions:

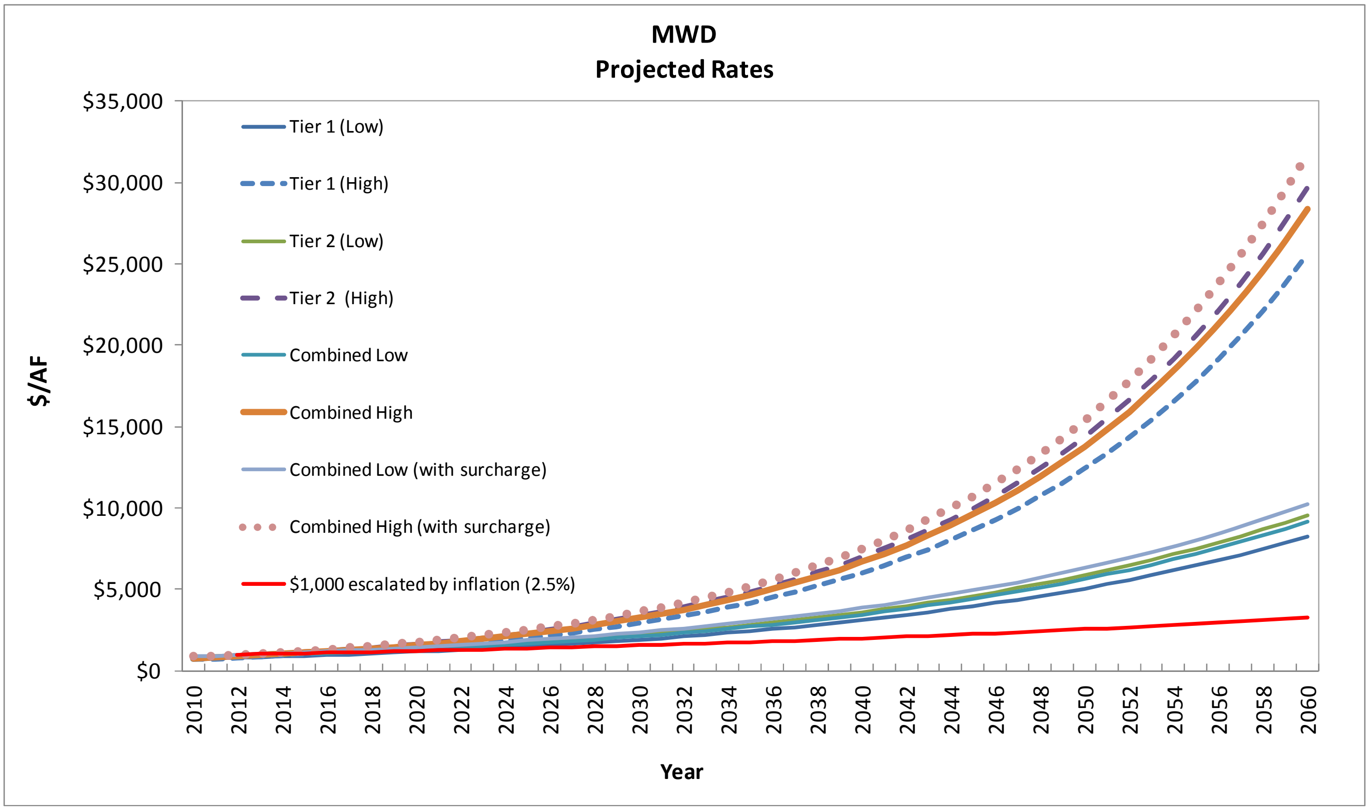
- Tier 1/Tier 2 prices are based on published Metropolitan rates up to the year 2012.
- "Low" indicates a low range projection that assumes annual increases at 5.0 percent.
- "High" indicates a high range projection that assumes annual increases based on historical (1960 to 2010) Metropolitan price increases at 7.5 percent.
- It is assumed that Tier 1 water is available 30 percent of the time, and Tier 2 water is available 70 percent of the time.
- "Combined Low" and "Combined High" unit costs are the weighted product of Tier 1 costs and Tier 2 costs based on the above assumed availability (30 and 70 percent, respectively), for the "Low" (5.0 percent) and "High" (7.5 percent) rate increase projections.
- Costs "with surcharge" include a $104 per AF surcharge for imported water served in the Central Basin.

In addition, as a point of comparison, Figure 2-2 shows the cost of $1,000 in 2012 dollars (which is very close to the current maximum imported water cost shown for Combined High with surcharge) when escalated by inflation (2.5 percent) over time. Thus, projects providing even relatively expensive source water today at $1,000 per AF will, over time, provide very cost-effective alternatives to replenishment with imported water, which is highly likely to exceed the inflation rate.

Long-term planning for the replacement of imported water as a source of replenishment water is needed to ensure that adequate treatment and conveyance facilities, in terms of size and treatment level, are in place in time to meet groundwater pumping demands cost-effectively.

This Draft GBMP is intended to be a tool or resource to be used by all basin stakeholders to aid in decision making for future development of groundwater resources in the West Coast and Central Basins. The components of the various Draft GBMP alternatives can be used as building blocks to provide comparative cost estimates of future basin management scenarios. By considering a long-term planning horizon, WRD can work with the basin stakeholders to cultivate those programs and projects that will ultimately provide cost-effective replenishment for adjudicated pumping rights in the basins.

FIGURE 2-2
Projected Rates for Imported Water through 2040 ($/AF)



2.2.2 Basin Operations

This section describes existing basin operations and associated facilities. These are the starting point from which GBMP alternatives were crafted.

2.2.2.1 Historical and Projected Groundwater Use

Historical basin operations with respect to pumping and replenishment supplies and quantities were evaluated for the Draft GBMP and are summarized in Appendix C. In the West Coast Basin, 42,000 AFY have been pumped, on average, over a recent 10-year period (2000-2010), which is approximately two-thirds of the adjudicated rights, or about 22,500 AFY less than the adjudicated limit. Similarly, in the Central Basin, 195,500 AFY has been pumped, on average, over the same 10-year period, which also is roughly 22,000 AFY below the adjudicated limit but represents only about 10 percent of the Central Basin APA. Discussions with basin stakeholders indicated that they plan to pump more of their groundwater rights in the future as the cost of purchasing imported water for potable use continues to rise. Thus, an estimated 44,500 AFY of additional replenishment water will be needed to meet the long-term future pumping demands in the West Coast and Central Basins.

2.2.2.2 Replenishment Facilities

Managed groundwater replenishment in the West Coast Basin is provided exclusively through injection at two seawater intrusion barrier systems. In the Central Basin, replenishment is provided both by injection at a single barrier system and with spreading. Provided below is a summary of these replenishment facilities.

West Coast Basin

The two injection barriers in the West Coast Basin are located along the west coast of the Los Angeles County Coastal Plain and along the south coast in the Dominguez Gap area. These barriers are used to reduce the amount of seawater intrusion along the coast and are owned, operated, and maintained by LACDPW. Initiated with a test injection well in 1951, the West Coast Basin Barrier Project (WCBBP), shown in Figure 2-3, now consists of over

150 injection wells and extends over 9 miles from Los Angeles International Airport in the north to Palos Verdes in the south. The Dominguez Gap Barrier Project (DGBP), shown in Figure 2-4, has been in operation since 1971 and protects the southern coast of Los Angeles County. The original DGBP consisted of 41 injection wells spaced over 4 miles, in a north/south alignment from F Street to E Street along the Dominguez Channel. In 2002, 17 additional injection wells were added to the DGBP, extending 1.5 miles eastward along Spring Street in Long Beach, from the Dominguez Channel to the Long Beach Freeway. Artificial replenishment of the basin via these injection barriers has historically averaged approximately 28,000 AFY since 1959 (WRD, 2012).

The operating permits for these barrier facilities are discussed in Appendix D.

Central Basin

Groundwater in the Central Basin is recharged via surface spreading at the Whittier Narrows Dam, Montebello Forebay Spreading Grounds (MFSG), which consists of the Rio Hondo Spreading Grounds and San Gabriel Coastal Spreading Grounds, infiltration in the unlined portions of the Lower San Gabriel River, and via direct injection at the Alamitos Barrier Project (ABP) (Figure 2-5). The lower San Gabriel River extends from the Whittier Narrows Dam though the Pacific coastal plain ending at Long Beach. Through most of the Montebello Forebay, the San Gabriel River is unlined, allowing spreading by percolation through its unlined bottom. The river is lined from about Firestone Avenue through the remainder of the Central Basin.

Natural recharge to the Central Basin includes surface infiltration of precipitation and applied water (such as landscape irrigation), subsurface inflow from the surrounding mountains (referred to as mountain-front recharge), through the Los Angeles and Whittier Narrows and along the boundary with the Orange County Basin, and through stormwater percolation at the spreading grounds and unlined portions of rivers. Sources of artificial recharge include recycled water, imported water, and stormwater. The volume of recharge varies significantly from year to year based on precipitation and availability of imported water. Artificial replenishment of the basin via the spreading grounds and injection barrier has historically averaged approximately 143,000 AFY since 1959, whereas production has averaged approximately 204,000 AFY (WRD, 2012). Projects recently implemented and currently planned for implementation by WRD are increasing the amount of the artificial recharge from both stormwater and recycled water in the Central Basin.

The ABP is jointly owned by LACDPW and the Orange County Water District (OCWD). As shown in Figure 2-5, the project can be divided into three major segments: (1) the main supply line that runs easterly and then southerly from the pressure reducing station to the T-vault, (2) the west leg that runs westerly to all injection wells west of the T-vault, and (3) the east leg that runs southerly and easterly to all injection wells east of the T-vault. Additionally, the City of Long Beach has four aquifer storage and recovery (ASR) wells that can be used to inject imported water available in wet years into the Central Basin. The combined injection capacity is estimated to exceed 3,250 AFY (MWD, 2007).

FIGURE 2-3
West Coast Barrier Project Facilities

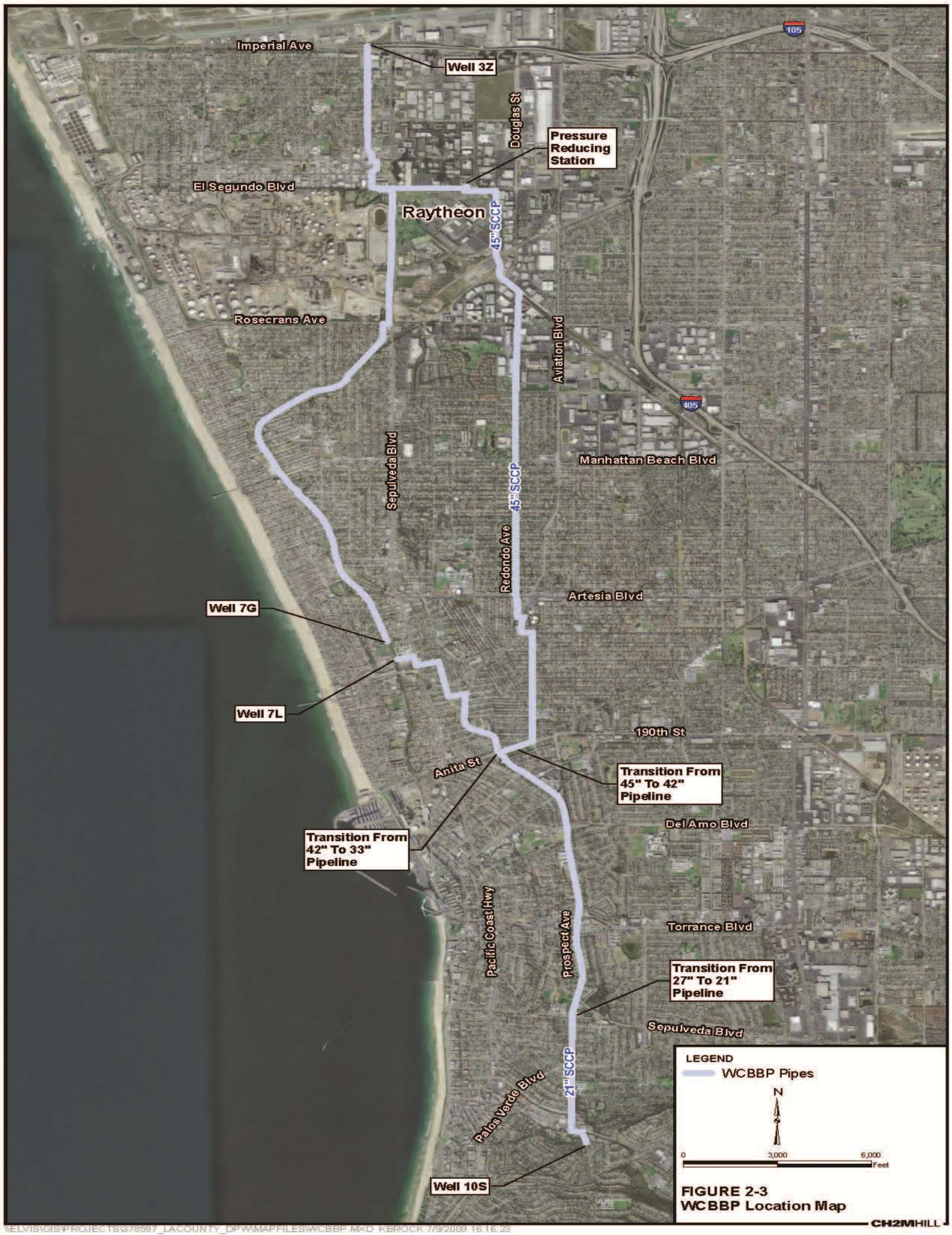


FIGURE 2-4
Dominguez Gap Barrier Project Facilities

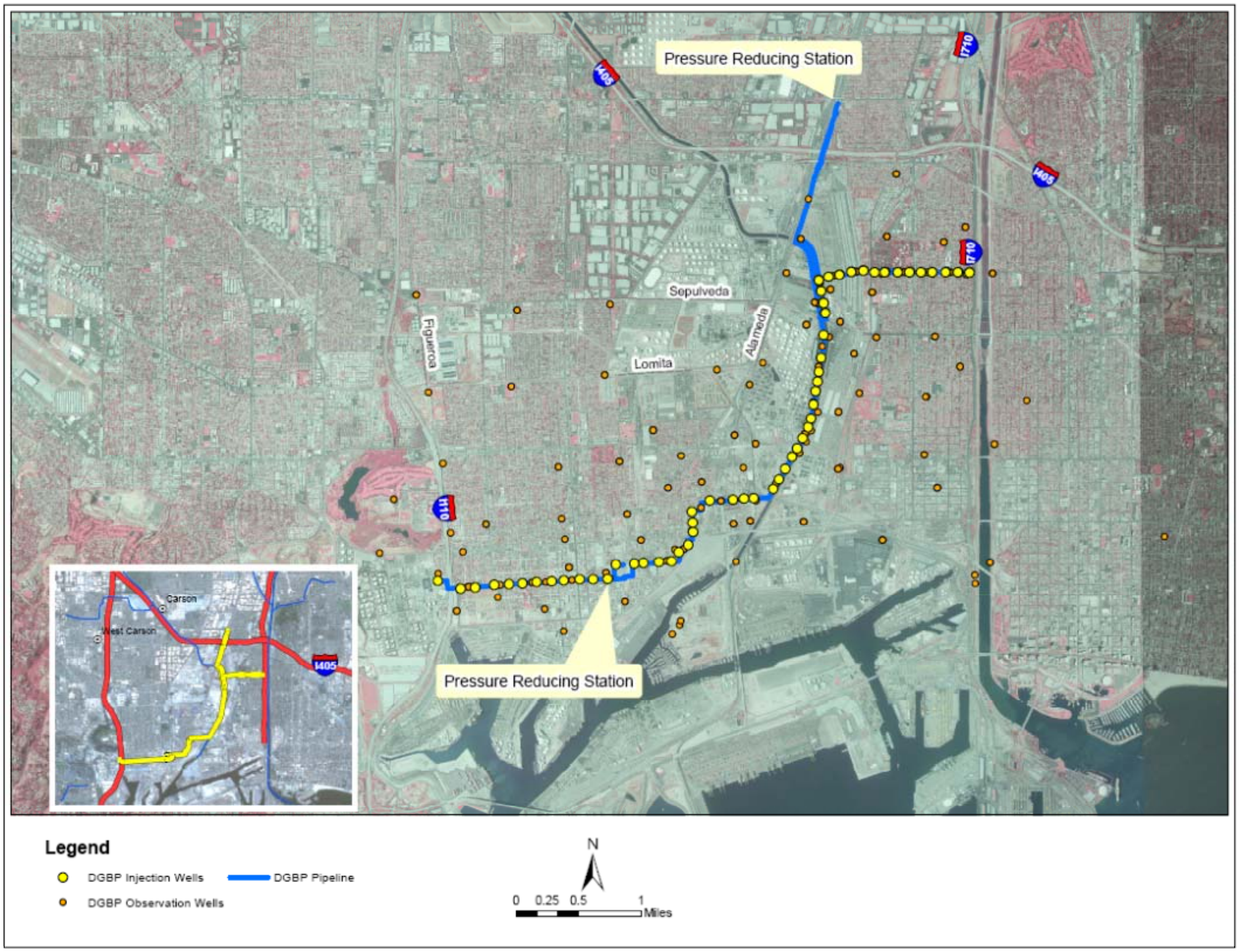
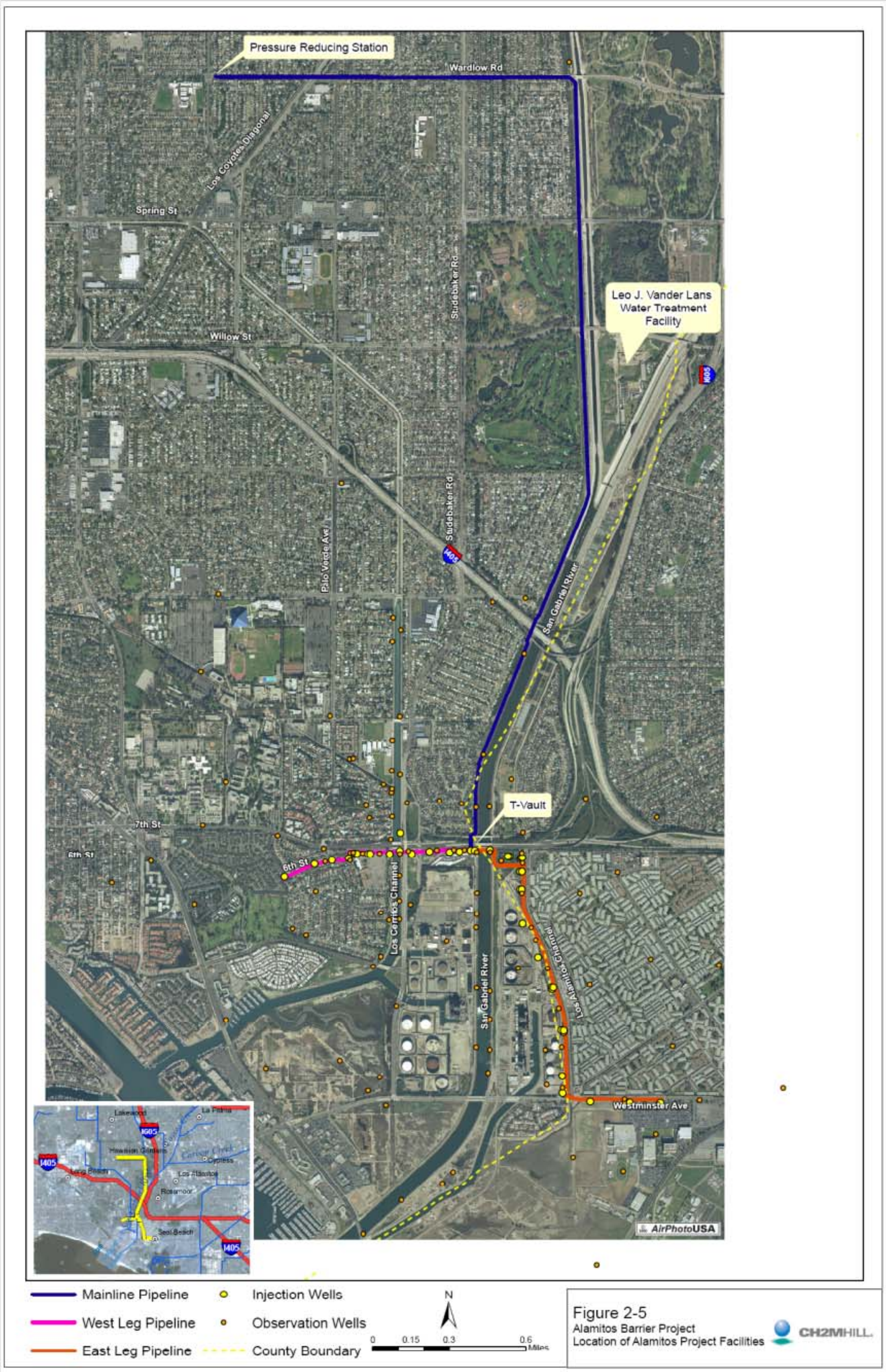


FIGURE 2-5
Alamitos Barrier Project Facilities



2.2.2.3 Saline Plume

Continuous operation of the barriers has effectively curtailed further seawater intrusion into the West Coast Basin. However, the residual saline plume that was trapped inland of the barriers continues to impact the water quality of the basin, thereby increasing the cost of produced water (as salt removal is required before it can be used).

WRD has been tracking the migration of the plume as it advances eastward with groundwater movement. Mapping of the plume has been updated periodically, with the most recent update in 2008. Figure 2-6 shows the plume within the Silverado aquifer, which is most highly impacted relative to the shallower Gage aquifer and the deeper Lower San Pedro aquifer. WRD has estimated that the plume is moving eastward at an average rate of 250 feet per year, or about 1 mile every 20 years. The volume of groundwater affected by the saline plume is approximately 650,000 AF (WRD, 2009). Adjustments to the plume map continue as additional monitoring data becomes available.

Two treatment facilities located in the City of Torrance extract water from the saline plume and treat to potable water standards. The 1-mgd product-water capacity Brewer Desalter is owned, operated, and maintained by WBMWD, and the treated water is provided to the California Water Services Company (CWSC). The Goldsworthy Desalter is owned by WRD and is operated and maintained by the City of Torrance who delivers the treated water to its customers. The treatment (product-water) capacity Goldsworthy Desalter studied for expansion to 5 mgd. Brine flows from these treatment facilities are discharged to nearby sanitary sewers for treatment at the downstream wastewater treatment plant (i.e., LACSD's Joint Water Pollution Control Plant (JWPCP).

The extent to which additional remediation projects should be considered and developed will be established as part of the Saline Plume Policy that will be addressed after completion of this Draft GBMP.

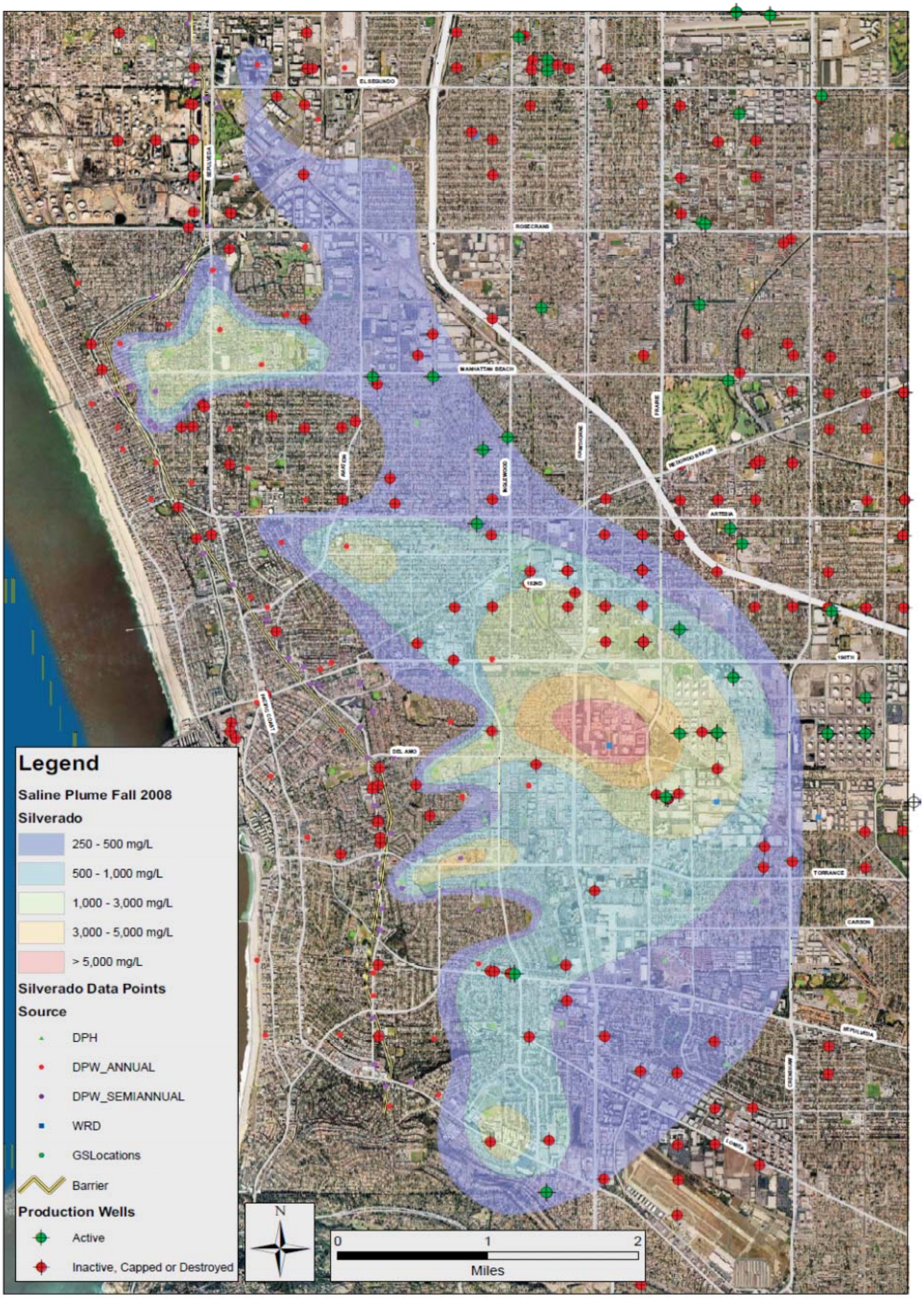
2.2.3 Conceptual Options

Alternatives for extraction, recharge, and supply were initially formulated based on broad concepts, and subsequently screened and refined for further analysis.

The underpinnings for operation of the West Coast and Central Basins are the provisions of the respective basin Judgments (Appendix B). These adjudications limit extraction from the West Coast Basin to 64,468.25 AFY and 217,367 AFY from the Central Basin. It is the responsibility of WRD to ensure that these limits can be extracted by the water rights holders (or their leasees). As such, the first series of conceptual options, "Concept A" provides for variations on the basin extraction and replenishment schemes within the current adjudicated limits.

The proposed judgment amendments would enhance the utilization of the groundwater basin storage capacities and could fundamentally change basin operations. "Augmentation" projects, involving recharge above replenishment requirements for existing water rights, would allow pumpers to extract a similar volume of groundwater as recharged over a specified period of time. The extraction limit is thus tied to the physical basin capacities, which are best approximated initially as historical maximum production, as well as supply limitations. Thus "Concept B" options provide for up to 30,000 AFY above the current West Coast Basin adjudication, or 94,468 AFY, which has historically been achieved. The Central Basin "Concept B" options were crafted to ultimately replace the imported water use with groundwater pumping for the service area overlying the basin. The target recharge volume was based on reasonably available local stormwater and recycled water supplies (that is, San Jose Creek Water Reclamation Plant [SJCWRP], Los Coyotes Water Reclamation Plant [LCWRP], and a potential new satellite advanced water treatment plant for the City of Los Angeles) totaling 320,000 AFY, which is approximately 103,000 AFY above the current APA.

FIGURE 2-6
West Coast Basin Saline Plume



2.3 Constraints

WRD is responsible for ensuring that pumper demands, up to the water rights in the West Coast Basin and APA in the Central Basin, can be met through sufficient replenishment. The replenishment volumes are limited by several factors, including existing stormwater infiltration capacity, available recycled water and blending supplies to meet the permitted recycled water contribution (RWC) for each recharge facility in each basin, as well as injection barrier system capacities and water quality challenges. These are described later in this section.

With these constraints in mind, planning scenarios for each basin were identified during the scoping phase (Phase 1) of the Draft GBMP process, and are described in Section 3.0. Supply options for each scenario were developed with consideration for the supply limitations from existing sources (based on historical and projected patterns of stormwater and recycled water availability). These scenarios were then developed into distinct alternatives for economic analysis in Phase 2 (discussed in Section 5.0).

Hydrogeological constraints within the groundwater basins are represented in the groundwater flow model discussed in Section 4.0.

2.3.1 Spreading Grounds Capacities

Replenishment of the groundwater basins with stormwater provides water supply as well as dilution credit to meet RWC requirements. The most cost-effective method for capturing and infiltrating large volumes of stormwater from the San Gabriel River and Rio Hondo is limited by the available capacity of the existing MFSG. Recharge is typically highest during the wet season when large volumes of stormwater are available from storm events and from subsequent releases from upstream dams. An analysis of historical, monthly recharge at the MFSG was conducted for the GBMP modeling and is described in Section 4.1.2.

2.3.1.1 Montebello Forebay Spreading Grounds Improvements

WRD is currently implementing three projects to increase capture of stormwater at the MFSG to offset purchase of imported water for replenishment—Whittier Narrows Conservation Pool, Spreading Grounds Interconnection Pipeline, and rubber dams. These projects are described in this section. Also, WRD is implementing the GRIP to offset the amount of imported water historically used for replenishment at the MFSG (21,000 AFY) with recycled water (see Appendix A, Section A.7.1 for more details). All of these projects are assumed to be completed as part of the baseline conditions for the GBMP.

Whittier Narrows Conservation Pool

The Whittier Narrows Dam captures local stormwater flows that would otherwise flow to the ocean. Water behind the dam can be released at a rate equal to the infiltration rate of the MFSG to maximize water replenishment. Operational enhancements to the Whittier Narrows Conservation Pool will allow the maximum conservation pool elevation behind the dam to 205 feet from 201.6 feet, which will increase the volume of stormwater captured and ultimately released for replenishment in the MFSG by approximately 3,000 AFY.

San Gabriel River Rubber Dams

The San Gabriel River currently has seven rubber dams along the unlined portion of the river located downstream of Whittier Narrows Dam. The rubber dams create a spreading facility within the river and enhance recharge of water that would otherwise be wasted to the ocean. WRD has plans to construct two rubber dams in the San Gabriel River to allow for the capture of an additional 3,600 AFY of stormwater, which would be released when the spreading grounds have available recharge capacity.

Spreading Grounds Interconnection Pipeline

The Spreading Grounds Interconnection Pipeline project enhances operational flexibility between the Rio Hondo and San Gabriel spreading grounds (which make up the MFSG), allowing the increase of stormwater capture and RW recharge. Existing operational constraints limit the opportunity to recharge approximately 5,700 AFY of recycled water and 1,300 AFY of stormwater, so the project is expected to allow for increased replenishment of 7,000 AFY. The interconnection pipeline was put into service in March 2011.

2.3.2 Recycled Water Availability

Use of recycled water for recharge of the West Coast and Central Basins will be limited by existing and planned use of potential supplies, as well as the seasonal and diurnal variations in non-potable reuse. Nearby water reclamation plants (WRPs) with potential recycled water supplies considered for this plan include the following:

- SJCWRP
- Los Coyotes WRP (LCWRP)
- Long Beach WRP (LBWRP)
- Hyperion Treatment Plant (HTP)
- Edward C. Little Water Reclamation Facility (ECLWRF)
- TIWRP
- JWPCP

Each plant, except for the JWPCP and HTP, produces at least tertiary-treated effluent for non-potable customers and groundwater recharge (GWR) via surface spreading while some of the effluent is further treated with full-advanced treatment (FAT) for injection into the groundwater basin (see Section 2.4.4.2 for a description of FAT). The various entities that currently purchase effluent from these facilities, including WRD, have potential future reuse plans for some of the unused flows. Also, some entities have purchase agreements for specific volumes of water; however, many of these agreements are expiring in the near future, and much of the effluent reflected in these agreements currently goes unused.

With the exception of recharge of San Jose Creek and Whittier Narrows WRPs effluent at the MFSG, the majority of reuse of effluent from these plants is for non-potable reuse. Most of the non-potable reuse is for irrigation uses, which have severe seasonal variations such that use in the summer is typically more than twice the annual average demand and over four times the winter demand. Therefore, more recycled water is generally available for recharge in the winter than in the summer; however, as discussed in the previous section, the MFSG capacity is limited in the winter due to recharge of stormwater.

The use of effluent from the Hyperion Treatment Plant or JWPCP (both of which currently discharge secondary-treated effluent to the Pacific Ocean), assumes some addition of advanced treatment. The volume of available effluent from these large plants (450 and 400 mgd, respectively) is not considered to be limiting for this plan.

2.3.3 Blending Supplies

In the Central Basin, recycled water has been used successfully as a source for GWR via surface spreading in the Montebello Forebay since 1962. Currently, disinfected tertiary recycled water, in addition to engineered stormwater recharge (local runoff and precipitation) and imported water, is used for replenishment at the spreading grounds. For the purpose of determining the allowable RWC, underflow from the Main San Gabriel Basin is also counted as dilution water. The amount of recycled water recharged at the spreading grounds will vary from year to year depending on the availability of recycled water, stormwater, imported water, and the capacity of the spreading grounds. The current Water Recycling Requirements (WRR) permit (discussed in Appendix D) allows for a 35 percent RWC over a 5-year period. As more recycled water is proposed to be recharged at MFSG, the volume could be limited by the availability of blend water because stormwater and imported water tend to be highly variable from year to year. The ultimate goal of this GBMP is to reduce or eliminate the use of imported blend water at the spreading grounds.

Imported water is currently the blend supply used at each of the seawater intrusion barriers; however, each barrier is expected to have an RWC of 100 percent in the near future, so no blend supply will be needed.

2.3.4 Injection Barrier Capacities

The ability to use the existing barrier systems for injection of additional replenishment water is dependent on both the condition and capacity of the existing systems. LACDPW is actively studying the condition of the barrier facilities, which consist of supply pipelines, injection wells, valves, and other appurtenances. The recommendations of these condition assessments, including valve replacement, telemetry, cathodic protection, and increased monitoring of higher-risk pipe segments, are being considered by LACDPW for implementation.

The current hydraulic capacities of these systems, however, have not been recently assessed, and are important considerations for evaluating the GBMP alternatives. If additional injection capacity is needed for a given alternative, then the associated costs would need to be included. To that end, a cursory analysis was performed as part of the Draft GBMP to identify whether sufficient was capacity available to receive the volumes of replenishment water needed for the Draft GBMP alternatives. The technical memorandum documenting the analysis approach and results is provided in Appendix E.

Based on this analysis, the ultimate capacities estimated for the three existing barrier systems are as follows:

- ABP: 8.0 mgd (8,960 AFY)
- DGBP – Total capacity is the sum of the following:
  - System south of Sepulveda Boulevard (original system): 9.8 mgd (10,976 AFY)
  - System north of Sepulveda Boulevard (extension): 23.5 mgd (26,320 AFY)
  - Total: 33.3 mgd (37,296 AFY)
- WCBBP – Capacity analysis was conducted based on two conditions: a) using well data available during the analysis period, or b) assuming use of the remaining, unused wells, and wells for which no data was available:
  - Based on wells actively in use: 38.4 mgd (43,008 AFY)
  - Based on all wells: 47.4 mgd (53,088 AFY)

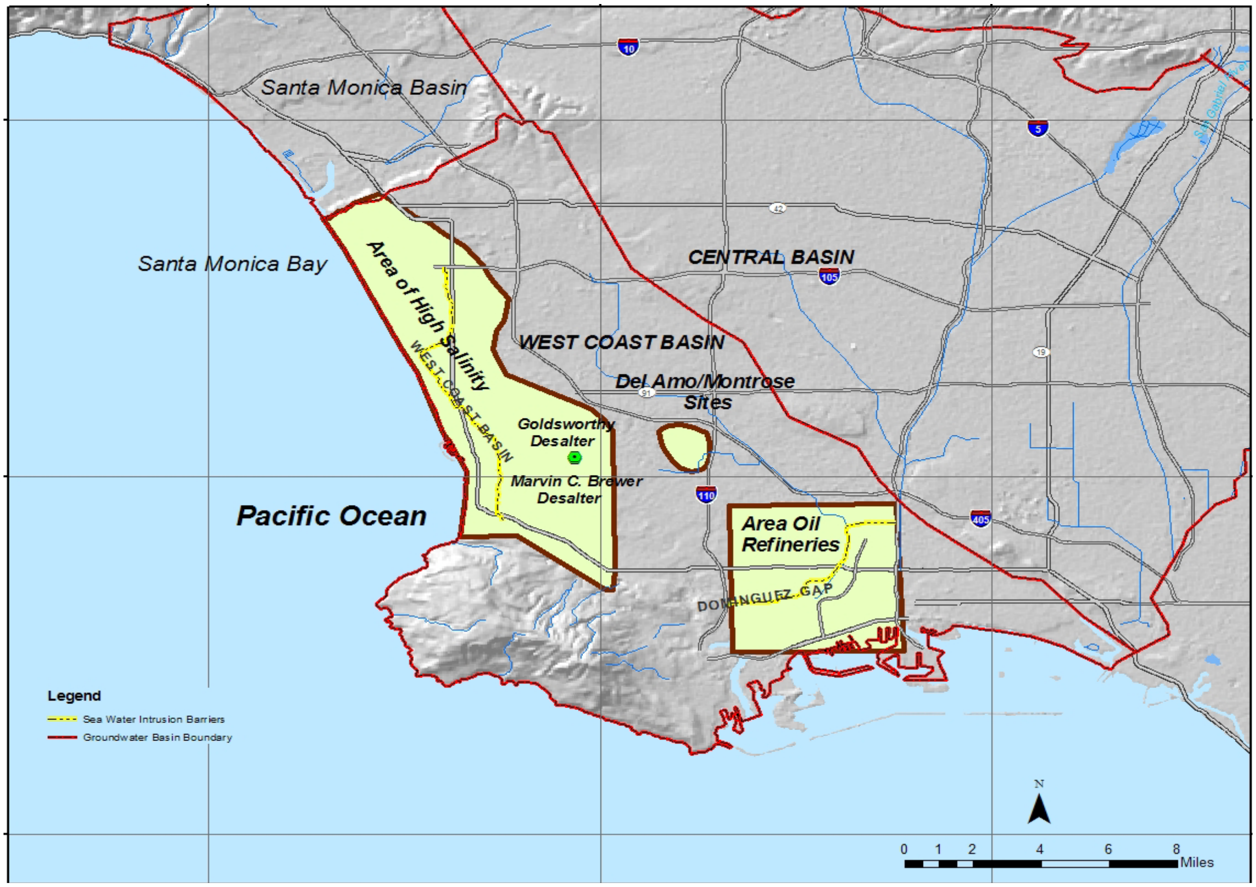
The Draft GBMP alternatives do not require expansion of the existing barrier systems. However, a comprehensive analysis of barrier capacity is recommended for injection schemes that significantly expand current operations.

2.3.5 Groundwater Remediation

In addition to the saline plume discussed in Section 2.2.2.3, additional water quality challenges within the West Coast Basin have arisen from historical industrial sources and are currently undergoing remediation activities. The Del Amo and Montrose Chemical Superfund sites are located near the center of the West Coast basin. The Del Amo site included industrial dumping between 1943 and 1972. The waste, including benzene, napthelene, ethylbenzene, and phenol, has contaminated the soil and groundwater around the site. The Montrose Chemical Corporation manufactured high-grade dichlorodiphenyltrichloroethane from 1947 to 1982. Groundwater flow from the Montrose and Del Amo sites is to the east-southeast. Groundwater contamination plumes from the Montrose and Del Amo sites have merged. The approximate extent of contamination is shown in Figure 2-7.

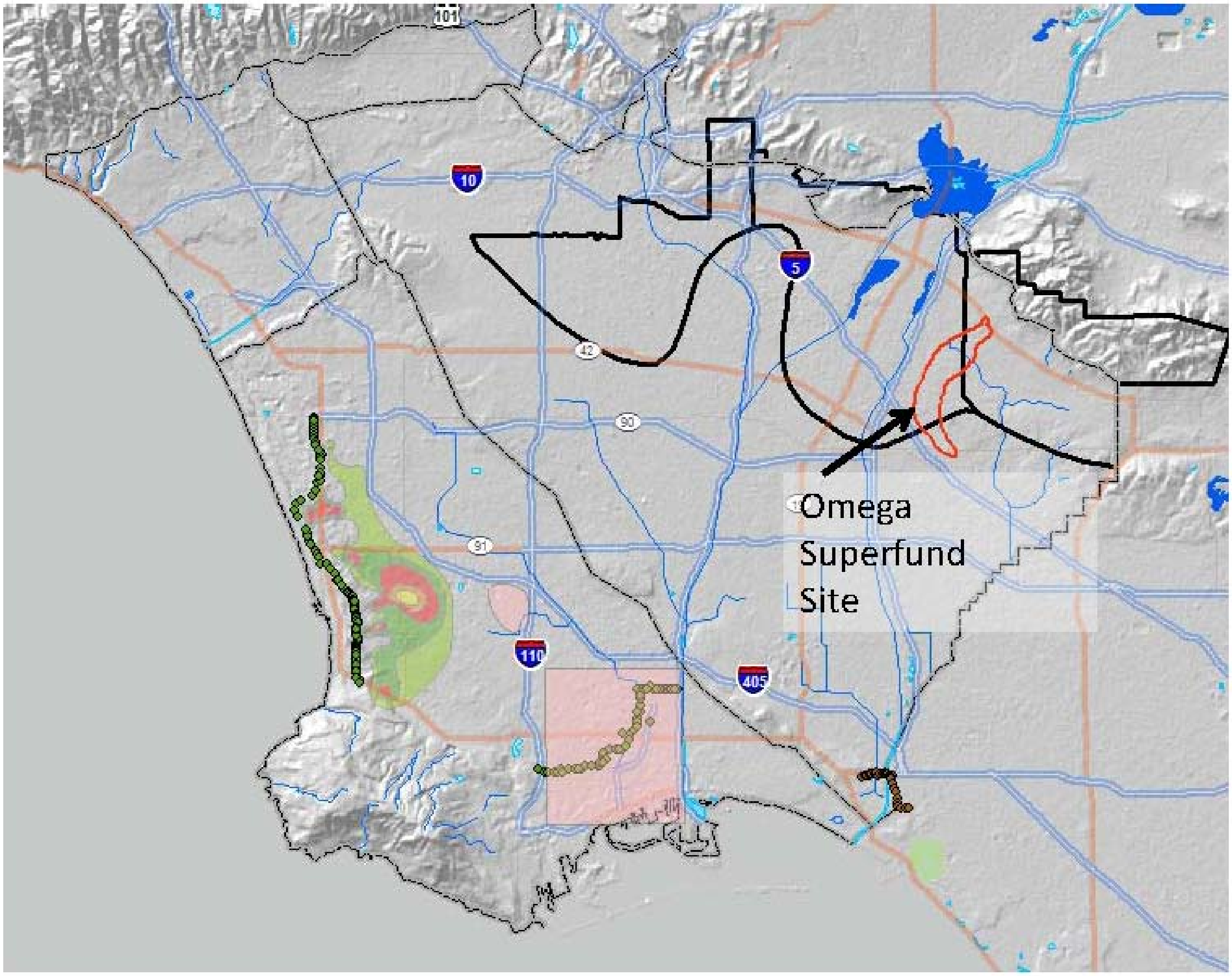
Several large oil refineries are located in the West Coast Basin. Most of these refineries are major water rights holders. Oil recovery and basin cleanup efforts by some of these oil companies are ongoing.

FIGURE 2-7
Locations of Groundwater Contamination – West Coast Basin



The confined layering in the Central Basin has provided it with a greater degree of natural protection from surface releases of contaminants than the forebay areas. Overall, the groundwater in the Central Basin is of high quality and suitable for potable use without treatment. The primary water quality issues are associated with shallow volatile organic compound plumes, one of which is located southeast of the San Gabriel Spreading Grounds, related to the former Omega Chemical Corporation parcel, as seen in Figure 2-8 and additional contamination migrating through the Whittier Narrows from the Main San Gabriel Basin. There are some natural occurrences of arsenic at levels above the maximum contaminant level. In addition, some other well sites have been contaminated with perchlorate and other volatile organic compounds, the sources of which have not yet been determined.

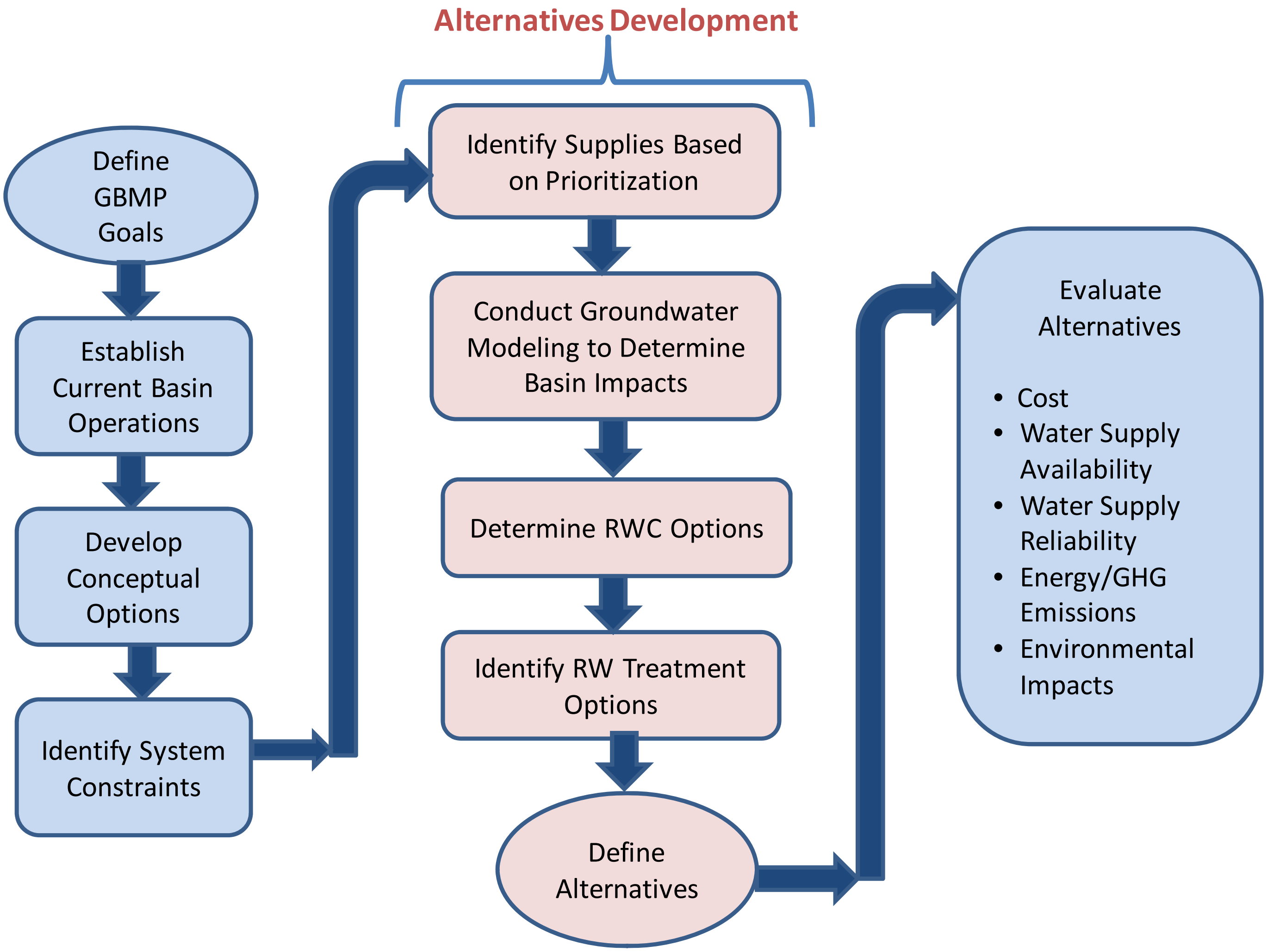
FIGURE 2-8
Omega Chemical Volatile Organic Compound Contamination



2.4 Alternatives Development and Analysis Process

The process of alternatives development began with the prioritizing of replenishment supplies with respect to available flow, water quality, and relative cost. Then, groundwater modeling was conducted to evaluate the basin impacts of the planning scenarios. The RWC to the basins then had to be considered in light of the November 2011 Groundwater Replenishment Reuse Regulation drafted by CDPH (2011 Draft Recharge Regulation, described in Appendix D), and in conjunction with the potential treatment options for recycled water. Finally, source water supplies, recharge, and extraction components were combined into GBMP alternatives for analysis and evaluation. These steps to developing the GBMP alternatives, highlighted in Figure 2-9, are described in this section.

FIGURE 2-9
Groundwater Basins Master Plan Alternatives Development



Focusing initially on varying the basin operations to meet pumping demands established under Concepts A and B for each basin (described previously in Section 2.2.3), a series of groundwater modeling runs were conducted to analyze the impacts of varying basin operating (injection and extraction) conditions. Future pumping demands were identified based on historical and current pumping patterns, water rights, and feedback received directly from the pumper stakeholders. Required recharge volumes were identified to meet the pumping demands of the Draft GBMP planning scenarios, described in Section 3.0.

Recharge patterns were modeled at the existing locations (MFSG, existing injection barriers), as well as at proposed locations (Los Angeles Forebay, inland injection). The pumping effects on the basin, in combination with assumed recharge patterns (via spreading basins or injection), but independent of specific supply sources, were analyzed using the WRD/U.S. Geological Survey (USGS) MODFLOW model under varying operating conditions. The basin modeling approach and results are described in detail in Section 4.0.

Specific sources of potential replenishment supplies were identified to meet the pumping demands for each of the planning scenarios, and a range of treatment options for recycled water were considered.

Combinations of supply options with recharge and extraction patterns were defined with specific, major cost components for cost estimating (that is, treatment, conveyance, extraction, injection, brine discharge, recycled water purchase, pumping). Alternatives were developed independently for the West Coast and the Central basins. Alternatives that met the range of pumping demands (that is, up to the adjudicated limits or beyond) were formulated from combinations of the costing components for the purposes of analysis and comparison.

2.4.1 Prioritized Replenishment Supplies

Specific sources of replenishment water were identified for replacement of imported water. In formulating alternatives for the GBMP, discounted, surplus imported water was assumed to be unavailable, as had been the case for the past 5 years (with the exception of a 5-month period during 2011). For the purposes of this study, only recycled water and stormwater were considered as potential replenishment supplies.

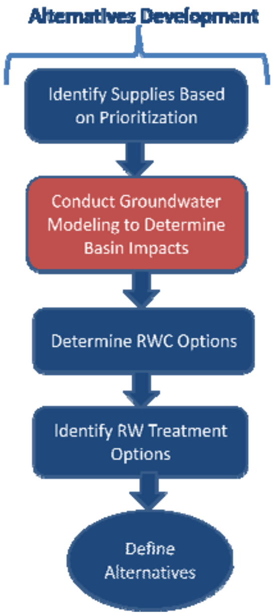
The priority given to delivering recharge water from these supplies was based on their relative availability with respect to (1) *flow* (quantity and frequency); (2) *quality*, with respect to water quality objectives for constituents such as total dissolved solids (TDS) and chloride and other constituents regulated or monitored in the current permits or 2011 Draft Recharge Regulation); and (3) *cost*. Cost considerations for formulating the alternatives were initially qualitative and related to distance and elevation change from water supply to replenishment location (spreading grounds or injection wells), type of source water, and level of recycled water treatment.

Sources of recycled water nearest to the MFSG and with higher-quality effluent are recognized as highest priority options, because their proximity and water quality minimizes conveyance and treatment costs. However, competing demands for the plant effluent may limit its availability for groundwater replenishment, particularly during the dry season when the spreading grounds are less likely to be filled with stormwater. Maximizing the use of existing facilities, such as the MFSG, will be a critical factor in minimizing recharge costs in the Central Basin.

Although stormwater is “free” in the sense that there is no charge directly related to the volume of stormwater used for replenishment, there are costs associated with constructing new facilities for storing and infiltrating the stormwater. No additional treatment of stormwater is assumed to be required beyond that achieved through the infiltration process via soil aquifer treatment (SAT).

2.4.2 Groundwater Basin Assessments

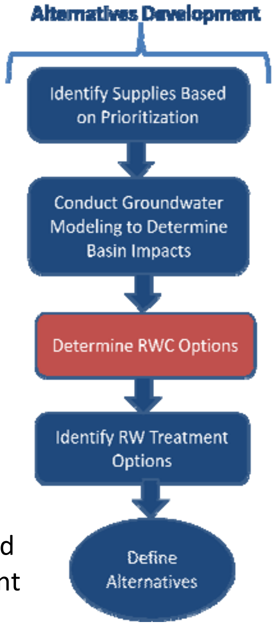
The WRD/USGS MODFLOW groundwater flow model of the West Coast and Central Basins was updated and refined for use in simulating groundwater conditions through water-year 2050, as described later in Section 4.0. Groundwater modeling of various basin operational conditions was conducted to assess the overall water balance in the West Coast and Central Basins, considering hydrologic variations over a long-term (40-year) period. Pumping and replenishment were balanced so that groundwater level fluctuations are maintained within historical limits of fluctuations. Scenarios that were simulated with the model include the following:



- Pumping at APA levels in the Central Basin and at Water Rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions
- Pumping above APA levels in the Central Basin and at Water Rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions
- Pumping at APA levels in the Central Basin and above Water Rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions
- Pumping above APA levels in the Central Basin and above Water Rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions

The modeling results are used to assess groundwater level fluctuations, identify trends in groundwater storage, and identify groundwater flow between adjacent groundwater basins and subareas within basins. The Draft GBMP modeling scenarios and results are discussed in Section 4.0.

2.4.3 Recycled Water Contribution Options



Current and proposed GWR regulations drafted by the California Department of Public Health (CDPH) limits the RWC of recharge projects based on the level of recycled water treatment and method of recharge. For example, the permit for the Montebello Forebay GWR project (discussed in Appendix D) allows for a maximum RWC of 35 percent using a 60-month running average for the total recharge in the MFSG. Also, the regulations usually limit the initial RWC of a new recharge project and allow for increased RWC if certain water quality goals are met after operation of a Groundwater Replenishment Reuse Project (GRRP[1]) begins. For example, each of the three injection barriers in the basins was previously limited to 50 percent RWC, but has received approval or is in the process of receiving approval to increase the RWC to 100 percent.

In general, higher levels of treatment result in a higher RWC. For this plan, recharge with FAT product was assumed to have an RWC of 100 percent, because the technology is proven and several thorough CDPH approval steps will likely occur prior to a project starting. Other than surface spreading at the MFSG and Los Angeles Forebay, the only feasible recharge method available across the basins is injection. FAT product was assumed for all of the potential injection projects considered in the Draft GBMP based on the current and expected regulations.

As noted previously, the MFSG in the Central Basin is currently permitted to recharge up to 35 percent tertiary-treated recycled water of the total recharge in the Central Basin. The 2011 Draft Recharge Regulation provides greater flexibility than the previous 2008 Draft Recharge Regulation regarding the maximum allowable RWC for surface application (spreading) GRRPs. While the 2008 Draft Regulation specified a maximum RWC of 50 percent, the 2011 Draft Regulation does not have such an explicit limit. Rather, the Draft Recharge Regulation allows for alternatives to any of the specified requirements (including RWC) with adequate demonstrations assuring at least the same level of protection to public health, including independent review by a scientific advisory panel. Increasing the designated total organic carbon (TOC) limit of (0.5 milligram per liter [mg/L]/[running monthly average RWC]) for a GRRP after 10 years of operation may be proposed if specific monitoring evidence, health effects evaluations, and associated peer review advisory panel reports support such a determination by CDPH. For the GBMP, the RWCs are not explicitly calculated for the various alternatives. Rather, a range of recycled water treatment options are considered, and their relative costs are examined to illustrate the potential cost savings that could be realized with alternatives to FAT, recognizing that such alternatives would require sufficient scientific demonstration and regulatory approval.

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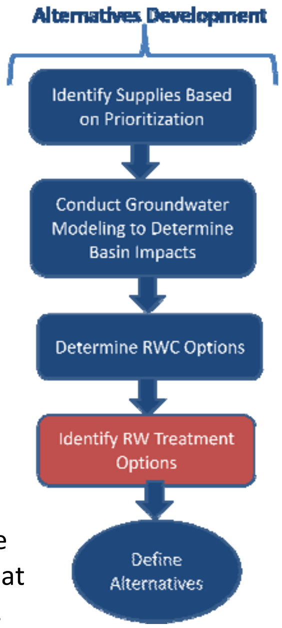
[1] A GRRP is a "project involving the planned use of recycled municipal wastewater that is operated for the purpose of replenishing a groundwater basin for use as a source of municipal and domestic water supply, or a project determined as a GRRP by the RWQCB based on a project's existing or projected replenishment of the affected groundwater basin." (CDPH, 2011)

2.4.4 Recycled Water Treatment Options



The available sources for recycled water in the Study Area include several municipal wastewater treatment plants that treat primarily domestic sewage. These plants produce various levels of treated effluent depending on their permitted discharge locations. The local treatment plants that discharge to the ocean provide undisinfected, oxidized wastewater using conventional biological, secondary treatment, which focuses on the removal of biodegradable organic material and suspended solids.

Wastewater treatment plants that provide disinfected, tertiary-treated recycled water, with filtration and disinfection to meet Title 22 requirements for recycled water are typically referred to as WRPs. The WRPs in the Study Area discharge their unused effluent to inland rivers or an enclosed bay. All of the reclamation plants in the Study Area that discharge to rivers have been upgraded in recent years to reduce nitrogen levels in their effluent.

Advanced treatment facilities in the Study Area are characterized as such because they provide the most extensive treatment commonly employed for municipal wastewater. The effluent from the advanced treatment facilities within the Study Area is currently injected at three groundwater intrusion barrier injection well systems in the two groundwater basins.

The specific wastewater treatment plants considered for the Draft GBMP alternatives are described in Section 5.0.

To develop discrete alternatives that can be compared for the Draft GBMP analysis, a range of treatment options were considered. These included tertiary, FAT, a blend of tertiary and FAT, and alternative advanced treatment processes that may be considered as alternatives to, or in conjunction with, tertiary or FAT. This broad range of treatment options provides WRD and the basin stakeholders with an indication of the degree to which regulatory flexibility offered in the recent Draft Recharge Regulation may be worth exploring.

2.4.4.1 Disinfected Tertiary Recycled Water

WRD has been recharging the Central Basin with tertiary-treated recycled water at the MFSG for 50 years. For the purposes of this study, it is assumed that this is the minimum level of treatment that would continue to be viable for groundwater replenishment via spreading. As defined in the Title 22 regulations governing recycled water in California, “disinfected tertiary recycled water” means a filtered and subsequently disinfected wastewater that meets specific criteria regarding pathogen inactivation/removal and coliform limits.

Ultimately, the selection of the appropriate treatment levels will be determined by CDPH, in conjunction with the Regional Water Quality Control Board (RWQCB), with due consideration for effluent quality and quantity, spreading area operations, soil characteristics, hydrogeology, residence time, and distance to withdrawal for drinking water.

2.4.4.2 Full-Advanced Treatment

In the Draft Recharge Regulation, and consistent with current practice, recycled water used for injection is expected to require FAT of the entire recycled water stream prior to subsurface application. The Draft Recharge Regulation defines FAT as treatment of an oxidized wastewater (that is, secondary-treated), using reverse osmosis (RO) and advanced oxidation processes (AOPs) that meet specific performance criteria. These specific criteria will be subject to additional discussion in the reuse community as the Draft Recharge Regulation is finalized, but they generally refer to the ability to achieve specific removal limits of indicator constituents.

2.4.4.3 50/50 Blend of Tertiary/Full-Advanced Treatment

The extent to which tertiary recycled water must be treated with FAT will depend on a variety of factors, including the source water quality, method of application (spreading/injection), and basin operations. The Draft Recharge Regulation allows alternatives to the specified requirements for spreading and injection with adequate demonstration that they achieve comparable levels of public health protection. Given the significant cost implications and potential technical viability of such alternatives, an example 50/50 blend of tertiary and

FAT-treated recycled water was considered for the Draft GBMP analyses. Project-specific blend percentages would need to be evaluated on a case-by-case basis, factoring in basin-wide water quality impacts of similar projects and activities.

2.4.4.4 Alternative Advanced Treatment Processes

In addition to RO and AOP, there is growing interest and research in alternative technologies that could be suitably applied for groundwater recharge projects with potentially lower costs and environmental impacts. The Draft GBMP considered two such alternatives—nanofiltration (NF) and treatment with ozone/biological activated carbon (BAC)/granular activated carbon (GAC).

The intent of the proposed NF or ozone-BAC schemes is to reduce the TOC concentration to allow a higher RWC. Therefore, achieving CDPH approval with this approach is not likely to be difficult as long as providing an increased RWC continues to comply with other water quality requirements (such as total nitrogen).

However, the alternative subsurface application (microfiltration [MF]-ozone-BAC-GAC-ultraviolet [UV]) described as follows would require extensive discussion with CDPH, including involvement by an independent scientific advisory panel and possibly extensive demonstration-scale testing and public hearings. In addition, approval from CDPH may be questionable due to the historical commitment made in RO-based approaches in Southern California, and full-scale implementation would likely take many years. However, consideration to an alternative approach may be warranted because of the significant cost and environmental benefits it offers.

Nanofiltration

Brine management from any advanced treatment process is potentially a significant cost component of such projects. Reducing the volume of the RO or NF waste stream can reduce the overall project costs. While such brine minimization strategies are not evaluated as part of the Draft GBMP alternatives, the costs for brine disposal to the sewer system are included and are directly proportional to the volume discharged. Such strategies are best considered on a project-specific basis. For example, a secondary RO system will be constructed as part of the WRD Leo J. Vander Lans Water Treatment Facility (LVLWTF) to treat brine from the primary RO system, thereby reducing the volume of waste stream discharged to the sewer. For the GRIP project, LACSD has developed and tested an integrated NF/RO system in which a secondary RO system treats the NF concentrate stream, then the NF and RO product water is blended prior to application.

Like RO, NF membrane systems typically consist of spiral-wound membrane operated under pressure. The feed pressures tend to be significantly lower than those required for RO treatment, thus reducing the energy requirements and associated costs and environmental impacts. NF membranes, however, have lower degrees of rejection of constituents of concern for groundwater recharge. Alternatives considered in the GBMP included full stream treatment with NF as well as a 50/50 blend of NF-treated and tertiary-treated effluents prior to application.

Ozone/Activated Carbon

Ozone is a powerful oxidant that breaks down organic material, which can then be biodegraded using BAC or adsorbed onto GAC. The ozone also provides pathogen inactivation but does not provide photolysis like UV does (photolysis is needed for N-nitrosodimethylamine [NDMA] removal). Liquid waste from this process is minimal, but bromonated disinfection byproducts might be formed.

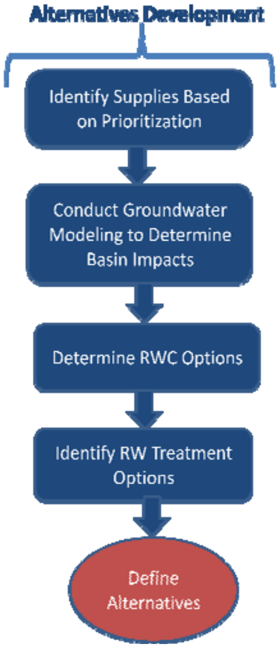
Following are two examples of ozone/activated carbon treatment options for surface and subsurface applications:

- **Surface Application** – Incorporating ozone-BAC into the tertiary treatment process will reduce TOC concentration and potentially allow more recycled water to be recharged (that is, increasing RWC).
- **Subsurface Application** – Use of MF-ozone-BAC-GAC-UV treatment process for direct injection of recycled water in lieu of the standard MF-RO-UV AOP will eliminate production of RO concentrate and the need for its disposal, which can be both environmentally challenging and costly. Although not practiced in California, non-RO based potable reuse treatment schemes have been implemented in other parts of the U.S. and the world because of the difficulty and cost of concentrate disposal for inland locations. For example, in northern Virginia, a GAC-based treatment process has successfully been used to augment inflows to a potable water

reservoir for more than 30 years. More recent potable reuse projects have also implemented a non-RO based approach, such as the UF-ozone-BAC-ozone process used in Gwinnett County, Georgia, which was implemented as part of a facility expansion in 2005.

The selection of the appropriate treatment technology, or combination of technologies, while reliably protecting the groundwater basins, requires consideration of many factors. As such, treatment options need to be evaluated on a project-specific basis.

2.4.5 Formulation and Analysis of Alternatives



For the West Coast Basin, planned extraction to meet the 64,468 AFY of adjudicated water rights under Concept A requires a total of 40,000 AFY of replenishment water provided via injection at the two existing barriers (that is, 32,500 AFY at the WCBBP and 7,500 AFY at the DGBP). Based on historical operation of the basin, the West Coast Basin is capable of delivering an additional 30,000 AFY of production. Thus the Draft GBMP alternatives that reflect extraction conditions for Concept B options (that is, beyond adjudicated water rights) assume an additional injection of 30,000 AFY at a combination of both of the existing barriers, as well as with a new inland injection system (that is, a total of 40,000 AFY at the WCBBP, 15,000 AFY at the DGBP, and 15,000 AFY at the new inland system). These are within the estimated hydraulic capacities of the existing barrier systems. These GBMP extraction and artificial replenishment volumes for the West Coast Basin are summarized in Table 2-1.

For the Central Basin, planned extraction to meet the APA of 217,637 AFY under Concept A requires a total of 146,000 AFY of replenishment. This consists of:

- 8,000 AFY (assuming the expansion of the LVLWTF to 8 mgd) from the ABP
- 57,000 AFY from current average stormwater infiltration
- 50,000 AFY of currently permitted tertiary recycled water
- 31,000 AFY of additional replenishment water needed

The Draft GBMP alternatives consider various sources of recycled and stormwater to provide this additional 31,000 AFY of replenishment water. These GBMP extraction and artificial replenishment volumes for the Central Basin are summarized in Table 2-2.

TABLE 2-1
Summary of Extraction and Replenishment for Concepts A and B – West Coast Basin

	Concept A	Concept B
Extraction (AFY)	**64,468**	**94,468**
Artificial Replenishment (AFY)		
Total	40,000	70,000
WCBBP	32,500	40,000
DGBP	7,500	15,000
New Inland Injection	N/A	15,000

Note:

N/A = not applicable

TABLE 2-2
Summary of Extraction and Artificial Replenishment for Concepts A and B – Central Basin

	Concept A	Concept B
Extraction (AFY)	217,367	275,137-320,617
Artificial Replenishment (AFY)		
Total	*146,000*	*203,410-248,890*
MFSG – Stormwater*	57,000	57,000
MFSG – Tertiary Recycled Water	50,000	50,000
LVLWTF/ABP	8,000	8,000
Additional Replenishment Needed (various sources)	31,000	88,410-133,890

*Based on historical spreading at the MFSG

The Draft GBMP alternatives that meet the Concept B conditions in the Central Basin include additional potential extraction of 57,770 AFY in the Montebello Forebay, assuming the maximum potential use of recycled water from SJCWRP and LCWRP beyond current non-potable reuse demands and enhanced capture of stormwater from the Rio Hondo, San Gabriel River, and Los Angeles River. Additionally, 45,480 AFY could be extracted from the Los Angeles Forebay assuming replenishment of the same volume from a potential new, satellite advanced water treatment plant. Several combinations of recycled water and stormwater sources are considered in the Draft GBMP alternatives for the additional replenishment in the Montebello Forebay, allowing for a total of 320,000 AFY of potential extraction.

The formulation and evaluation of draft GBMP alternatives that satisfy these planning scenarios is described in Section 5.0. The GBMP alternatives were evaluated with respect to water supply availability, water supply reliability, basin utilization, energy (greenhouse gas) emissions, and broad environmental impacts. A more-detailed environmental analysis is conducted in the accompanying programmatic environmental impact report (PEIR).

Groundwater Basin Extraction/Replenishment Planning Scenarios

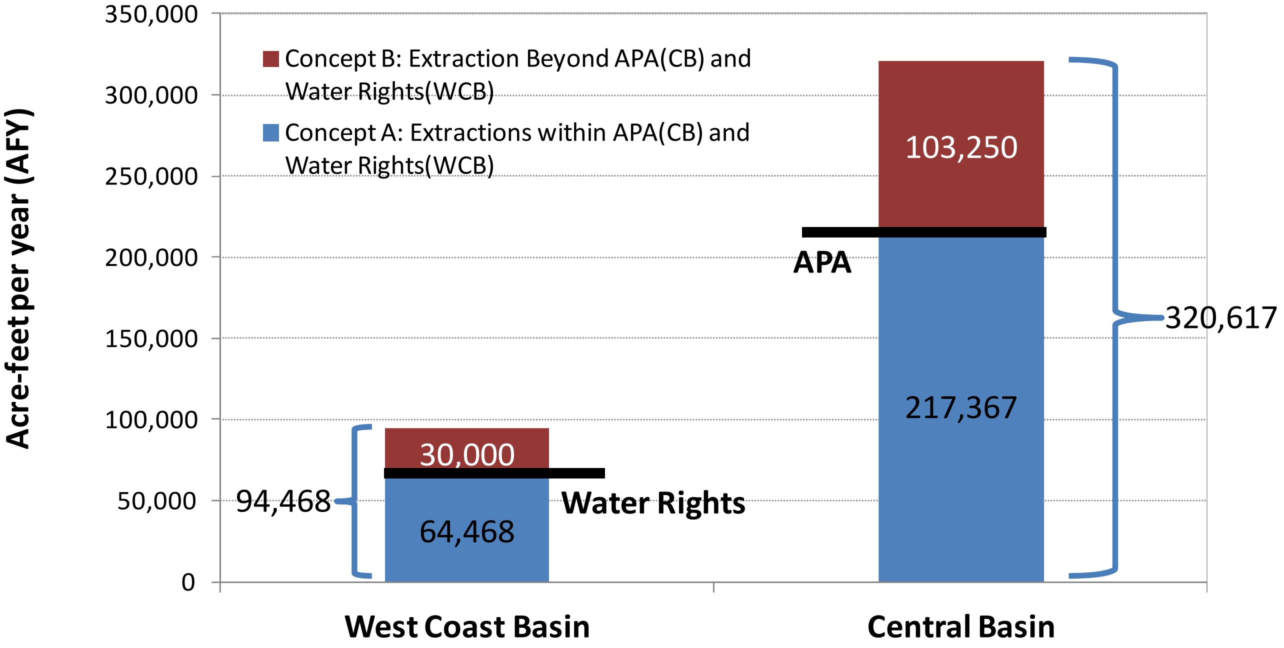
3.1 Groundwater Basins Master Plan Planning Scenarios

GBMP planning scenarios that reflect extraction and replenishment conditions were developed during the scoping phase (Phase 1) for each groundwater basin. These scenarios were based on the conceptual options defined by the current and proposed amendments to the basin Judgments (as described in Section 2.2.3). Those include:

- Concept A scenarios are limited to extraction patterns within the West Coast Basin Water Rights and Central Basin APA.
- Concept B scenarios expand extraction beyond the water rights and APA, assuming approval of the Judgment amendments as currently proposed.

Figure 3-1 shows the target extraction flows for Concepts A and B for the West Coast and Central Basins. Using these concepts, various scenarios were developed for each basin.

FIGURE 3-1
Concept A and Concept B Target Extractions for the West Coast and Central Basins



The overall goals for developing the planning scenarios for these concepts were to:

- Assure that the scenarios meet replenishment obligations up to the water rights in the West Coast Basin and APA in the Central Basin.
- Evaluate operational conditions assuming pumping to water rights in West Coast Basin and APA in Central Basin with respect to replenishment locations and pumping distribution.
- Maintain at or near water balance over 40-year period.
- Develop projects that can be combined into alternatives that satisfy the Concept A and Concept B scenarios.

- Prioritize development of alternatives using anticipated low-cost water supplies, then add more costly water supplies to increase replenishment, thus allowing increased pumping.

A description of the key components that serve as the building blocks for developing the GBMP planning scenarios is provided below. Following the description, an approach for each scenario is discussed based on the goals of the study. After the screening of the scenarios, only the viable scenarios were considered for modeling (described in Section 4.0) and further analysis.

3.2 West Coast Basin Scenarios

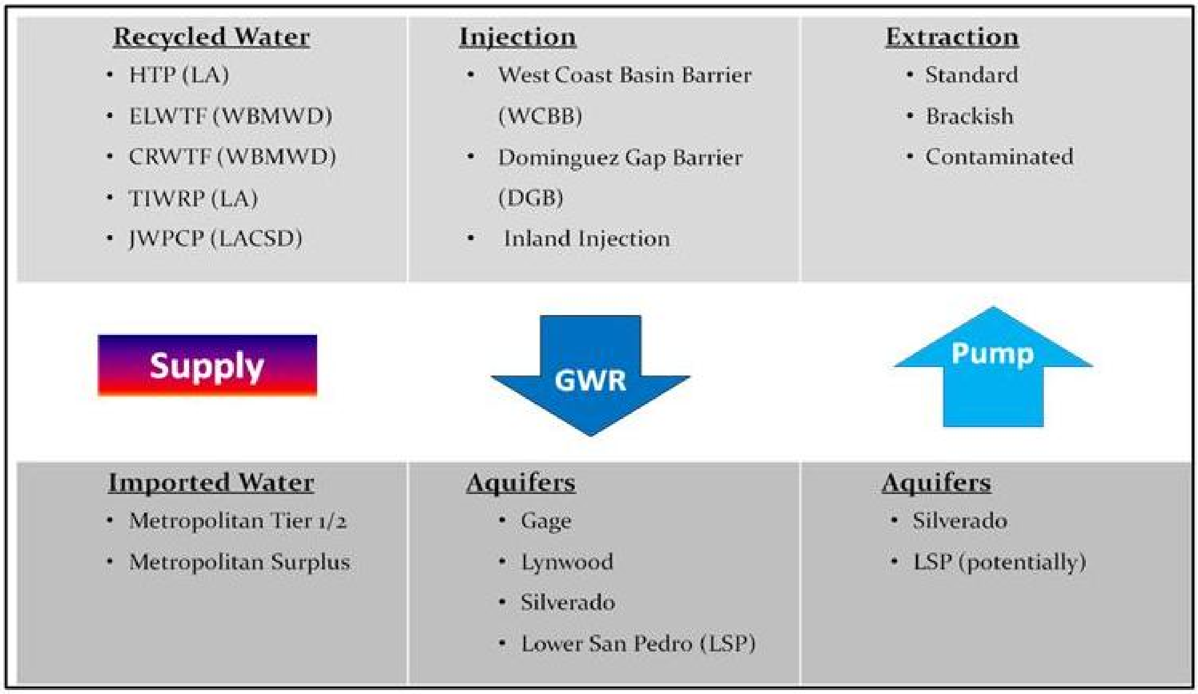
This section summarizes the formulation of GBMP planning scenarios for the West Coast Basin during Phase 1. The supply, recharge, and pumping components used to define these scenarios are described below, along with the potential sources of replenishment water. Finally, the specific West Coast Basin planning scenarios were defined and evaluated, and viable scenarios were identified to serve as the basis for the GBMP alternatives evaluated in the Phase 2 analysis (as discussed in Section 5.0).

3.2.1 Components Used for Developing West Coast Basin Scenarios

The GBMP planning scenarios comprise three fundamental components: water supply sources, groundwater recharge mechanisms, and pumping patterns. For the West Coast Basin, these components consisted of the following elements, as illustrated in Figure 3-2:

- Water supply sources for injection into the basin – Recycled water and imported water
- Injection locations and aquifer targets – Existing barriers (WCBBP and DGBP), as well as new inland injection systems; target aquifers are those currently injected (that is, Gage, Lynwood, Silverado, and Lower San Pedro). Consider practice of in-lieu use of imported water to replace groundwater pumping. (Note that in-lieu recharge will occur as in the past; that is, this would be an opportunistic activity that will occur if discounted imported water is available at a rate that is of a lower cost than use of other supplies. Given the uncertain nature of imported water supplies, in-lieu operations have not been specifically analyzed; however, given the offsetting effects of pumping and recharge, limited in-lieu operations are not expected to significantly change the analysis presented herein.)
- Pumping-extraction quality and aquifer target – Extraction quality dictates wellhead treatment requirements; pumping based on current operational schemes (predominantly from the Silverado aquifer, with some existing and potential pumping from the Lower San Pedro aquifer) and varied according to specific planning considerations, discussed below.

FIGURE 3-2
Components of Planning Scenarios in the West Coast Basin



The following are the overall goals for developing the West Coast Basin scenarios:

- Provide replenishment necessary to support pumping at water rights of 64,468 AFY.
- Increase replenishment at existing barriers using recycled water to allow for pumping to water rights.
- Shift oil refineries to recycled water and then shift this groundwater pumping to municipal purveyors.
- Adjust pumping pattern to maximize containment and removal of saline plumes.
- Assess potential to stop injection into the Lower San Pedro aquifer.
- Assess potential to extract instead of inject into the Lower San Pedro aquifer.
- Continue to protect the Lower San Pedro aquifer for overall preservation of groundwater basin.
- Increase injection to allow for extraction above the water rights.

Table 3-1 summarizes the key extraction and replenishment operational considerations that provided the basis for formulating the planning scenarios for the West Coast Basin. The supply sources needed to support these extraction/replenishment operations are discussed below.

TABLE 3-1
Key Operational Considerations for the West Coast Basin Scenario Formulation

Operational Factors	Considerations for Concept A Scenarios	Considerations for Concept B Scenarios
Basin Pumping	Up to adjudicated rights (up to 64,468 AFY)	Beyond adjudicated rights (greater than 64,468 AFY)
West Coast Basin Barrier	100 percent recycled water (17,000 AFY existing[2] supply capacity) Additional injection needed	Same as in Concept A, but more injection may be needed

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[2] Based on the Phase V expansion of the ECLWRF, currently underway.

TABLE 3-1
Key Operational Considerations for the West Coast Basin Scenario Formulation

Operational Factors	Considerations for Concept A Scenarios	Considerations for Concept B Scenarios
Dominguez Gap Barrier	100 percent recycled water (5,000 AFY existing[3] supply capacity) Additional injection needed	Same as in Concept A, but more injection may be needed
Inland Injection	Not considered	Included in some concepts
Lower San Pedro Aquifer	Adjust injection/extraction strategy	Same as in Concept A
Saline Plume	Pump/treat saline plume as additional water source	Same as in Concept A

Several scenarios were developed for the West Coast Basin based on (1) the components provided in Figure 3-2; (2) the planning goals for basin identified above; (3) the considerations summarized in Table 3-1; and (4) the potential sources of replenishment water identified below. These specific scenarios for Concepts A and B are described below.

3.2.2 Potential Sources of Replenishment Water

Potential sources of groundwater replenishment supply for the West Coast Basin considered for the GBMP were imported water and recycled water. Because the West Coast Basin aquifers are largely confined, stormwater infiltration is not a viable source of basin replenishment. Desalination projects, such as those currently being considered by WBMWD and others in the region, would be delivered directly into the potable water distribution system rather than serve as a groundwater replenishment supply. Thus, the two viable options for West Coast Basin replenishment are imported water and recycled water, consistent with current practice. These water sources are discussed below.

3.2.2.1 Imported Water

While imported water has been used historically to replenish the West Coast Basin at the two seawater intrusion barriers (WCBBP and DGBP), they ultimately will be replenished with 100 percent RWC, thereby eliminating the need for imported water used for blending. Because this GBMP seeks to replace the use of imported water, it is not included in the GBMP alternatives as a future supply source for the West Coast Basin.

Additionally, Metropolitan is proposing to replace the current Replenishment Service Program with a new “Multilevel Replenishment Program”.[4] The new program’s “Level 2” most closely resembles the current Replenishment Service Program with respect to refill of overdraft in groundwater basins. Level 2 is available on an infrequent basis and provides a smaller discount on the Full Service Water Rates compared with the current program. Metropolitan estimates that Level 2 has a 21 percent probability of availability in 2015, which is equivalent to 2 out of every 10 years.

Early in the GBMP planning process, the use of such surplus imported water was considered for just one of the West Coast Basin planning scenarios, described in Section 3.2.3.6. Ultimately, the alternatives developed in this GBMP assume that no surplus discounted water is available so that they can be compared against the availability, reliability, and costs of imported water. The actual use of discounted “Level 2” imported water for replenishment would continue to be considered by WRD on an annual basis as the opportunities for its purchase and use for replenishment in the West Coast Basin arise.

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[3] Based on the current capacity of the TIWRP AWTF.

[4] www.mwdh2o.com/mwdh2o/pages/board/current/pdf/01102012 percent20BOD percent209-1 percent20Letter.pdf

3.2.2.2 Recycled Water

Recycled water is the largest source of untapped, local supply across Los Angeles County, and two of the largest wastewater treatment plants in California are located within the West Coast Basin. WRD and other local agencies reuse some of this supply, but much remains unused. As a result, recycled water is a key component considered for basin replenishment supplies.

The locations of wastewater treatment plants and water reclamation plants in the vicinity of the West Coast and Central Basins are shown in Figure 3-3. Those in closest proximity to the potential recharge locations were considered for the GBMP and are discussed further below.

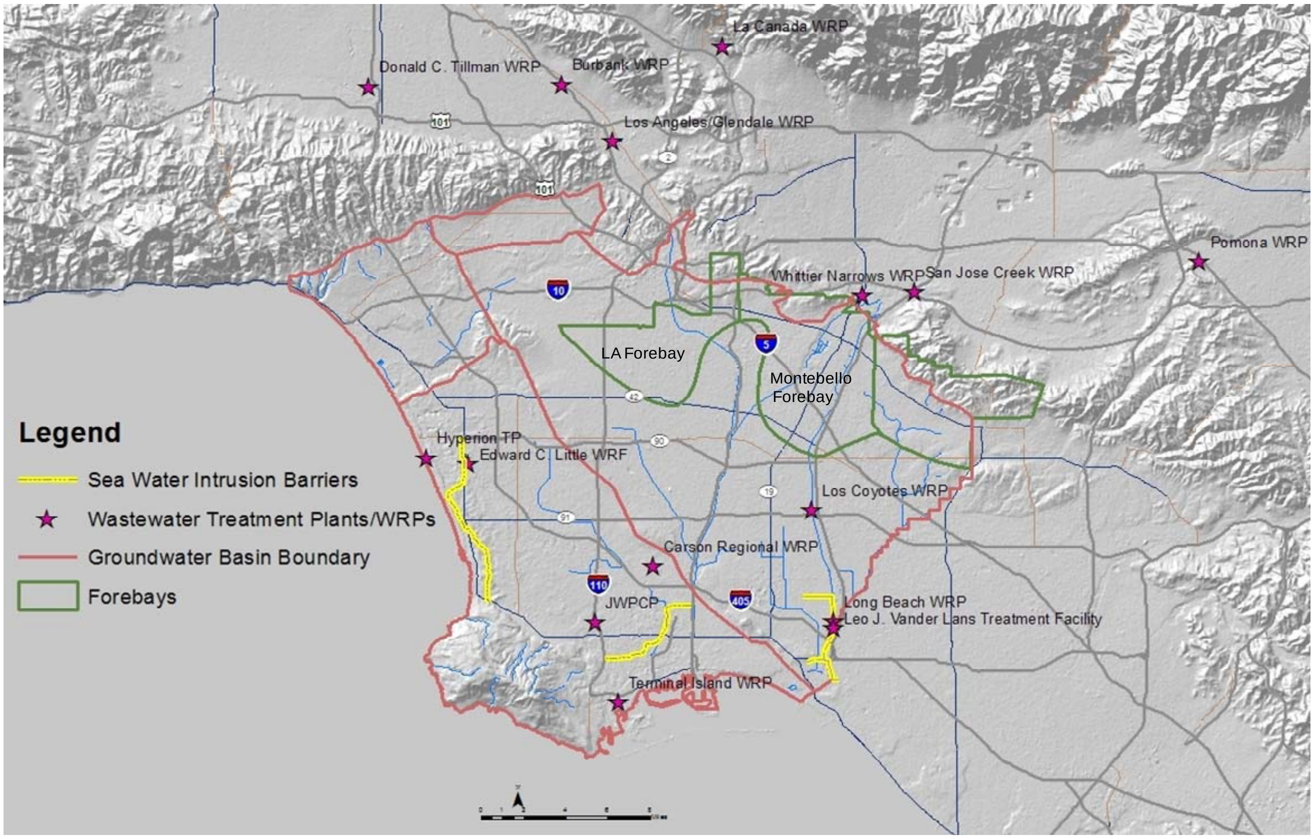
3.2.2.3 Hyperion Treatment Plant

The Hyperion Treatment Plant (HTP), located south of the Los Angeles International Airport, is the largest wastewater treatment plant owned and operated by the City of Los Angeles and has a permitted average dry weather capacity of 450 mgd. All wastewater is treated to a secondary level, and the majority is discharged through a 5-mile ocean outfall.

The Los Angeles Department of Water and Power (LADWP), in conjunction with the City's Department of Public Works, recently prepared a LA RWMP, described in Appendix A (Section A1.3.2). This summary of available supply reflects the current understanding and analysis as described in the LA RWMP documents.

Based on the LA RWMP Long-Term Concepts Report (RMC, 2012a), HTP can produce 160 mgd of FAT-treated recycled water occurring in four distinct implementation phases based on long-term plans. However, simultaneous construction of any of the phases could potentially be accomplished. These phases in combination provide a production capacity of 128 mgd within the HTP site (Phase 1 through 3) and an additional 32 mgd of production capacity using nearby offsite areas (Phase 4). A phased approach is recommended so that the recycled water production capacity can match incremental increases in recycled water demands.

FIGURE 3-3
Locations of Wastewater Treatment Plants and Water Reclamation Plants



3.2.2.4 Terminal Island Water Reclamation Plant

Also owned and operated by the City of Los Angeles, the Terminal Island Water Reclamation Plant (TIWRP) is located on a 22-acre site on Terminal Island in the port area of San Pedro near the entrance to the Los Angeles Harbor. TIWRP has a permitted treatment capacity of 30 mgd and is currently operating at an average influent flow rate of 15.4 mgd. The treatment plant discharges undisinfected tertiary effluent on a continuous basis through its permitted harbor outfall into the Los Angeles Harbor, which is hydraulically connected by the harbor entrance to the Pacific Ocean. TIWRP also has a 5-mgd capacity advanced water treatment facility (AWTF), which consists of MF, RO, and disinfection with sodium hypochlorite. Advanced treated disinfected recycled water from TIWRP is sent to the DGBP as well as to non-potable customers, while RO concentrate waste and other residuals from the advanced treatment process are dechlorinated and discharged through the Harbor Outfall to San Pedro Bay.

Based on the *TIWRP Barrier Supplement and Non-potable Reuse (NPR) Concepts Report* (RMC, 2012b), the TIWRP has the potential capacity to produce 12.5 mgd of purified treated recycled water by expanding the AWTF influent treatment capacity to 16.2 mgd.

3.2.2.5 Edward C. Little Water Reclamation Facility

WBMWD currently serves an estimated 32,000 AFY of recycled water to over 220 customer sites from the ECLWRF in El Segundo. The ECLWRF treats secondary effluent from HTP to produce four different qualities of recycled water onsite and feeds other downstream treatment plants. The product water is conveyed through a network of nearly 100 miles of distribution pipelines. One of the treatment streams is produced at an AWTF onsite for delivery to the WCBBP. WBMWD estimated that the AWTF could be expanded onsite by 10 mgd beyond its current capacity of 17 mgd; expansion beyond 10 mgd could be accomplished in the vicinity of ECLWRF, but land would need to be acquired.

3.2.2.6 Juanita Millender-McDonald Carson Regional Water Reclamation Facility

Also owned and operated by WBMWD is the Juanita Millender-McDonald Carson Regional Water Reclamation Facility (CRWRF). The CRWRF treats tertiary-treated water conveyed from ECLWRF with nitrification and advanced treatment for industrial use. Expansion of the nitrification plant capacity by a minimum of 12 mgd, and possibly up to 17 mgd, is currently being planned for the City of Los Angeles to serve industrial customers in the Los Angeles Harbor area. The existing site is very constrained and the current product water is fully committed to end users; thus there is limited opportunity to expand or tap this plant for additional replenishment of the West Coast Basin.

3.2.2.7 Joint Water Pollution Control Plant

The LACSD wastewater treatment facilities in the Los Angeles Basin area are part of an interconnected network of sewers, pump stations, and treatment plants called the Joint Outfall System (JOS). The JOS collects and treats sewage in Los Angeles County that is not otherwise managed by the City of Los Angeles. There are six water reclamation plants in the JOS that return their solids to the sewer system for conveyance and treatment at the JWPCP. Brine waste from upstream dischargers, including WBMWD's CRWRF, are also conveyed to the JWPCP.

The JWPCP has a permitted capacity of 400 mgd and currently treats an estimated 300 mgd of influent sewage. Secondary-treated effluent is discharged from the plant through two tunnels for approximately 6 miles to the outfall structure off the Palos Verdes Peninsula, which then extends approximately 2 miles offshore.

Although none of the JWPCP secondary effluent is currently being reused, it was considered in WBMWD's recent recycled water master plan as an alternative water source for the ECLWRF and was the subject of a recent Metropolitan/LACSD Joint Water Purification Study.

Water recycling at the JWPCP is currently limited to in-plant uses. LACSD estimates that, dependent on regulatory compliance issues associated with the brine discharge, approximately 200 mgd of treated wastewater from this plant may be currently available for reuse.

Consideration of these potential sources of additional replenishment is important to the formulation of GBMP scenarios. Sufficient available replenishment water needs to be identified to satisfy the planning scenarios. The specific assumptions regarding which plant delivers to which replenishment locations in the basin are addressed in the alternatives developed for each planning scenario. The alternatives are discussed in Section 5.0.

3.2.3 Concept A Scenarios – West Coast Basin

The Concept A scenarios for the West Coast Basin were formulated so that the extraction patterns are limited to the West Coast Basin adjudicated water rights. Four scenarios under Concept A were identified for the West Coast Basin. They differ with respect to the operation of the Lower San Pedro aquifer, which receives replenishment water to protect it from seawater intrusion, but has limited extraction. The possibility of reducing or eliminating replenishment to this aquifer was explored through these four scenarios. All Concept A scenarios assume recharge at the two existing injection barriers in the West Coast Basin with 100 percent RWC at each barrier, sufficient to meet the adjudicated water rights of 64,468 AFY of extraction.

The specific, assumed, pumping distributions for these scenarios are provided in Table 3-2. Note that these extraction assumptions were purely for basin analysis purposes, and, although shared with the stakeholders during the GBMP development, do not represent extraction agreements.

Each of these Concept A scenarios assumes the following:

- Shifting of oil companies' non-potable demands from groundwater to recycled water and shifting of this groundwater pumping to municipal purveyors
- Increasing recycled water contribution to injection barriers
- Increasing injection required for extraction of 64,468 AFY

Initial screening of these scenarios was conducted using WBMWD's groundwater flow and solute transport model. Subsequent modeling of West Coast Basin operations in conjunction with Central Basin operations (defined as "modeling combinations") for the various GBMP alternatives was conducted with the WRD/USGS groundwater model, as described in Section 4.0. A description of the Concept A scenarios for the West Coast Basin is provided below.

3.2.3.1 Scenario WCB-A1

Scenario A1 for the West Coast Basin (Scenario WCB-A1) assumes increased extraction by the water rights holders up to the adjudicated limit with three distinct pumping patterns, described below in three scenarios (Scenario WCB-A1a, Scenario WCB-A1b, and Scenario WCB-A1c).

Recent pumping in the West Coast Basin averaged about 42,000 AFY (over the past 10 years). Thus, to enable the full adjudicated water rights of 64,468 AFY to be pumped under this scenario, additional replenishment of approximately 22,500 AFY would be needed. This can be delivered through the existing barrier systems.

To match the pumping under this scenario, a total of 32,500 AFY was assumed to be injected at the WCBBP, which is 15,500 AFY more than planned with the current expansion of the ECLWRF AWTF; and 7,500 AFY was injected at the DGBP, which is 2,500 AFY more than the current capacity of the TIWRP's AWTF. This injection distribution between the two barriers was based on the pumping concentration in the more northern part of the basin as well as to avoid overpressuring the DGBP where the depth to the aquifers is much shallower than near the WCBBP.

TABLE 3-2
Assumed Groundwater Pumping Distribution[a] under Scenarios WCB-A1a, WCB-A1b, and WCB-A1c (AFY)

			Scenario WCB-A1a		Scenario WCB-A1b		Scenario WCB-A1c	
Purveyor/ Pumpers	**Water Right**	**Current (based on last 3 yrs)**	**Distribute to Major WR Holders & LA**	**Differential from Current Pumping**	**Distribute to Major WR holders & LA**	**Differential from Current Pumping**	**Regional Partnership (Remediate Saline Plume)**	**Differential from Current Pumping**
Golden State Water Co.	7,502	13,500	14,000	500	13,000	(500)	14,000	500
CWSC (Hermosa-Redondo)	4,070	1,000	2,000	1,000	2,000	1,000	2,000	1,000
CWSC (Dominguez)	10,417	7,000	16,000	9,000	14,000	7,000	16,000	9,000
CWSC (Hawthorne)	1,882	40	2,500	2,460	2,500	2,460	**2,500**[b]	2,460
City of Torrance	5,639	2,400	11,000	8,600	9,000	6,600	**11,000**[b]	8,600
City of El Segundo	953	0	1,500	1,500	1,500	1,500	1,500	1,500
City of Inglewood	4,450	3,700	6,000	2,300	5,000	1,300	6,000	2,300
City of Lomita[c]	1,352	5	2,465	2,460	2,468	2,463	2,465	2,460
City of Manhattan Beach	1,131	1,500	2,000	500	2,000	500	2,000	500
City of Los Angeles	1,503	0	1,503	1,503	7,500	7,500	**1,503**[b]	1,503
Oil Companies[d]	23,128	10,600	4,000	(6,600)	4,000	(6,600)	4,000	(6,600)
Minor Water Rights Holders	2,440	1,300	1,500	200	1,500	200	1,500	200
TOTAL	64,468	41,045	64,468	23,423	64,468	23,423	64,468	8,420

[a] For **planning purposes only** to assess the range in potential distribution of pumping that could develop in the future. Actual distribution will be determined (outside of this study) by pumper needs, lease market, and economics.

[b] Extraction by CWSC (Hawthorne), City of Torrance and City of Los Angeles eliminated from existing well locations and replaced with pumping from saline plume. Volumes pumped may or may not use water rights depending on the total dissolved solids of the extracted groundwater.

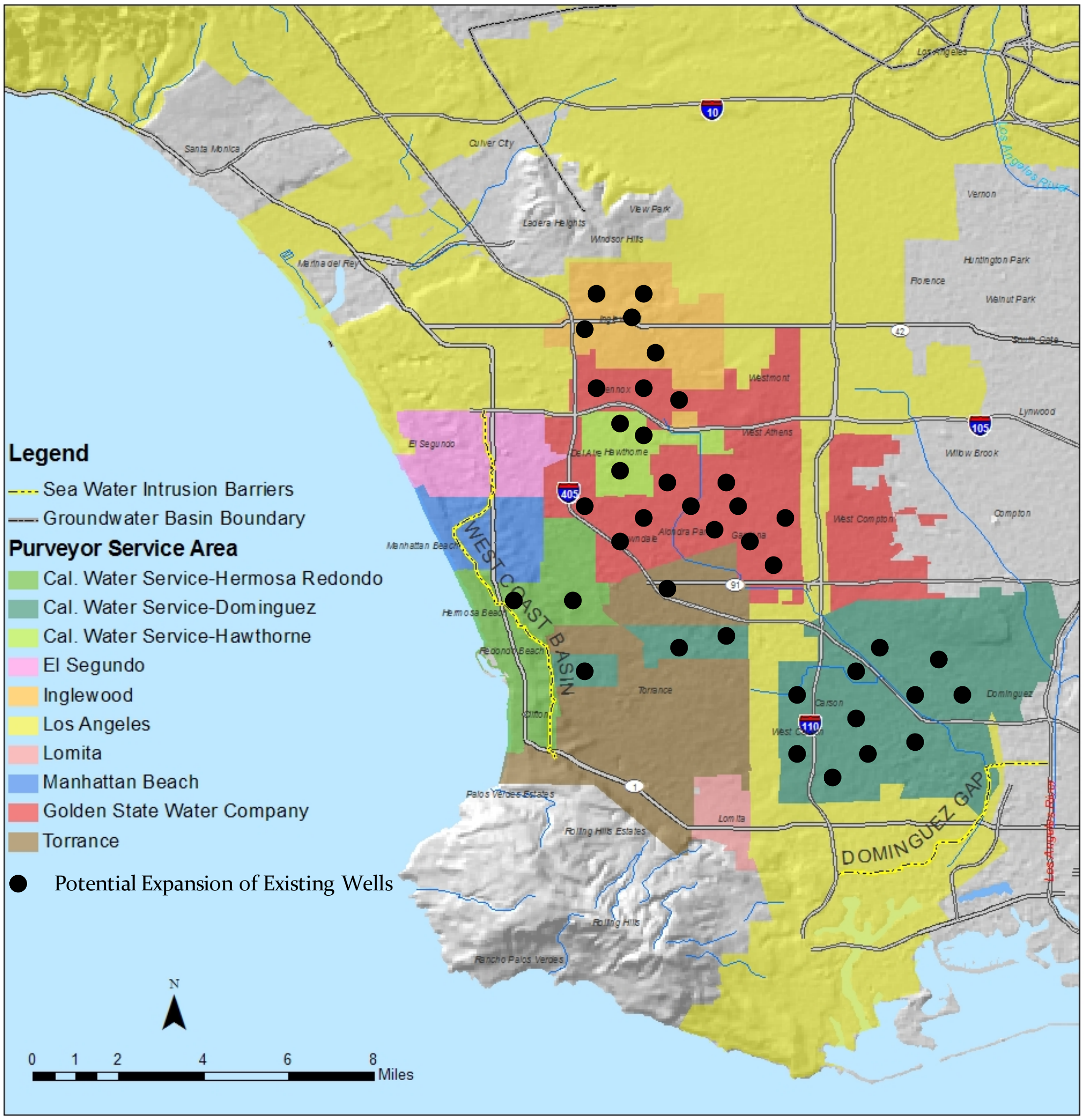
[c] Groundwater usage designated for City of Lomita used to bring TOTAL basin pumping to 64,468 AFY.

[d] Assumes reduction of refinery use of groundwater through conversion to recycled water, assuming favorable economic and lease agreements are developed to support conversion.

3.2.3.2 Scenario WCB-A1a

Scenario WCB-A1a assumes additional extraction by large water rights holders (except oil companies); it also assumes that the City of Los Angeles extracts its 1,500 AFY of adjudicated rights (which it has not been doing for the past 30 years). Figure 3-4 is a schematic illustrating how this scenario could be implemented by potential expansion of existing wells to provide additional pumping capacity by pumper.

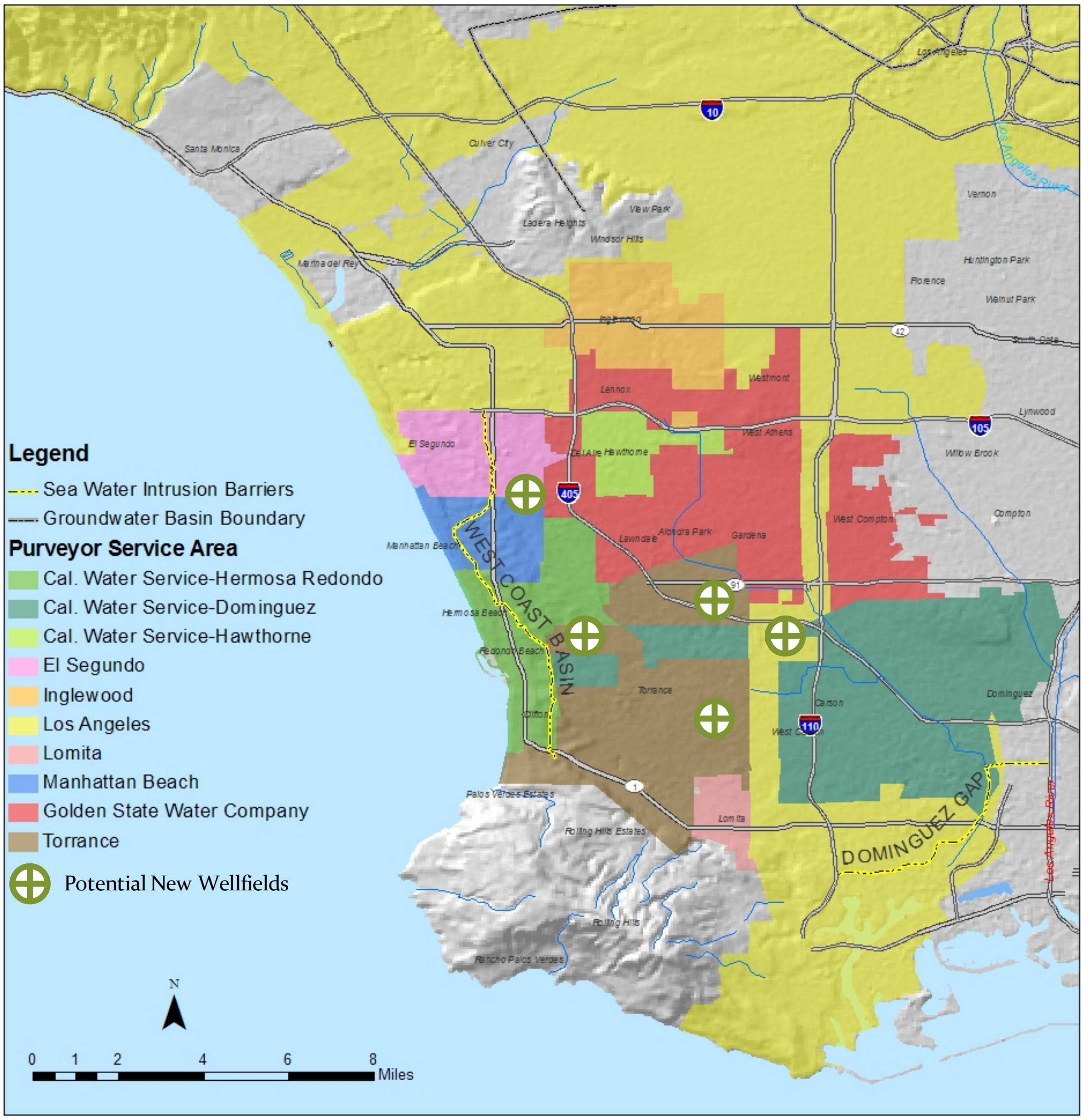
FIGURE 3-4
Schematic of Potential Expansion of Existing Wells for Major Water Rights Holders under Scenario WCB-A1a



3.2.3.3 Scenario WCB-A1b

Scenario WCB-A1b assumes additional extraction by large water rights holders (except oil companies) as well as by the City of Los Angeles in excess of its adjudicated rights (that is, to 7,500 AFY). Figure 3-5 is a schematic illustrating how this scenario could be implemented by some of the pumpers (see Table 3-2).

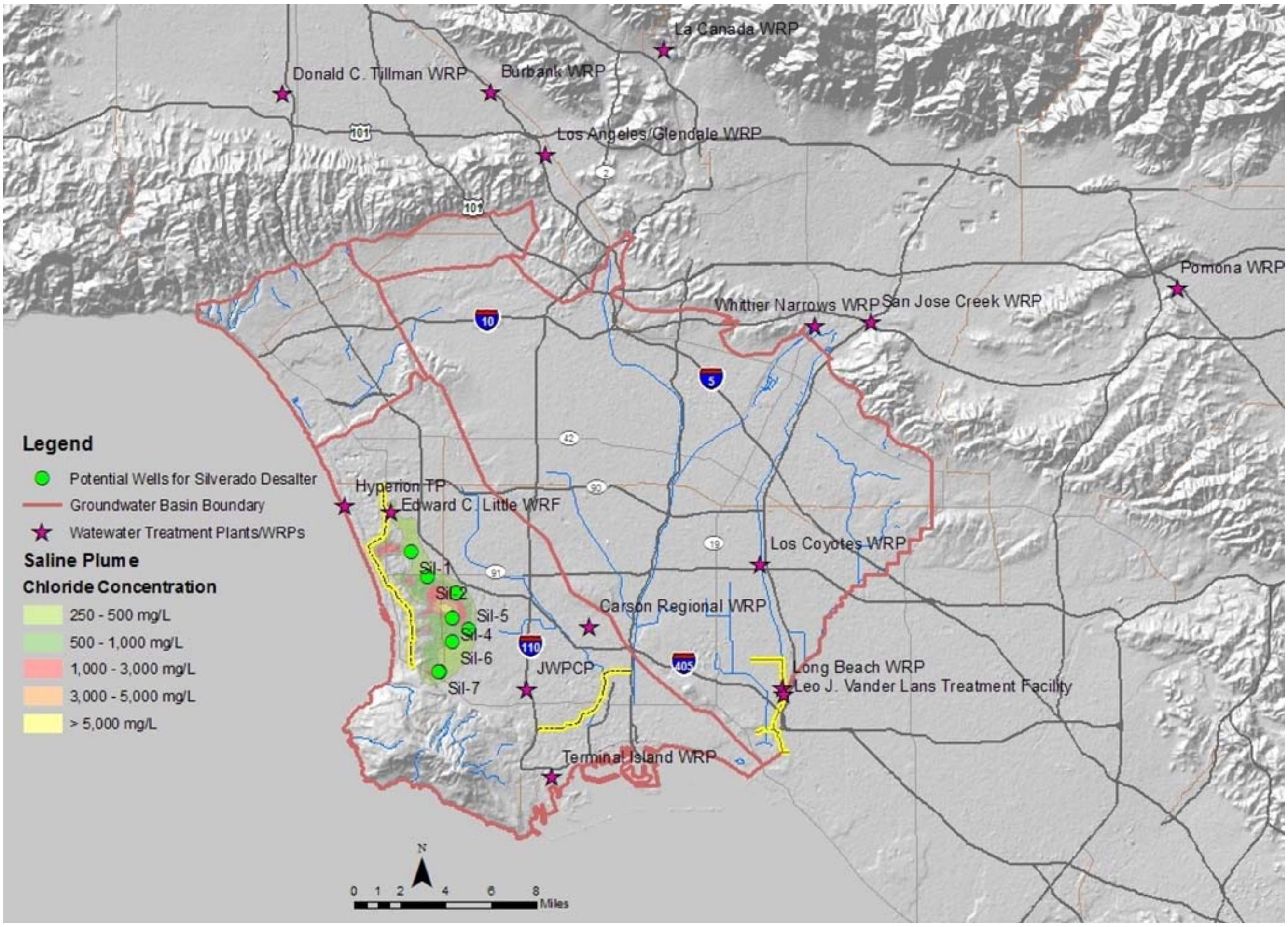
FIGURE 3-5
Schematic of Expansion of Potential Wellfields for Increased Extraction under Scenario WCB-A1b



3.2.3.4 Scenario WCB-A1c

Under Scenario WCB-A1c, pumping is redistributed with the goal to contain and remove the saline plume in the Silverado aquifer. It was assumed that three pumpers (CWSC – Hawthorne, City of Torrance, and City of Los Angeles) would use the total 15,000 AFY of desalinated water. Thus extraction for these three pumpers was shifted from their current well locations to seven new desalters in the Silverado aquifer. The assumed locations of these wells/desalters are shown in Figure 3-6. The locations of these desalters are based on, 1) being on the leading edge of the saline plume in order to contain the plume from further migration, 2) generally located downgradient of parts of the plume containing higher concentrations of salts, 3) potential availability of land to site a demineralization facility, and 4) within or near the service areas of the pumpers.

FIGURE 3-6
Potential New Wellfields in the Saline Plume Area under Scenario WCB-A1c

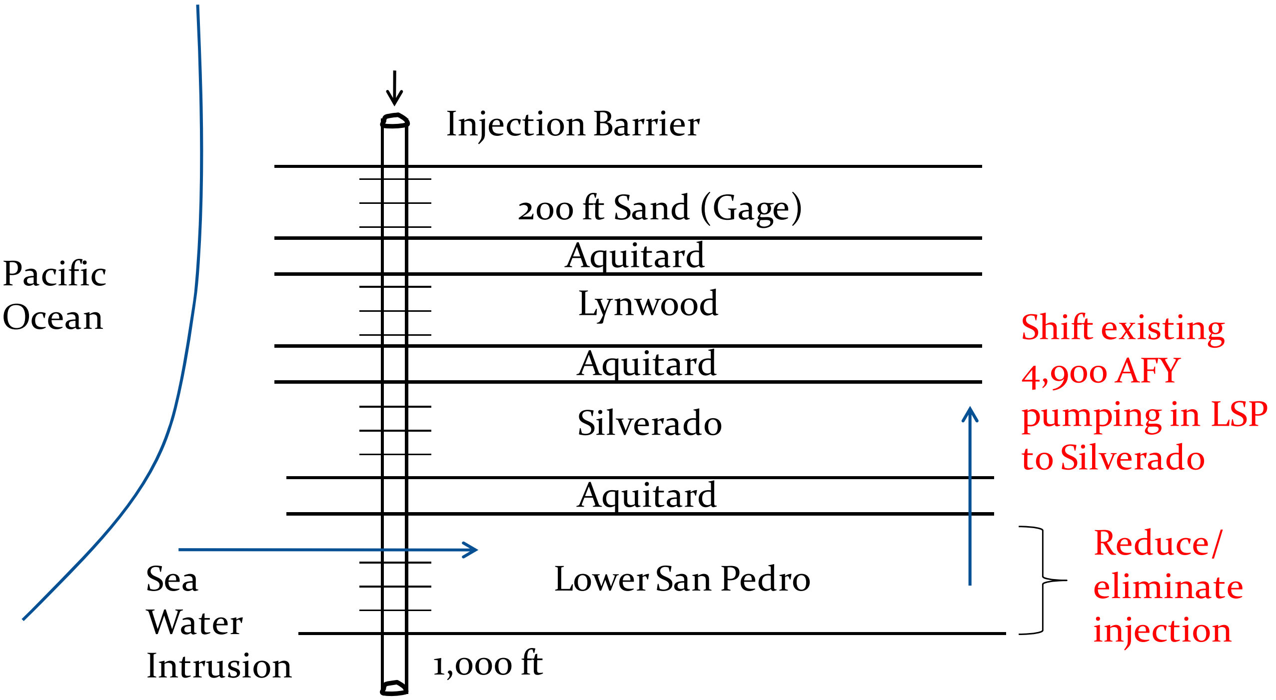


3.2.3.5 Scenario WCB-A2

Scenario WCB-A2 modified Scenario WCB-A1 by reducing or eliminating injection and extraction from the Lower San Pedro aquifer, while providing protection from seawater intrusion by balancing pumping in the Silverado aquifer. Figure 3-7 provides a conceptualization of this scenario. The purpose of exploring this scenario was to determine whether the amount of replenishment water that needed to be purchased to support full extraction of the adjudicated basin rights could be reduced by this modified basin operation.

The extraction pattern for Scenario WCB-A2 was identical to that of Scenario WCB-A1a with respect to the geographic well locations and pumped flows. However, the extraction zones were changed by shifting approximately 4,900 AFY of pumping and 10,390 AFY injection from the Lower San Pedro aquifer to the Silverado aquifer. The 4,900 AFY pumping is largely associated with wells screened across the Silverado Aquifer and Lower San Pedro Aquifer and this represents the portion estimated to come from the Lower San Pedro Aquifer. Most of this pumping is in the Torrance area.

FIGURE 3-7
Conceptualization of Scenario WCB-A2



Note:

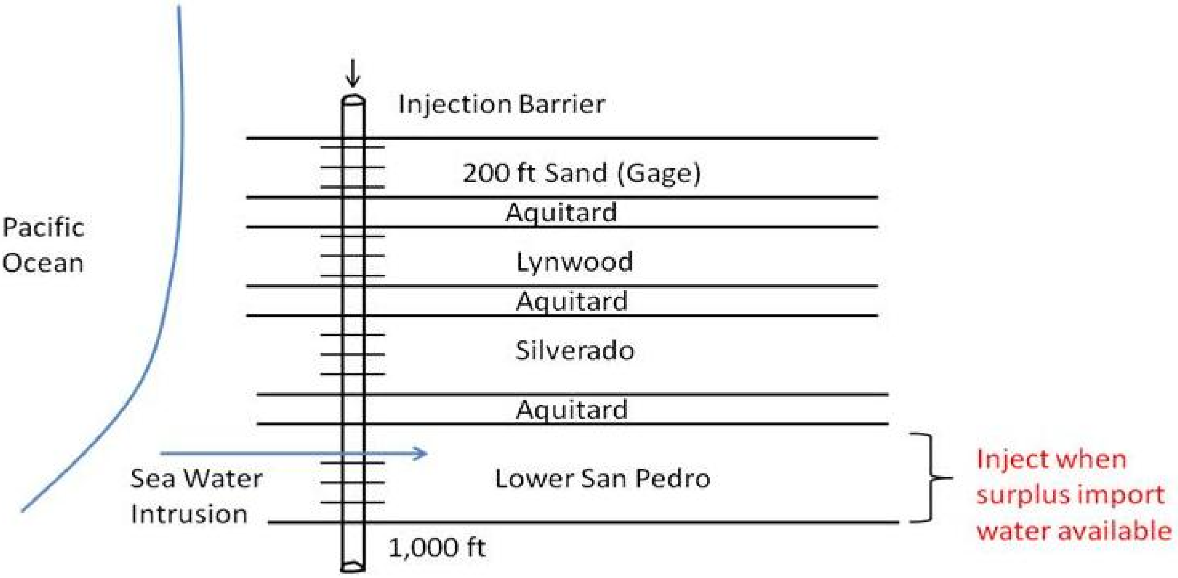
ft = feet

3.2.3.6 Scenario WCB-A3

Scenario WCB-A3 limited injection to the Lower San Pedro aquifer to be based on the availability of discounted, surplus (or “Level 2”) imported water, assumed to be available 2 out of 10 years. The purpose of exploring this scenario was to ultimately develop a cost/benefit analysis of injecting and storing surplus water in the Lower San Pedro aquifer for subsequent extraction. A variation on this was suggested by one of the stakeholders—that is, to consider injection near the points of extraction from the Lower San Pedro aquifer rather than at the existing barrier wells.

The extraction pattern for Scenario WCB-A3 is assumed to be identical to that of Scenario WCB-A2. Figure 3-8 provides a conceptualization of this scenario.

FIGURE 3-8
Conceptualization of Scenario WCB-A3

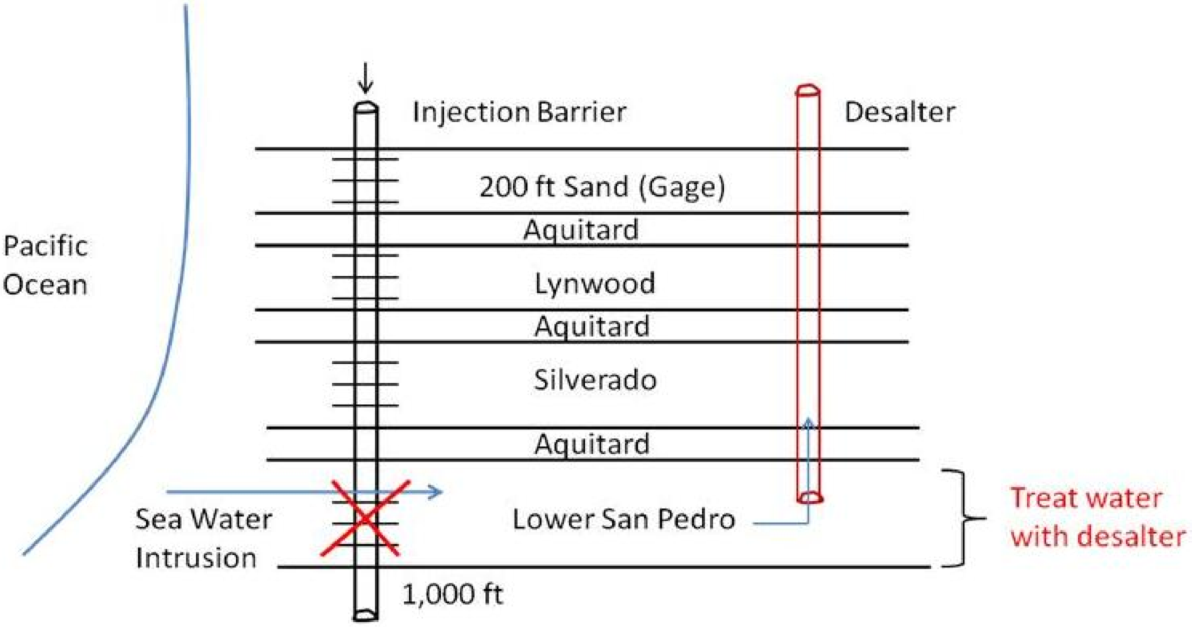


3.2.3.7 Scenario WCB-A4

Scenario WCB-A4 eliminates injection of highly treated barrier water to the Lower San Pedro aquifer. Rather than prevent seawater intrusion into this formation, extraction of brackish groundwater from this aquifer was assumed to be treated at the wellhead.

The extraction pattern for Scenario WCB-A4 is assumed identical to that of Scenario WCB-A1a with the exception of the added extraction from the Lower San Pedro. Figure 3-9 provides a conceptualization of this scenario.

FIGURE 3-9
Conceptualization of Scenario WCB-A4



3.2.3.8 Summary of Injection and Extraction Options in WCB-Concept A Scenarios

As discussed above, various options for injection and extraction were considered in the Concept A scenarios for the West Coast Basin. These included increased injection into the Silverado aquifer, and potentially decreased or eliminated injection into the San Pedro aquifer while increasing current extractions from Silverado aquifer to pump up to the adjudicated water rights. Table 3-3 summarizes the primary differences in these scenarios.

3.2.3.9 Screening of WCB-Concept A Scenarios

WBMWD's groundwater flow and solute transport model was used to evaluate the WCB-Concept A scenarios. Based on the model results, only the Scenario WCB-A1 series was found to be viable for further analysis.

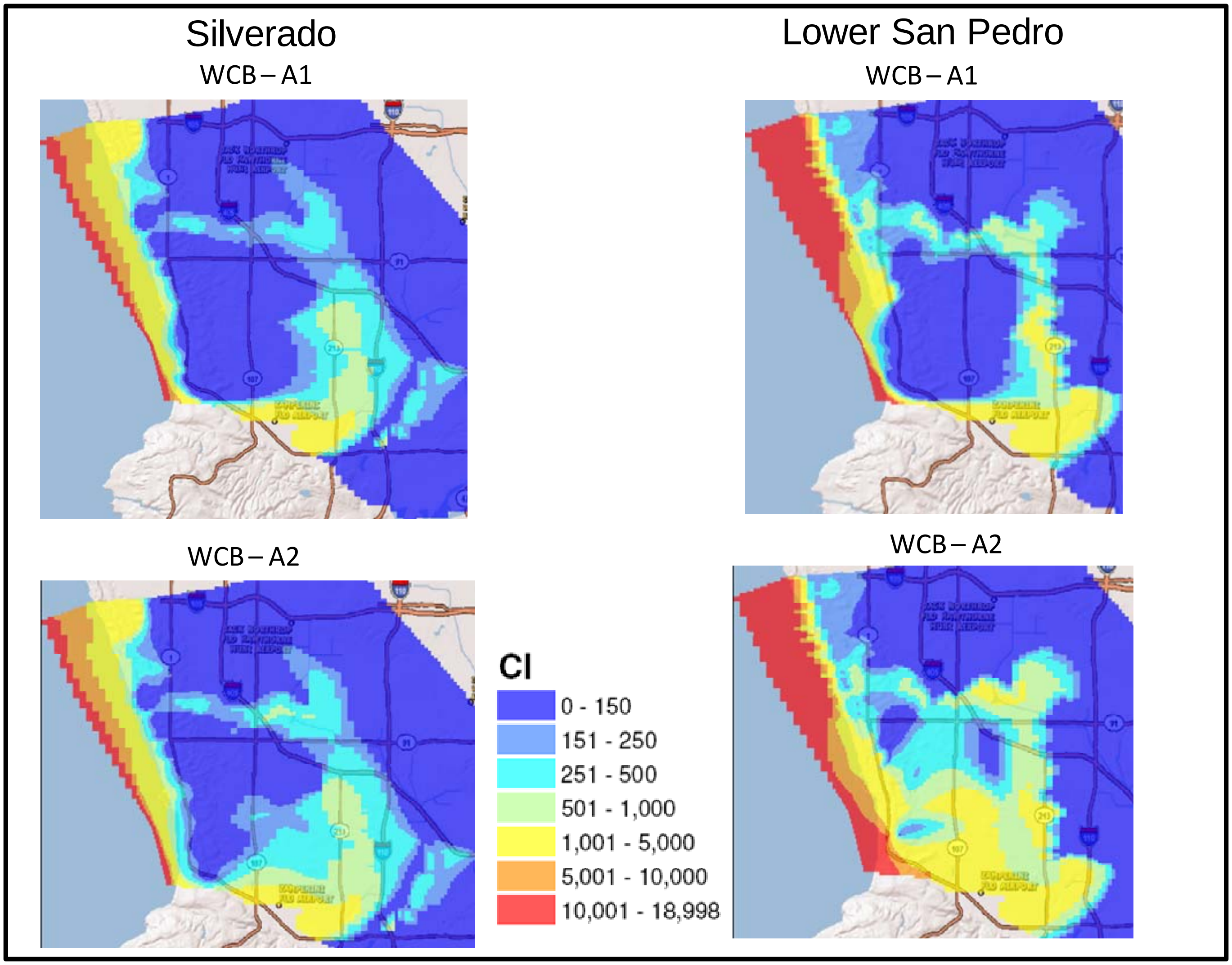
Shifting pumping and injection from the Lower San Pedro aquifer to the Silverado aquifer in Scenario WCB-A2 was found to increase seawater intrusion significantly into the Lower San Pedro, and even somewhat into the Silverado. Thus Scenario A2 was deemed too risky to for further consideration. And, since Scenario WCB-A2 was ineffective, Scenario WCB-A3, an even riskier operation, was thus not considered for modeling and analysis. The model results for Scenarios WCB-A1 and WCB-A2 are compared in Figure 3-10, demonstrating the effect of seawater intrusion in the West Coast Basin.

TABLE 3-3
Location of Extraction and Injection under WCB – Concept A Scenarios

Concept A Scenarios	Silverado Aquifer		Lower San Pedro Aquifer	
	Injection*	Silverado Extraction	Injection	Extraction
Scenario A1 (A1a, A1b, A1c)	Increase beyond current plans	Increase to adjudicated rights; pump from saline plume	No change to current level of protection	None
Scenario A2	Same as in Scenario A1	Same as in Scenario A1, plus move Lower San Pedro pumping to this aquifer	Eliminate injection and shift pumping to Silverado	None
Scenario A3	Same as in Scenario A1	Same as in Scenario A1	Eliminate injection unless surplus water available	None
Scenario A4	Same as in Scenario A1	Same as in Scenario A1	Eliminate injection	Consider extraction and treatment of brackish groundwater

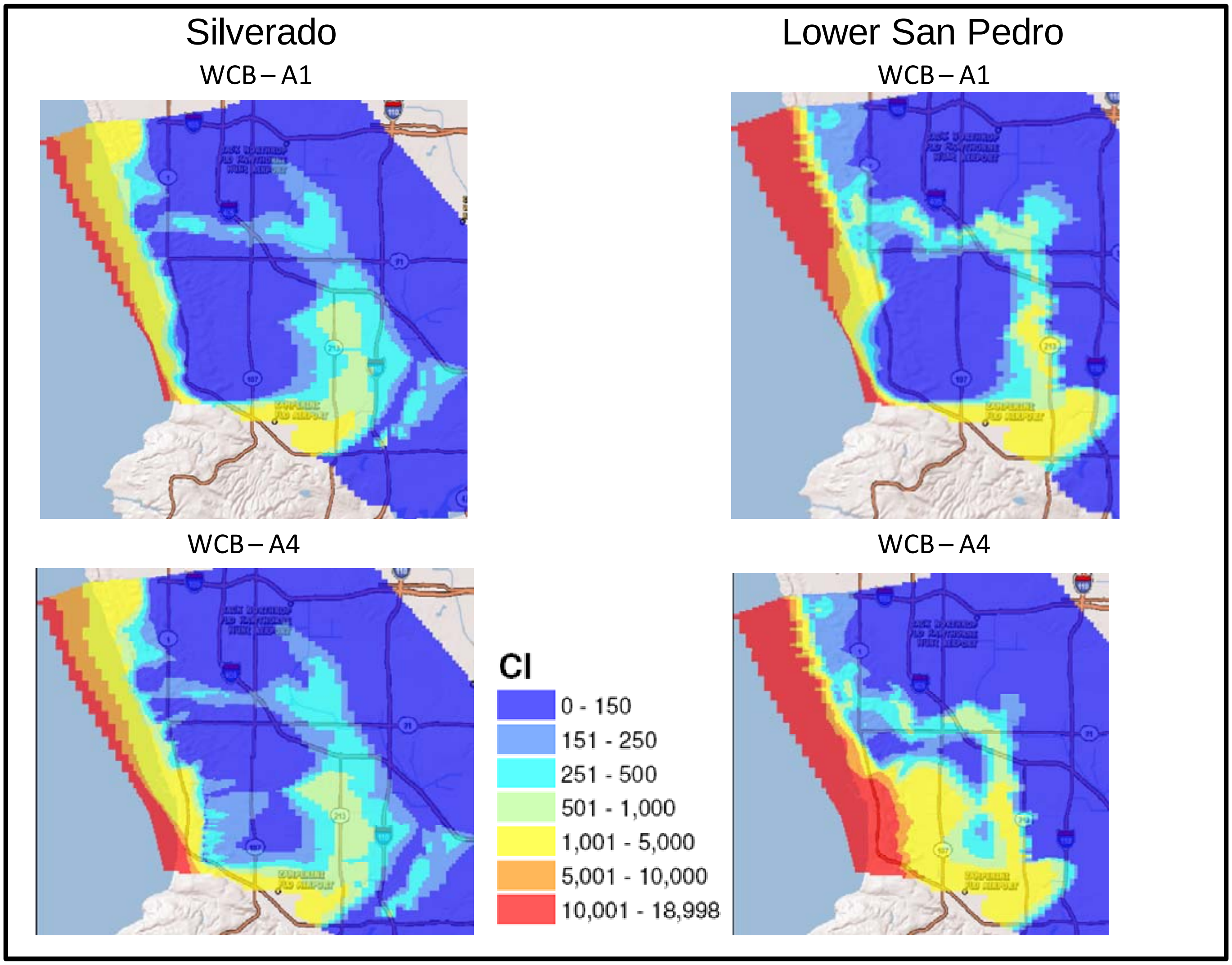
*Injection occurs at existing barriers only.

FIGURE 3-10
Comparison of Model Results for Chloride Concentrations in mg/L for Scenario WCB-A1 and Scenarios WCB-A2 for Year 2040



Scenario WCB-A4 eliminated injection in the Lower San Pedro aquifer, but extraction (with assumed wellhead treatment for desalination of the brackish groundwater) was introduced as a means to manage seawater intrusion. The effects on the basin were significant as seawater intrusion occurs around the extraction wells of the Lower San Pedro aquifer and brackish water moves into the Silverado aquifer. If extraction were stopped for any reason, the intruded seawater would be trapped inland, degrading overall basin water quality, which is an unacceptable operational scheme. Thus, Scenario WCB-A4 was also eliminated from further consideration. The model results for Scenarios WCB-A1 and WCB-A4 are compared in Figure 3-11, demonstrating the extent of the seawater intrusion in the Silverado and Lower San Pedro aquifers of the West Coast Basin.

FIGURE 3-11
Comparison of Model Results for Chloride Concentrations in mg/L for Scenarios WCB-A1 and Scenario WCB-A4 for Year 2040



3.2.4 Concept B Scenario – West Coast Basin

The Concept B scenario for the West Coast Basin was formulated such that the extraction expands beyond the adjudicated water rights, assuming approval of the Judgment amendments as currently proposed. For the West Coast Basin, extraction beyond the water rights was evaluated with one extraction/replenishment scenario. Extraction up to an additional 30,000 AFY was assumed, because this approximates historical production from the basin. Replenishment for this scenario included the use of a new, inland injection well system, as well as increased injection at the existing barriers.

As with the Concept A scenarios, the Concept B scenario for the West Coast Basin assumes the following:

- Shifting of oil companies' non-potable demands from groundwater to recycled water and shifting of this groundwater pumping to municipal purveyors
- 100% recycled water contribution to injection barriers
- Increasing injection required for extraction of 94,468 AFY

3.2.4.1 Scenario WCB-B1

Scenario B1 for the West Coast Basin (Scenario WCB-B1) increases extraction by water rights holders to 30,000 AFY beyond the adjudicated limit by assuming additional pumping by the following water purveyors from wells at or near their existing wells to offset their imported water demands:

- CWSC: 15,000 AFY
- City of Torrance: 5,000 AFY
- City of Los Angeles: 10,000 AFY

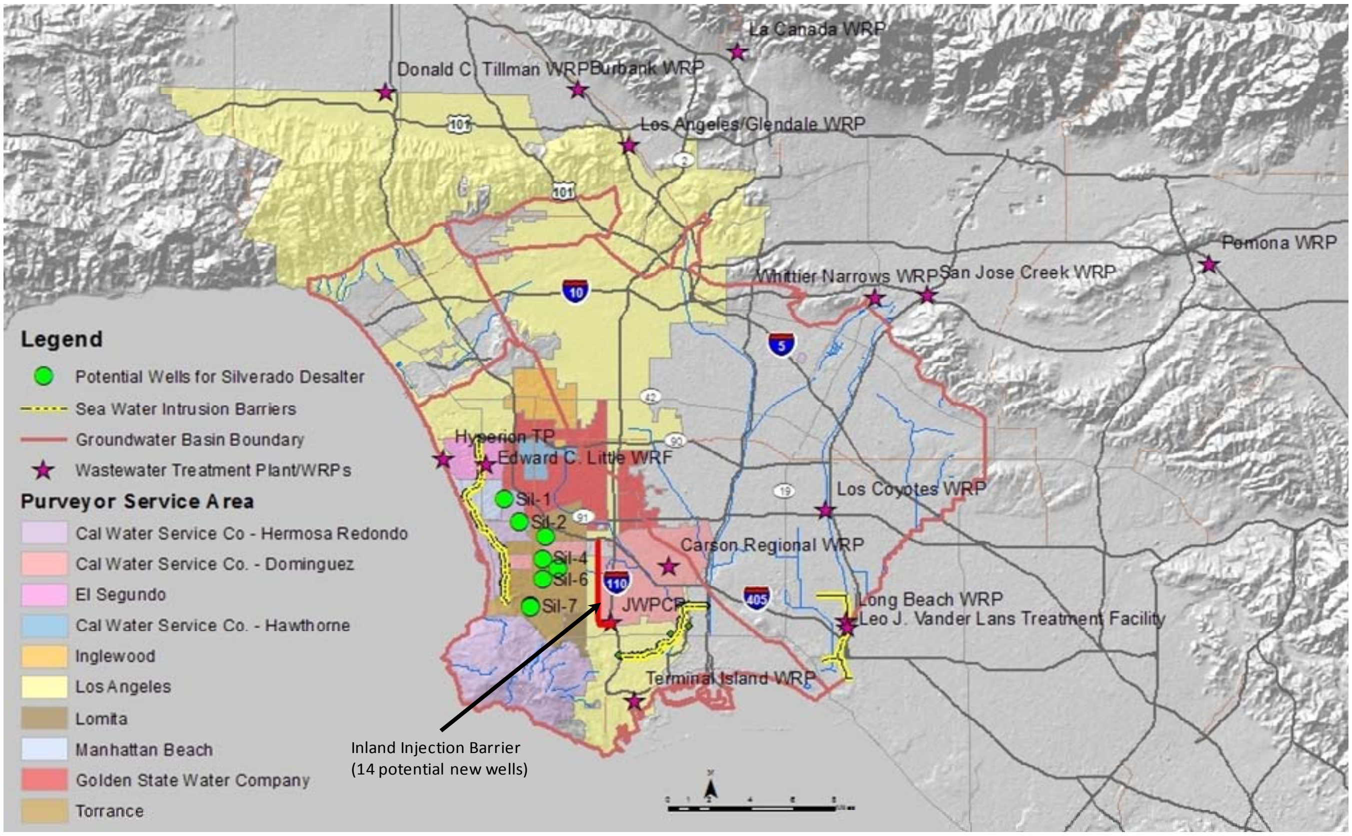
Pumping for all other purveyors will be the same as in Scenario WCB-A1a. Extraction under this scenario also included use of the new Silverado Desalters to mitigate the saline plume, thus applying the pumping locations as described for Scenario WCB-A1c.

This additional 30,000 AFY of extraction would require a comparable level of additional replenishment. For Scenario WCB-B1, replenishment was assumed to occur as follows:

- Injection of 15,000 AFY into 14 new injection wells in the southeastern area of basin (assumed along Normandie Street, west of the 110 freeway)
- Current injection of 17,000 AFY expanded by 15,500 AFY to meet the pumping up to the adjudicated limit of Concept A (see Section 3.2.3.1). Additional injection of 2,500 AFY is assumed under this scenario to provide a total of 35,000 AFY of artificial replenishment to the WCBBP to pump beyond the adjudicated limit.
- Current injection of 7,500 AFY is expanded by 7,500 AFY to provide a total 0f 15,000 AFY of artificial replenishment to the DGBP to allow additional pumping beyond the adjudicated limit of the Concept B scenarios.

The locations of the facilities associated with this replenishment scheme are shown in Figure 3-12.

FIGURE 3-12
Conceptualization of Scenario WCB-B1



3.3 Central Basin Scenarios

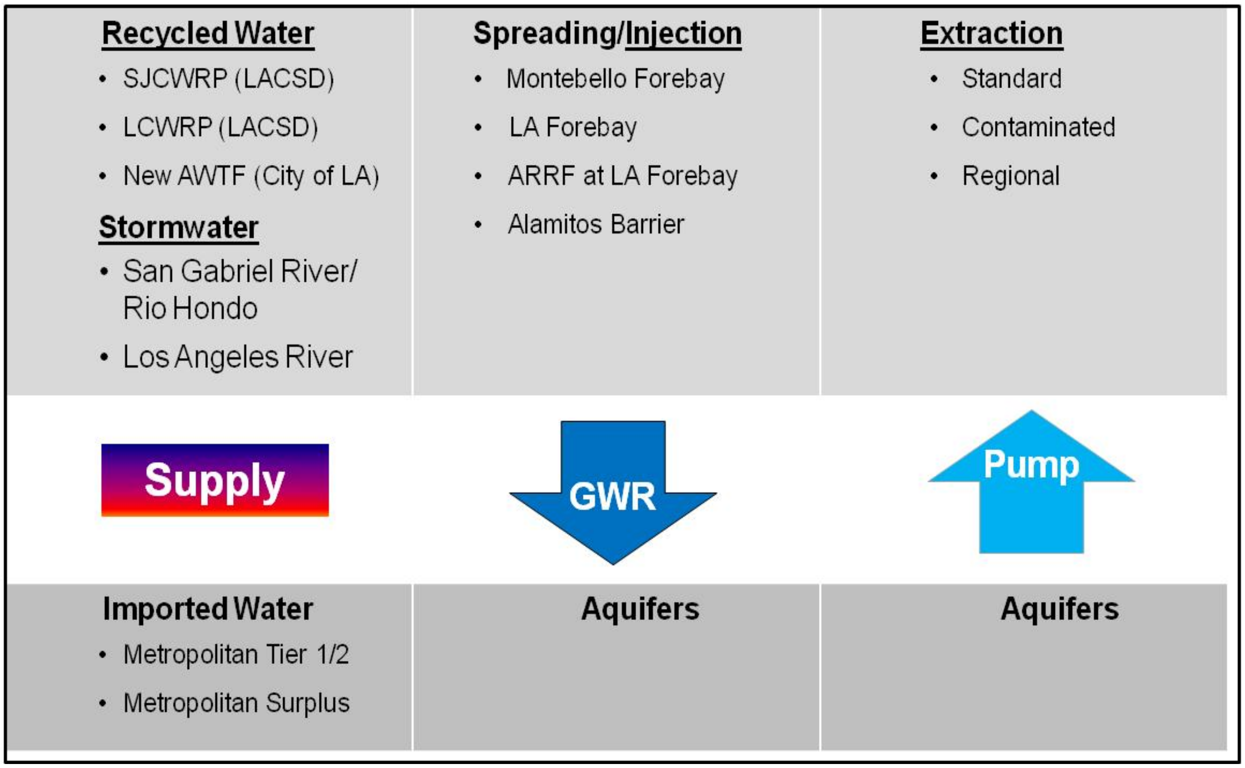
This section summarizes the formulation of GBMP planning scenarios for the Central Basin during Phase 1. The supply, recharge, and pumping components used to define these scenarios are described below, along with the potential sources of replenishment water. Finally, the specific Central Basin planning scenarios were defined and evaluated, and viable scenarios were identified to serve as the basis for the GBMP alternatives evaluated in the Phase 2 analysis.

3.3.1 Components Used for Developing Central Basin Scenarios

For the Central Basin, the components of the GBMP planning scenarios (water supply sources, groundwater recharge mechanisms, and pumping patterns) consisted of the following elements, as illustrated in Figure 3-13:

- Water supply sources for injection and spreading in the basin – Recycled water and imported water for injection; stormwater, and recycled water for spreading.
- Injection and spreading locations – Existing barrier (ABP) as well as new inland injection system; consider practice of in-lieu use of imported water to replace groundwater pumping. (As noted for the West Coast Basin, assume that in-lieu recharge will occur as in the past; that is, this would be an opportunistic activity that will occur if discounted imported water is available at a rate that is of a lower cost than use of other supplies. Given the uncertain nature of imported water supplies, in-lieu operations have not been specifically analyzed; however, given the offsetting effects of pumping and recharge, limited in-lieu operations are not expected to significantly change the analysis presented herein.)
- Pumping locations – Extraction is expected to be expanded by pumpers in their service areas; however, large increases in extraction are assumed to be focused near areas of recharge (such as forebay areas) to minimize large fluctuations in groundwater levels. However, extraction patterns could be optimized in subsequent implementation phases to consider containment or cleanup of selected areas of groundwater contamination.

FIGURE 3-13
Elements for Developing Scenarios in the Central Basin



The overall goals for developing the Central Basin scenarios are as follows:

- Replenish Central Basin within current APA of 217,367 AFY (Concept A scenarios) and above APA (Concept B scenarios).
- Further develop sources of local water, principally stormwater and recycled water (excluding imported water).
- Maximize use of supplies and spreading grounds in Montebello Forebay.
- Provide for increased pumping to offset imported water demands consistent with increased replenishment.
- Maintain an overall water balance in the basin.
- Use groundwater basin storage space as required to meet the objectives.

In the Central Basin, Concept A and B GBMP planning scenarios were varied according to extraction and recharge patterns related to enhancing the potential for stormwater recharge and increased injection and spreading of recycled water at both the existing spreading grounds and new injection wells.

Several scenarios were developed based on (1) the components identified in Figure 3-13; (2) the planning goals for the basin identified above; and (3) the potential sources of replenishment water described below. These specific scenarios for Concepts A and B are described below.

3.3.2 Potential Sources of Replenishment Water

Potential sources of groundwater replenishment water for the Central Basin include:

- Imported water
- Recycled water
- Stormwater

3.3.2.1 Imported Water

While imported water has been used historically to replenish the Central Basin, the existing ABP seawater intrusion barrier will ultimately be replenished with 100 percent RWC with the expansion of the LVLWTF. And the imported water that has been used in recent years to replenish the basin at the MFSG will be replaced by the GRIP Recycled Water Project.

The alternatives developed in this GBMP assume that no surplus, discounted imported water is available so that they can be compared against the availability, reliability, and costs of imported water. The actual use of discounted “Level 2” imported water for replenishment (discussed in Section 3.2.2.1) would continue to be considered by WRD on an annual basis as the opportunities for its purchase and use for replenishment in the Central Basin arise, particularly for the MFSG. Therefore, use of imported water will be considered on an opportunistic basis to provide for replenishment via in-lieu operations. The occasional implementation of in-lieu operations is not expected to significantly alter the analysis presented herein.

3.3.2.2 Recycled Water

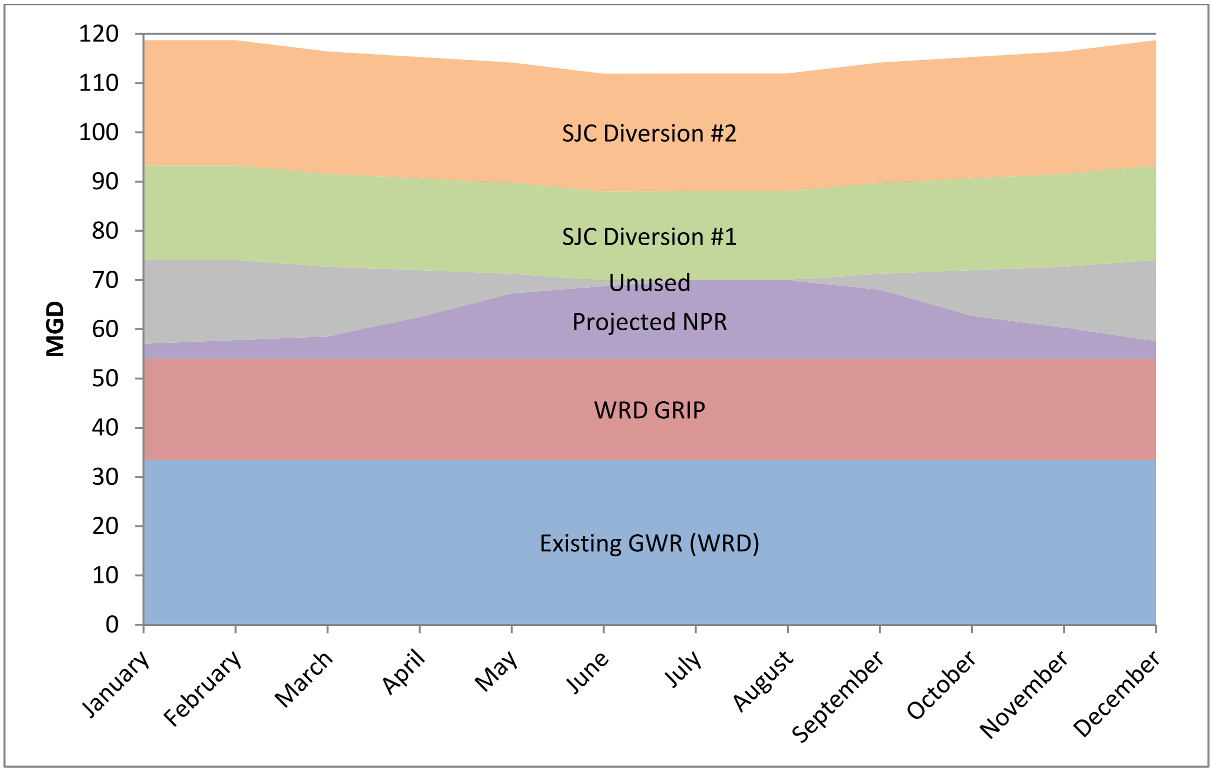
As noted in Section 3.1.1 and shown in Figure 3-3, there are several potential sources of recycled water in the Study Area. This section discusses the WRPs considered for sources of replenishment water in the Central Basin.

San Jose Creek Water Reclamation Plant

The SJCWRP provides primary, secondary, and tertiary treatment for up to 100 mgd. The plant serves a large residential population of approximately one million people. Approximately 35 mgd of the tertiary-treated water was reused at 17 different reuse sites in 2010, including groundwater recharge and irrigation of parks, schools, and greenbelts (LACSD, 2011). The remainder is discharged to the San Gabriel River.

NPR demand totaled approximately 4,500 AFY in fiscal year 2009/2010[5] and is projected to increase to 10,500 AFY by 2030 as a result of planned increases in use by each existing customer. In addition, WRD plans to increase recharge of SJCWRP effluent at the MFSG by 21,000 AFY as part of the GRIP Recycled Water Project (i.e., from 40,000 AFY to 61,000 AFY). Existing SJCWRP production is approximately 70 mgd (78,400 AFY), and current expectations are for increased flows due to economic and population growth to be offset by increased implementation of conservation measures. Therefore, an average of 70 mgd is conservatively assumed to be the future SJCWRP effluent production. Based on these projections, nearly all SJCWRP effluent is projected to be reused during the summer. Recycled water production and projected reuse by month is shown in Figure 3-14.

FIGURE 3-14
SJCWRP Monthly Supplies



As indicated in Figure 3-14, sewer diversions and plant modifications are necessary to increase influent flows to the SJCWRP, which will increase effluent flows to help supply potential GBMP projects. Based on an LACSD technical memorandum (2010), the following "Diversion No.1" projects could increase SJCWRP influent by 20,900 AFY at a cost of $1.6 million:

- Terminate Pico Rivera contract (400 AFY at no additional cost).
- Route Phase 1 membrane filter backwash to plant influent (1,200 AFY at no additional cost).
- Re-route Miller Brewing Company discharge to sewers tributary to SJCWRP (1,400 AFY at no additional cost).
- Implement flow equalization and treat additional flow at SJCWRP (8,400 AFY at no additional cost, assuming it is implemented as part of the GRIP Recycled Water Project).
- Route media filter backwash to plant influent (3,300 AFY for $100,000).
- Re-route sewers in the vicinity of the Pomona WRP to SJCWRP (4,400 AFY for $1,500,000).

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[5] Reuse by CBMWD is supplied by both SJCWRP and LCWRP, but the split between each source is not measured. SJCWRP and LCWRP non-potable reuse estimates assume that approximately two-thirds of CBMWD total reuse (3,750 AFY) is supplied from SJCWRP and the other one-third is supplied by LCWRP.

- Route Phase 2 membrane filter backwash to plant influent (1,800 AFY at no additional cost).

The “Diversion No.2” project could increase tributary flow to the SJCWRP by 27,600 AFY by diverting available flows from the Whittier Narrows WRP drainage area at an estimated by cost of $76 million.

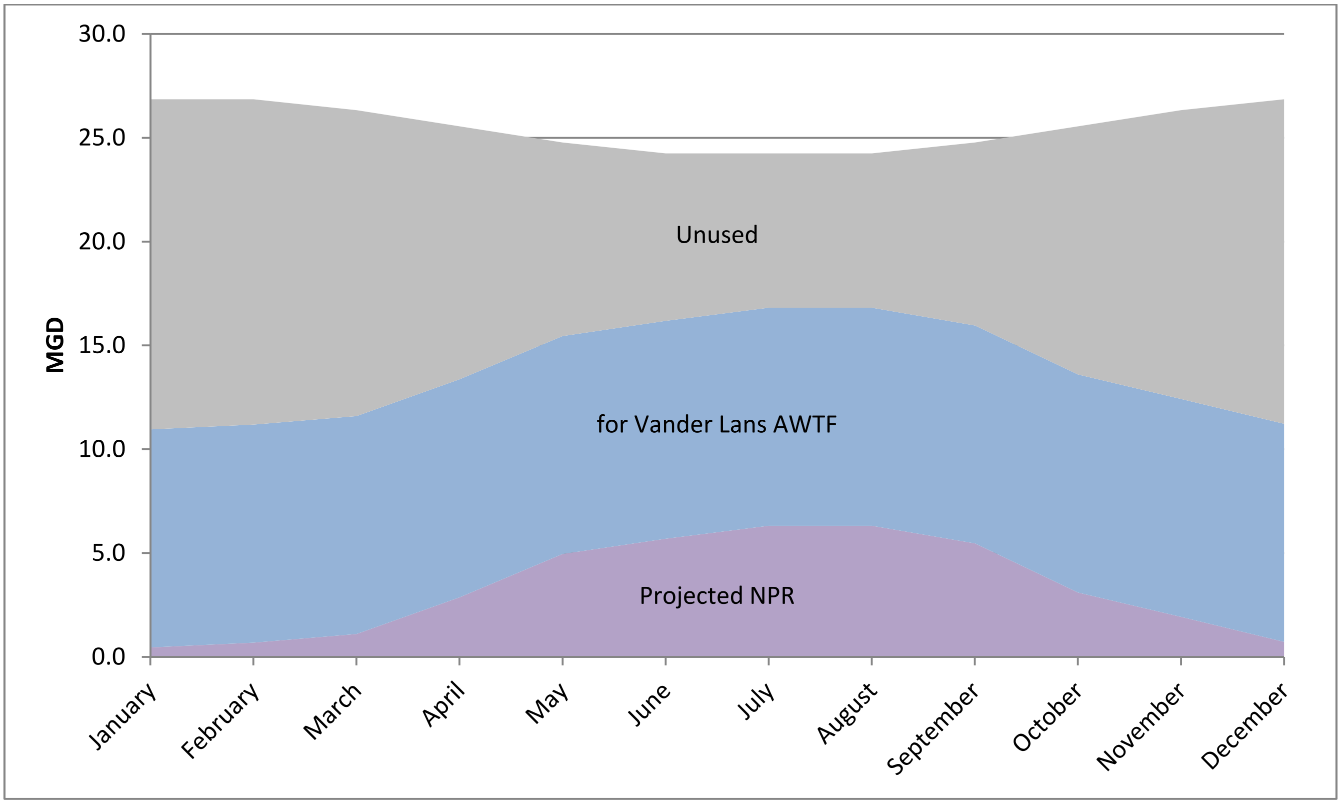
Los Coyotes Water Reclamation Plant

The LCWRP provides primary, secondary, and tertiary treatment for up to 37 mgd. The plant serves a population of approximately 370,000 people. Over 5 mgd of the tertiary-treated water is reused at over 200 sites. Reuse includes landscape irrigation of schools, golf courses, parks, nurseries, and greenbelts; and industrial use at local companies for carpet dying and concrete mixing (LACSD, 2011). The remainder of the effluent is discharged to the San Gabriel River.

NPR demand totaled approximately 3,600 AFY in fiscal year 2009/2010[6] and is projected to increase to 4,200 AFY by 2030 as a result of planned increases in use by each existing customer. In addition, because of potential limitations on feed water from the LBWRP, WRD is currently considering using up to 10.5 mgd of LCWRP effluent as feedwater for the LVLWTF. At the time of writing this Draft GBMP, this issue has not yet been resolved.

Existing LCWRP production is approximately 26 mgd, and current expectations are for increased flows due to economic and population growth to be offset by increased implementation of conservation measures. Therefore, an average of 26 mgd is conservatively assumed to be the future LCWRP effluent production. Based on these projections, an annual average of approximately 12 mgd is projected to be available. Recycled water production and projected reuse by month is shown in Figure 3-15.

FIGURE 3-15
LCWRP Monthly Supplies



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[6] Reuse by CBMWD is supplied by both SJCWRP and LCWRP, but the split between each source is not measured. SJCWRP and LCWRP non-potable reuse estimates assume that approximately two-thirds of CBMWD total reuse (3,750 AFY) is supplied from SJCWRP and the other one-third is supplied by LCWRP.

Long Beach Water Reclamation Plant

The LBWRP provides primary, secondary, and tertiary treatment for 25 mgd. The City of Long Beach owns the rights to recycled water produced at LBWRP in exchange for the land it sits on. They also operate and maintain the LVLWTF. In fiscal year 2009/2010, 5.8 mgd (6,550 AFY) of the effluent produced at the plant was reused beneficially at 56 individual sites. NPR demand totaled approximately 4,272 AFY in fiscal year 2009/2010, delivered by the Long Beach Water Department for landscape irrigation of schools, golf courses, parks, and greenbelts. An additional 2,278 AFY was delivered to the LVLWTF for replenishment at the ABP. The majority of the effluent is discharged to the lined portion of Coyote Creek, which then joins the San Gabriel River and flows to the Pacific Ocean (LACSD, 2012)

Existing LBWRP production is approximately 18 mgd, and current expectations are for increased flows due to economic and population growth to be offset by increased implementation of conservation measures. Therefore, an average of 18 mgd is conservatively assumed to be the future LBWRP effluent production.

In their *2010 Recycled Water Master Plan* (MWH, 2010), described in Appendix A, (Section A1.4.1), the City of Long Beach identifies at least 2,505 AFY of additional recycled water demand from potential NPR customers, and acknowledges additional potable water demands that could be served with recycled water that could reach more than 4,510 AFY. The expansion demands of LVLWTF are assumed to be met after the other customer demands are met. Because of this, the reliability of LBWRP as a supply source for LVLWTF is uncertain, and WRD is thus considering the use of LCWRP effluent as either a source of facility expansion supply or potentially as a replacement source for LBWRP source water. Due to the high projected demand for LBWRP recycled water, it is not considered as a viable potential supply source of additional replenishment water for the GBMP alternatives.

3.3.2.3 Stormwater

Stormwater from the San Gabriel River, Rio Hondo, and Los Angeles River can be captured and used for recharge. The potential to capture more stormwater for recharge requires that 1) capacity to recharge additional stormwater exists and, 2) additional stormwater is available to divert into the spreading basins. Provided below is a description of the amount of water available from the San Gabriel River and Rio Hondo and the Los Angeles River, which can be captured and used for recharge, instead of it discharging to the ocean.

San Gabriel River and Rio Hondo

The Montebello Forebay recharge facilities consist of two off-stream spreading facilities operated by LACDPW, including the Rio Hondo Spreading Grounds and San Gabriel Spreading Grounds (collectively referred to as the MFSG), as well as several in-stream facilities in the San Gabriel River for replenishment of recycled water, direct precipitation, local runoff, and imported water. LACDPW monitors the source of water supplies and locations of recharge of these waters at the MFSG. The recharge waters at the spreading grounds have averaged approximately 128,000 AFY, composed of about 57,000 AFY of local runoff, 21,000 AFY of imported water, and about 50,000 AFY of recycled water. The use of imported water for replenishment at the MFSG is being replaced with either increased capture of stormwater or recycled water, given that the WIN program goal is to replace the use of imported water.

In 2000, WRD completed the Montebello Forebay Recharge Optimization Study (MFROS). This study concluded that on average, approximately 17,000 AFY additional stormwater could be captured and recharged at the MFSG if there was approximately 25,000 AFY of additional pumping in the forebay area to reduce groundwater levels, so that recharge would not be reduced due to rising groundwater levels during high-rate recharge events. A project to provide this combination of pumping and enhanced stormwater recharge is included in this GBMP, and referred to as the Forebay Infiltration and Extraction Intra-basin Transfer (FIX-IT) project.

Large volumes of San Gabriel River and Rio Hondo flows bypass the spreading grounds following large storm events and are wasted to the ocean. In fact, approximately 55,000 AFY was bypassed on average during the period of record shown in Figure 3-16 (October 1996-May 2011). LACDPW maintains records of stormwater captured at the MFSG and reports approximate volumes of water “wasted to the ocean” when they could not capture all of the stormwater in a given storm event. Although these records are not complete for all years between water years 1971 to 2010, Figure 3-16 shows the historical volumes of water wasted to the ocean where these data are available, i.e., beginning in 1996. Typically, the volumes of stormwater are very large and much greater than can reasonably be captured and recharged; therefore, only a fraction of these flows can be diverted and captured for additional recharge. Future projections assume stormwater will be available in the same quantities in the future as it was in the past. This means that any non-captured stormwater in years past when stormwater was wasted to the ocean is now assumed to be excess stormwater available for capture and recharge.

Figure 3-17 shows the monthly volume of water recharged at the MFSG, including the Whittier Narrows Dam, for all water supplies combined, for water years 1971 through 2010. The maximum monthly quantity of water recharged exceeds 60,000 AF once, 40,000 AF in a few months, and 30,000 AF in many months over this period. Figure 3-18 shows the monthly volumes of stormwater captured and spread at the MFSG.

Based on a review of these historical spreading data, the short-term, back-to-back, maximum monthly recharge rate is assumed to be a no more than 45,000 acre-feet per month (AFM), limited to no more than 3 months, and the average “typical” operating recharge rate is set at a maximum of 15,000 AFM, to allow for routine drying and maintenance activities.

3.3.2.4 Los Angeles River

The City of Los Angeles has recently conducted a Recycled Water Master Planning effort, which outlines potential strategies for reusing some of the recycled water for upstream beneficial uses, while acknowledging the role that recycled water plays in the Los Angeles River as well. The GBMP analysis takes a conservative approach and excludes dry-weather flows in the Los Angeles River from consideration as a source of recharge water to the underlying basin. The GBMP only considers wet-weather stormwater flows as a potential supply.

The Los Angeles River drains a highly urbanized basin, with storm flows originating from local mountains and canyons, urban runoff, and tertiary recycled water from three WRPs: the Tillman WRP, the Los Angeles-Glendale WRP, and the Burbank WRP, owned and operated by the City of Burbank. During dry weather, a majority of the flow in the Los Angeles River is composed of tertiary-treated disinfected effluent from these WRPs. During a snapshot monitoring event by the Southern California Coastal Water Research Project in 2000, it was reported that 72 percent of the flow discharged into the Los Angeles River was WRP effluent (Ackerman et al., 2003). During wet weather, WRPs account for less than 1 percent of the total flow in the river (CREST, 2009).

The storm flows in the Los Angeles River typically occur during the months of October through March. The Los Angeles River is lined through most of the Central Basin and the area along the river is developed, so there is very limited potential to capture stormwater even though there is significant stormwater runoff. However, there is a possibility to divert the stormwater runoff from the river to a recharge facility, such as an Aquifer Recharge Recovery Facility (ARRF), discussed below, to utilize the storm flows for groundwater recharge. The Los Angeles River flow data collected by LACDPW at two monitoring stations (*Los Angeles River above Arroyo Seco* and *Los Angeles River below Firestone Boulevard*) were analyzed to determine the availability and amount of storm flow runoff available for spreading in the Los Angeles Forebay, reducing downstream flows during storm periods.

FIGURE 3-16
Historical Monthly Volumes of Stormwater Wasted to the Ocean

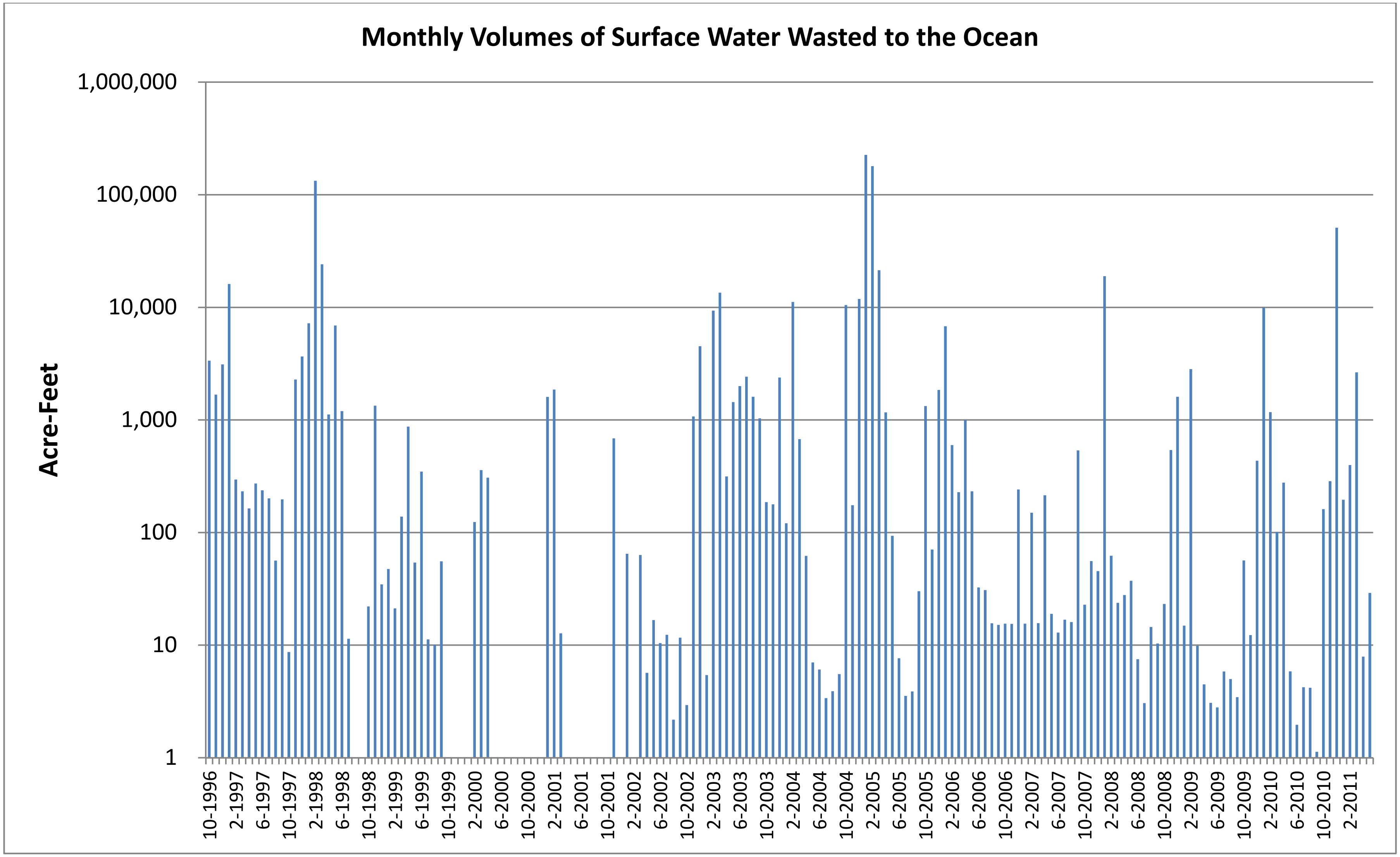


FIGURE 3-17
Historical Monthly Recharge for All Supplies Combined at Montebello Forebay Spreading Basins

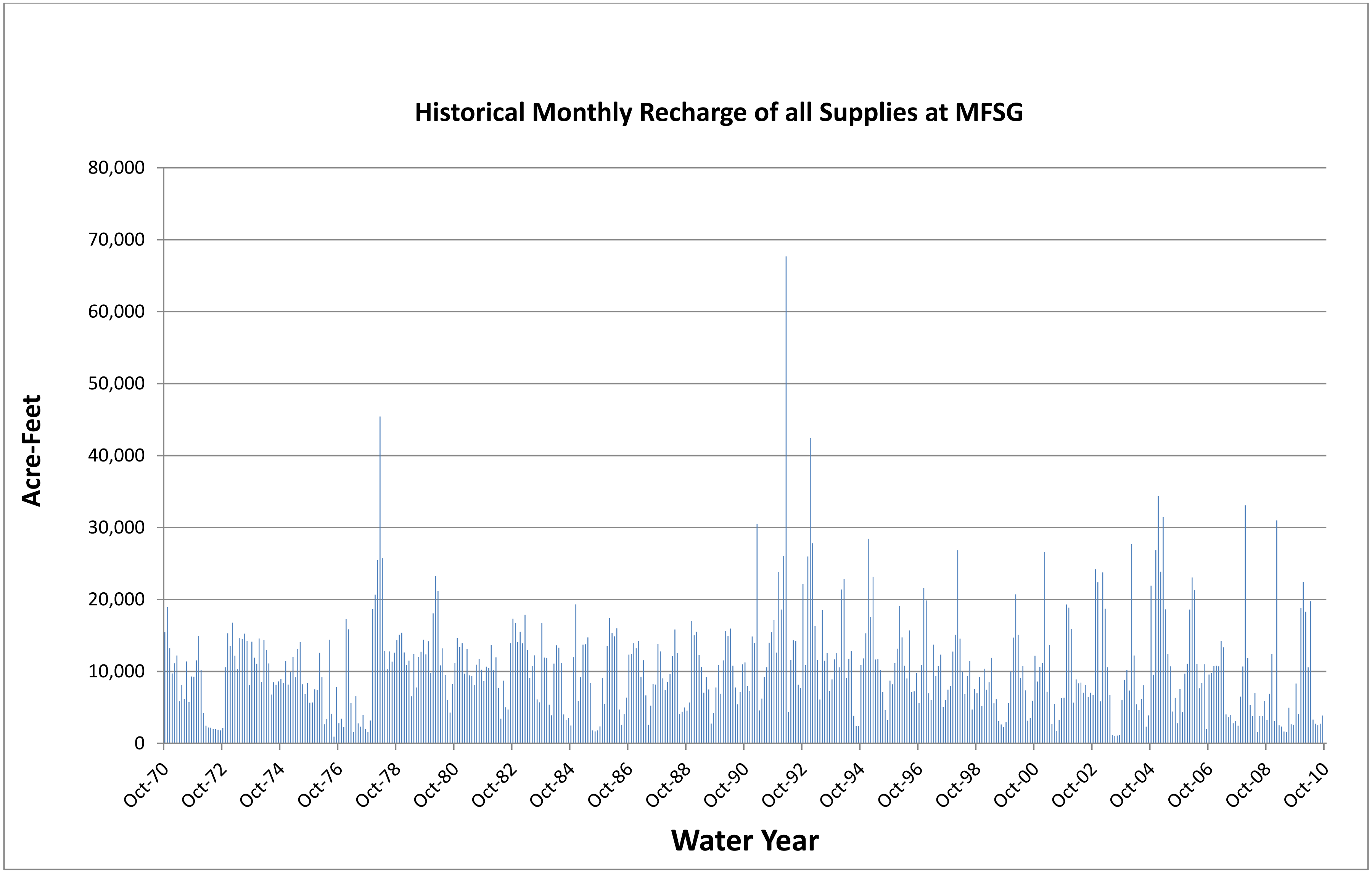
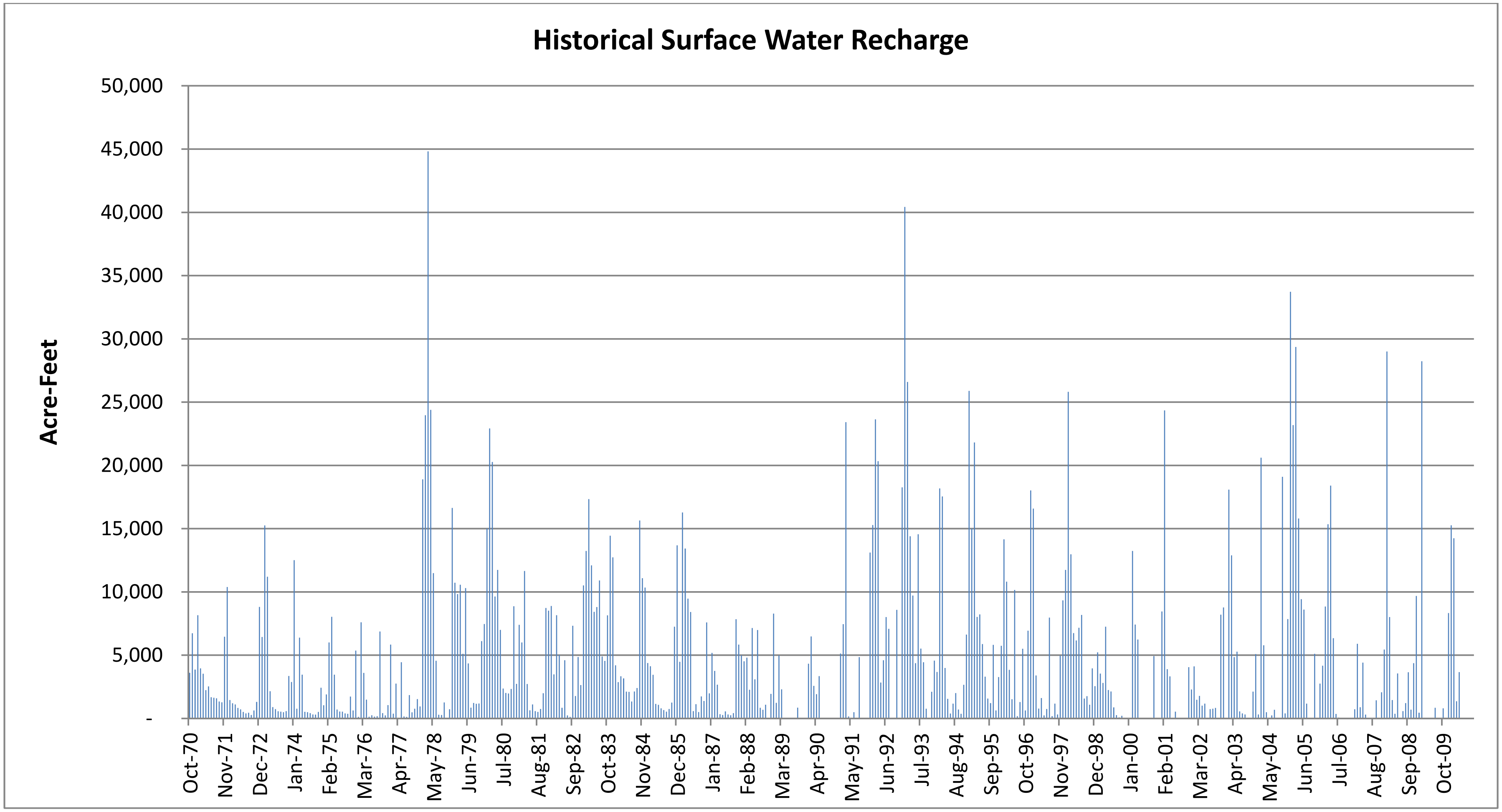


FIGURE 3-18
Historical Monthly Recharge of Stormwater at Montebello Forebay Spreading Basins



The flow data for these stations represented the period from 1971 through 2010. In the summer months (April through September), the baseflows currently average about 150 ft^3/s. As shown in Table 3-4, the baseflow during this period has increased from 50 ft^3/s to 150 ft^3/s. This increase in flows is due to increases in discharges from three WRPs noted above.

The available storm flows above the baseflows were calculated during this time period to estimate the amount of water available for recharge. Appendix F contains the details of the analysis conducted for flow data available at the *Los Angeles River above Arroyo Seco* and *Los Angeles River below Firestone Blvd.* stations. Based on this analysis, at least 5,000 AFY of stormwater is considered to be available above baseflow conditions for capture and recharge of the Central Basin.

TABLE 3-4
Average Baseflow at the Los Angeles River Stations (F34D-R and F57C-R)

Period	Average Baseflow (ft^3/s)
1971-1980	50
1981-1990	50
1992-2000	100
2001-2010	150

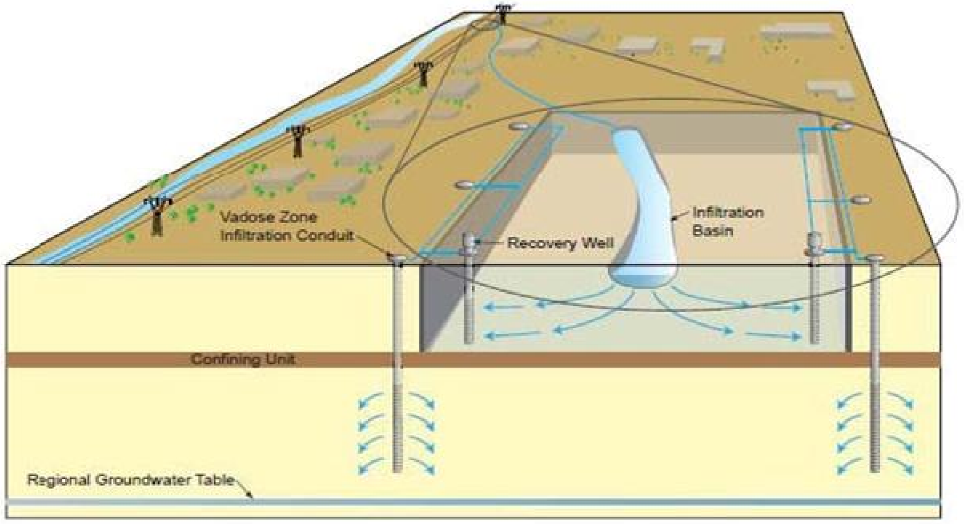
Note:

Locations of these Los Angeles River Stations can be found in Appendix F.

Los Angeles River Aquifer Recharge Recovery Facility Description

The Los Angeles River ARRF project consists of a system that would inject naturally treated stormwater from the Los Angeles River. As shown in Figure 3-19, storm flows would be diverted to an easement along the Interstate 710 freeway into an infiltration basin where it would percolate into the upper, shallow aquifer above the confining aquitard. This would serve as a natural filtration process that removes nitrate, pathogens, and micro-pollutants and provides a physical separation from the source of supply (that is, the Los Angeles River). Then, the treated water would be recovered (pumped) for subsequent injection through a vadose zone infiltration conduit into the groundwater basin as a source of supplemental replenishment supply.

FIGURE 3-19
Los Angeles River Aquifer Recharge and Recovery Facility



3.3.3 Concept A Scenarios – Central Basin

Concept A scenarios for the Central Basin were formulated so that the extraction patterns are limited to the Central Basin APA. Three scenarios under Concept A were identified for the Central Basin. They differed with respect to the specific source water used for replenishment, and whether the recycled water was applied using surface spreading alone or in combination with injection.

All Concept A scenarios for the Central Basin assume that the recharge occurs at the ABP and MFSG. The ABP planned recharge of 8,000 AFY of FAT recycled water from the LVLWTF is assumed as a baseline operating condition. The GBMP scenarios reflect replenishment of recycled water and stormwater needed to meet the full APA of 217,367 AFY of extraction.

Each of these Concept A scenarios assumes the following:

- Increasing replenishment to allow pumping up to the APA
- Pumping patterns will be similar to those of the past 10 years, but unused water rights are leased by imported water users

Modeling of Central Basin operations represented in these scenarios, in conjunction with West Coast Basin operations for the various GBMP alternatives, was conducted with the WRD/USGS updated and refined groundwater model, as described in Section 4.0. A description of the Concept A scenarios for the Central Basin is provided below.

3.3.3.1 Scenario CB-A1

As shown in Figure 3-20, Scenario A1 for the Central Basin (Scenario CB-A1) increases extraction by water rights holders up to the APA by replenishing the basin by spreading an additional 31,000 AFY[7] (which includes 21,000 AFY for GRIP) of recycled water from the SJCWRP at the MFSG.

Table 3-5 provides the assumed distribution of annual pumping for Scenario CB-A1. It is assumed that pumpers will (1) increase capacity of existing wells, (2) bring on standby wells, (3) activate wells that have been inactivated, (4) replace existing wells with new wells, (5) drill new wells generally in the area of existing wells, and/or, (6) collaborate with adjacent pumpers to use common wells to meet demands jointly. This pattern of pumping is not expected to result in a significant shift in the general geographic distribution of pumping in the basin. Other pumping patterns are possible as pumpers determine their actual pumping plan; however, these alternative pumping distributions are not likely to significantly change the modeling results unless there is substantially different geographical redistribution of pumping than assumed herein.

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[7] 31,000 AFY of additional replenishment was estimated from the revised and refined WRD/USGS model to be the average replenishment required to balance the water budget in the Central Basin over the 40-year period, based on hydrological conditions represented by 1970 through 2010 and pumping distribution based on 2000 through 2010 and increased to the full APA.

FIGURE 3-20
Conceptualization of Scenario CB-A1

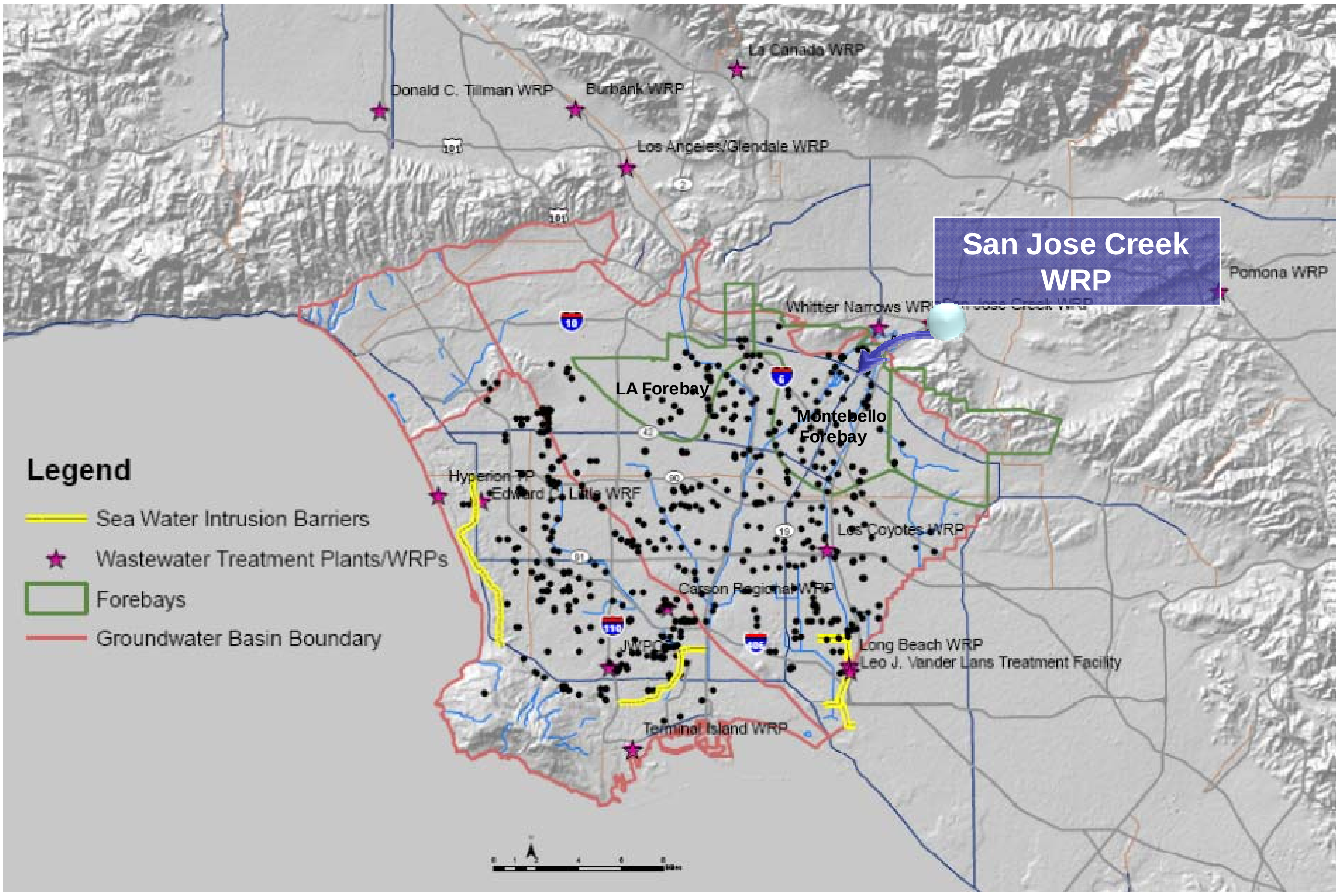


TABLE 3-5
Assumed Distribution of Pumping in the Central Basin for Concept A Scenarios

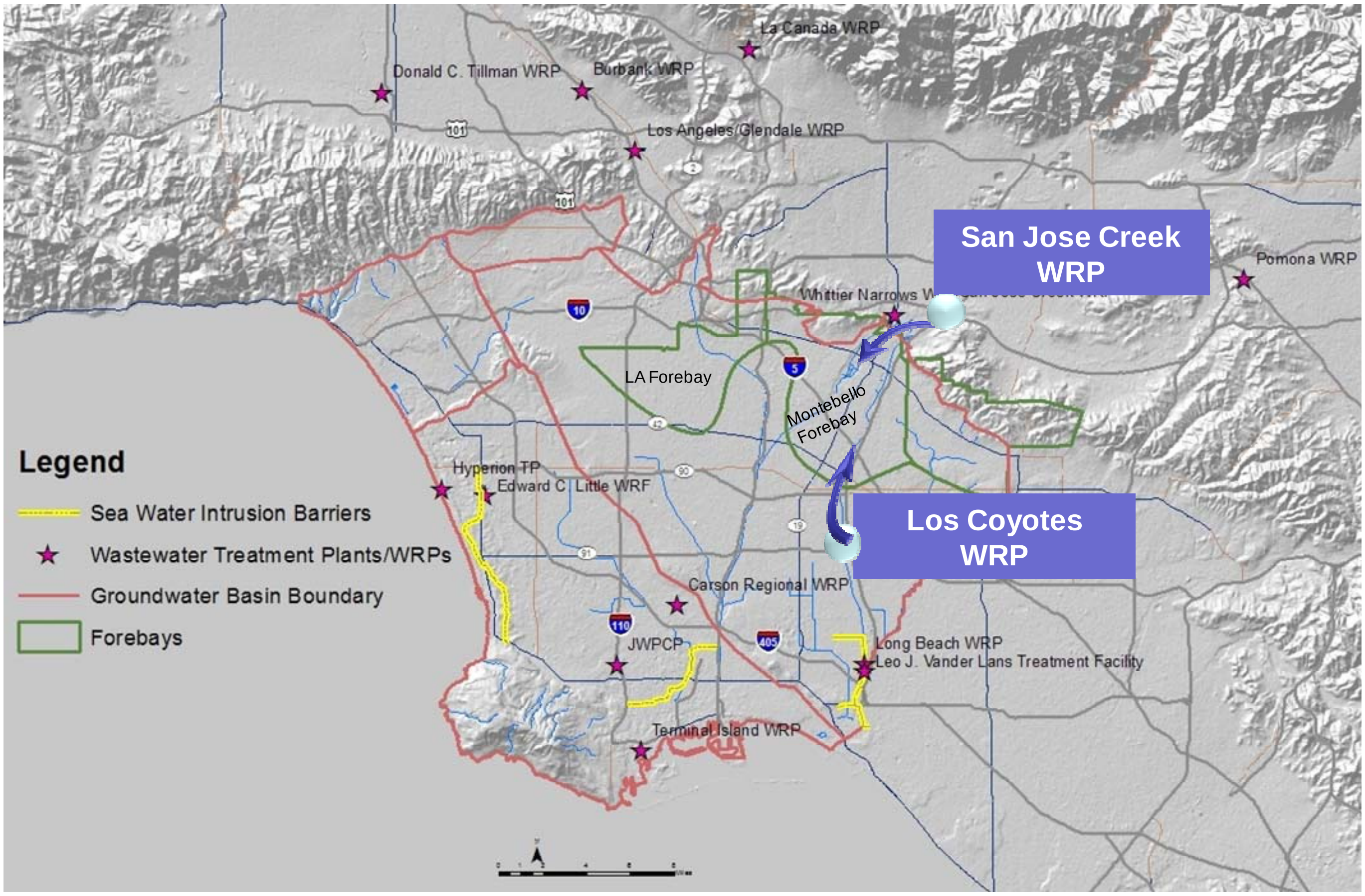
Pumper	APA (AFY)	Assigned Pumping (AFY)
City of Long Beach	32,692	32,692
Golden State Water Company	16,439	20,504
City of Downey	16,554	17,325
City of South Gate	11,183	10,363
City of Cerritos	4,680	10,617
City of Lakewood	9,432	9,432
City of Vernon	8,039	8,527
City of Compton	5,780	6,511
California Water Service Company	11,774	11,774
City of Lynwood	5,337	5,302
City of Los Angeles	15,000	15,000
City of Pico Rivera	5,579	4,479
City of Paramount	5,883	5,883
Bellflower Somerset Mutual Water Company	4,313	4,398
Montebello Land and Water Company	1,624	3,662
Pico Water District	3,624	3,702
City of Huntington Park	3,853	4,000
City of Santa Fe Springs	4,036	4,700
California Water Service Company (Dominguez)	6,480	6,480
California American Water Company	2,067	2,311
La Habra Heights County Water District	2,596	3,846
Park Water Co.	2	1,674
San Gabriel Valley Water Company	2,565	2,565
Suburban Water Systems	3,721	1,751
City of Commerce	5,081	1,976
South Montebello Irrigation District	1,268	1,880
Tract Number One Hundred & Eighty Water Company	2,137	1,700
Maywood Mutual Water Company No. 3	1,407	3,012
City of Signal Hill	2,022	2,022
Walnut Park Mutual Water Company	996	1,026
City of Whittier	895	879
All Other*		7,372
Total	217,367	217,367

* Pumping to other water rights holders distributed to their existing wells using the average of their last 10 years of pumping.

3.3.3.2 Scenario CB–A2

Scenario A2 for the Central Basin (Scenario CB-A2) modifies Scenario CB-A1 by using recycled water from both the SJCWRP as well as the LCWRP, as shown in Figure 3-21. The extraction pattern is identical to Scenario CB-A1.

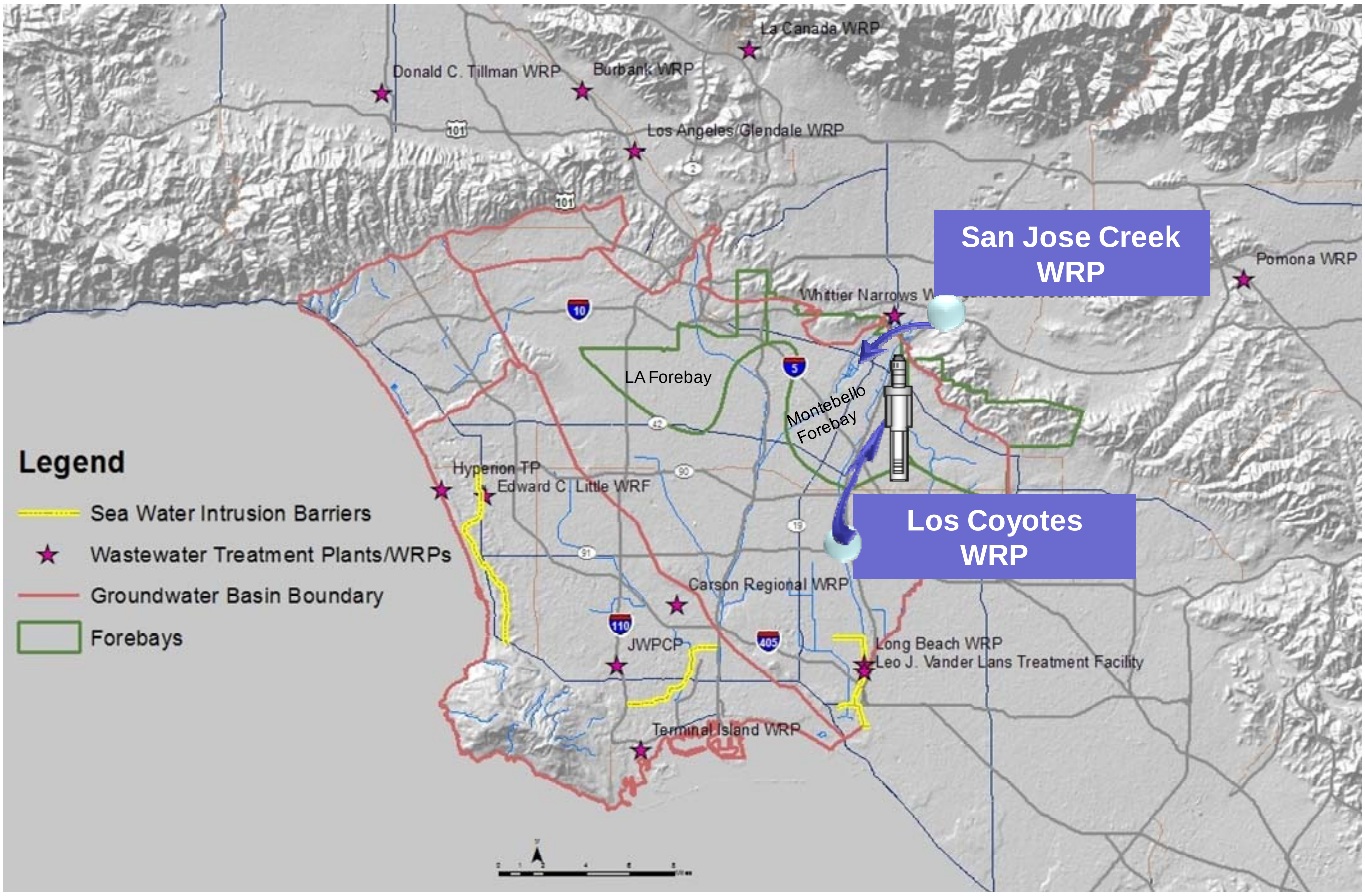
FIGURE 3-21
Conceptualization of Scenario CB-A2
Additional recycled water from both SJCWRP and LCWRP is spread at the Rio Hondo and San Gabriel Coastal Spreading Grounds.



3.3.3.3 Scenario CB–A3

Scenario A3 for the Central Basin (Scenario CB-A3) modifies Scenario CB-A2 by injecting recycled water from the LCWRP, as shown in Figure 3-22. The extraction pattern is identical to Scenario CB-A1 and Scenario CB-A2.

FIGURE 3-22
Conceptualization of Scenario CB-A3
Additional recycled water from SJCWRP is replenished at the MFSG and recycled water from LCWRP is injected at the MFSG.



3.3.3.4 Scenario CB–A4

Scenario A4 for the Central Basin (Scenario CB-A4) modifies Scenario CB-A1 by increasing the amount of stormwater that can be captured from the San Gabriel River and recharged in the MFSG, as shown in Figure 3-23. By increasing the pumping in the vicinity of the spreading grounds, groundwater levels are kept from rising to ground surface, thereby allowing additional stormwater replenishment. As mentioned in Section 3.1.1.4, MFROS has estimated that on average, approximately 17,000 AFY additional stormwater could be recharged with 25,000 AFY of additional pumping. Thus, Scenario CB-A4 assumes that 17,000 of the 31,000 AFY of additional replenishment required to satisfy pumping of the full APA in the Central Basin is provided by stormwater with implementation of the FIX-IT project, while the remaining 14,000 AFY of additional replenishment needed is provided by recycled water from the SJCWRP.

The extraction patterns for this scenario will be similar to Scenario CB-A1. However, the pumping for the City of Long Beach, Golden State Water Company, Paramount, and Santa Fe Springs will be shifted to the FIX-IT wellfield pumping as shown in Table 3-6, then delivered to these pumpers service areas by a conveyance system from the wellfield.

FIGURE 3-23
Conceptualization of Scenario CB-A4

Additional replenishment at MFSG includes 17,000 AFY of stormwater and 14,000 AFY of recycled water from the SJCWRP. 25,000 AFY of pumping near the MFSG keeps groundwater levels from rising above ground surface.

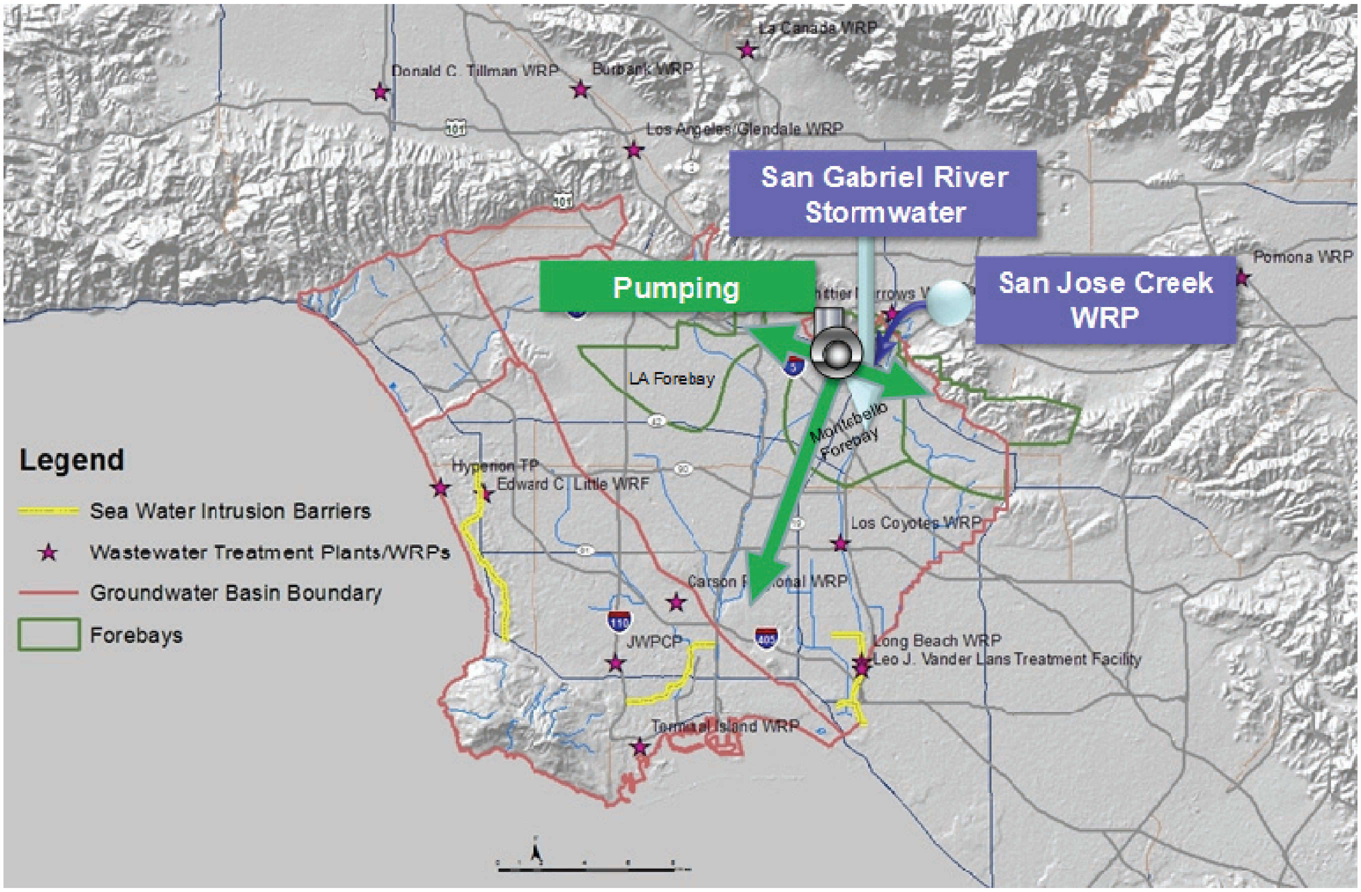


TABLE 3-6
Allowed Pumping Allocation Redistribution for Selected Pumpers

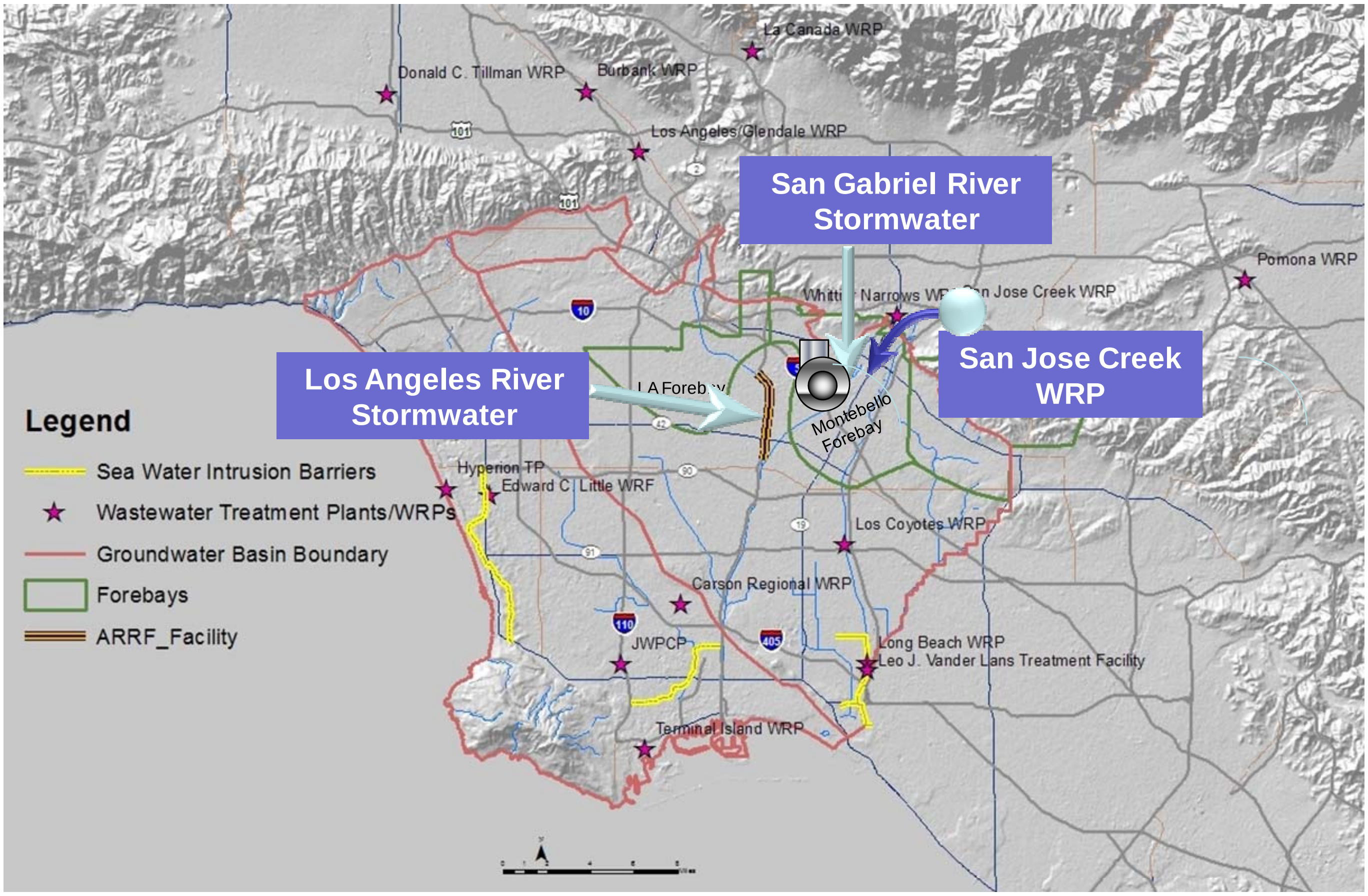
Pumper	Original Central Basin Baseline Pumping (AFY) (per Table 3-5)	Scenario CB-A4 Pumping (AFY)	Pumping Assigned to Montebello Forebay Extraction Wellfield (AFY)
Golden State Water Company	20,504	16,504	4,000
City of Long Beach	32,692	18,692	14,000
City of Paramount	5,883	1,883	4,000
City of Santa Fe Springs	4,700	1,700	3,000
Total	63,779	38,779	25,000

3.3.3.5 Scenario CB–A5

Scenario A5 for the Central Basin (Scenario CB-A5) modifies Scenario CB-A1 by increasing the amount of stormwater that can be captured from the Los Angeles River and recharged in the MFSG, as shown in Figure 3-24. As described, 5,000 AFY of stormwater from the Los Angeles River can be recharged in a Los Angeles River ARRF. The location of the ARRF facility is shown in Figure 3-24. To meet the 31,000 AFY total recharge volume, 26,000 AFY of recycled water from SJCWRP is assumed.

The specific extraction patterns for this scenario were identical to those in Scenario CB–A1.

FIGURE 3-24
Conceptualization of Scenario CB-A5
Additional Replenishment includes Spreading at MFSG with 26,000 AFY of Recycled Water from the SJCWRP and 5,000 AFY of Stormwater from the LA River ARRF Project.



3.3.4 Concept B Scenarios – Central Basin

The Concept B scenarios for the Central Basin were formulated so that the extraction is increased beyond the APA. Two scenarios under Concept B were identified for the Central Basin. They differed with respect to the total amount and locations of recharge and extraction as follows:

- Scenario CB-B1 – Increased recharge and pumping in both the Montebello and Los Angeles Forebays
- Scenario CB-B2 – Implementation of a new AWTF as well as increased recharge and pumping per Scenario CB-B1

Each of these Concept B scenarios assumes the following:

- Replenishment supply will be increased to allow pumping beyond the APA based on implementation of assumed recharge options.
- Pumping patterns will be similar to those of the past 10 years, and additional pumping is allocated to imported water users to ultimately replace nearly all imported water demand in the basin.

Modeling of Central Basin operations represented in these scenarios, in conjunction with West Coast Basin operations for the various GBMP alternatives, was conducted with the WRD/USGS updated and refined groundwater flow model, as described in Section 4.0. A description of the Concept B scenarios for the Central Basin is provided below.

3.3.4.1 Scenario CB-B1

As shown in Figure 3-25, Scenario B1 for the Central Basin (Scenario CB-B1) increases extraction by additional extraction above the APA from the Montebello Forebay.

The replenishment water to satisfy this increased pumping demand is provided by a combination of 17,000 AFY of increased stormwater capture from the San Gabriel River as well as capture and recharge of 5,000 AFY of stormwater from the Los Angeles River. In conjunction with replenishment of the maximum available recycled water from the SJCWRP and LCWRP (estimated at 89,550 AFY through a combination of spreading and injection), up to 57,770 above the APA (or a total of 57,770+217,367=275,137 AFY) would be available for pumping from the Central Basin.

This additional assumed pumping for analysis purposes was allocated as shown in Table 3-7.

FIGURE 3-25
Conceptualization of Scenario CB-B1
Maximizes Replenishment from San Gabriel River and Los Angeles River Stormwater and Spreading and Injection of Recycled Water from the SJCWRP and LCWRP to Provide Pumping of 57,770 AFY above the APA.

TABLE 3-7
Redistribution of Pumping for Maximizing Replenishment in the Montebello Forebay Area

Pumpers	Pumping from Montebello Forebay Extraction Wellfield (AFY)
Golden State Water Company	6,770
Park Water Company	9,000
City of Santa Fe Springs	3,300
City of Paramount	2,000
Cal Water Service Company	4,700
City of Long Beach	30,000
City of Compton	2,000
Total	57,770

3.3.4.2 Scenario CB-B2

As shown in Figure 3-26, Scenario B2 for the Central Basin (Scenario CB-B2) builds off of Scenario CB-B1 with additional injection and extraction in the Los Angeles Forebay. Under this scenario, additional replenishment supply would come from a new AWTF, identified in the City of Los Angeles' Recycled Water Master Plan, that would skim wastewater from a major sewer trunk line otherwise destined for the HTP. The assumed capacity of this new AWTF is 40.6 mgd, or 45,480 AFY. Thus, Scenario CB-B2 provides for a total of 45,480+57,770 = 103,250 AFY of additional pumping beyond the APA, or a total basin pumping of 103,250+217,367=320,617 AFY, as shown in Figure 3-27. Such utilization of the groundwater basin can offset nearly all of the area's imported water demands above the Central Basin.

This additional assumed pumping for analysis purposes was allocated as shown in Table 3-8. As noted, most of this additional pumping is assumed to take place within the individual pumpers' service areas, with the exception of the City of Los Angeles, which would pump from a new wellfield in the Los Angeles Forebay.

FIGURE 3-26
Conceptualization of Scenario B2 in the Central Basin

Addition of 45,480 AFY Recycled Water Recharge in LA Forebay in Combination with Montebello Forebay Facilities Allows for Increased Pumping to 103,250 AFY above the APA.

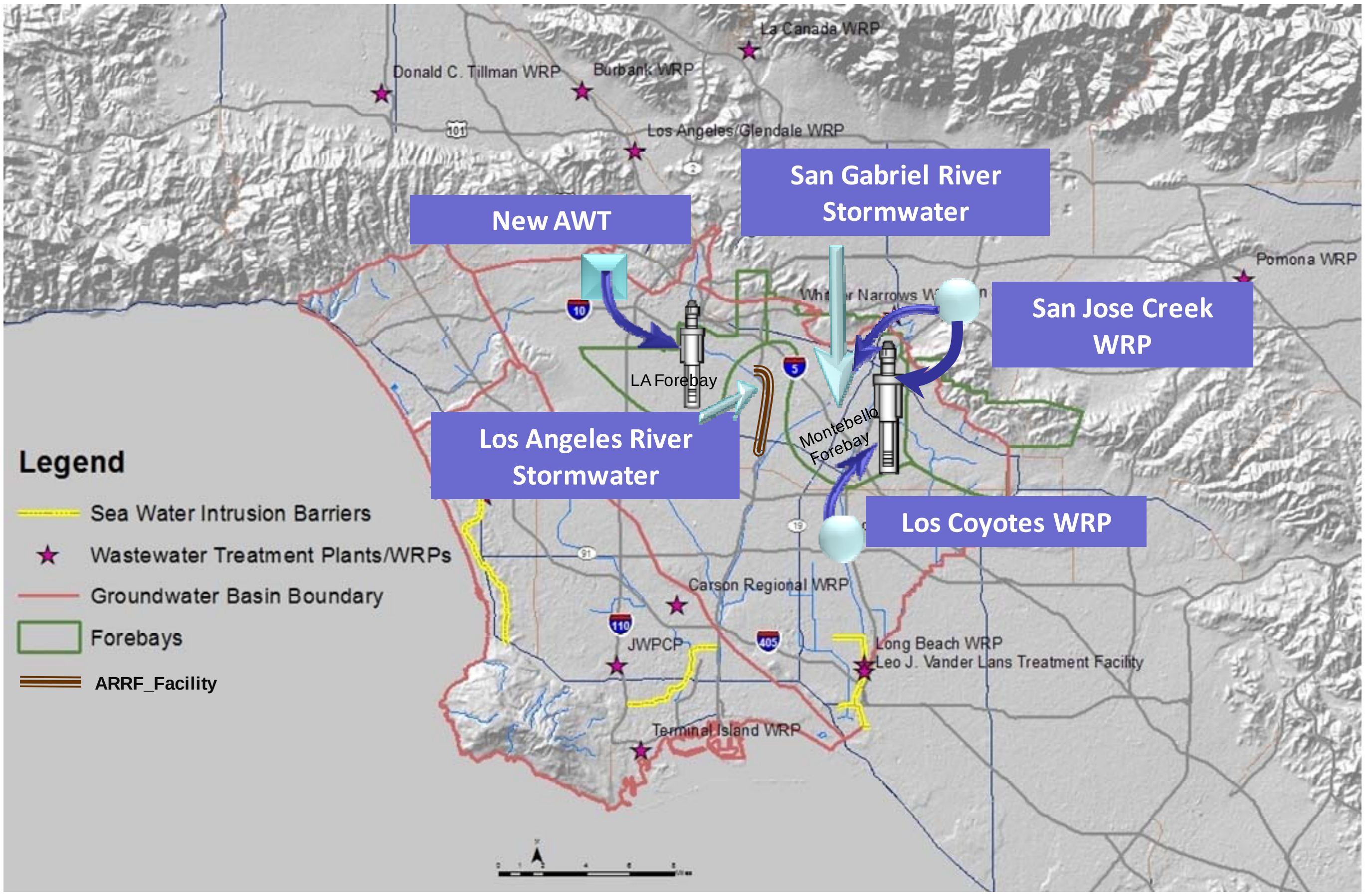
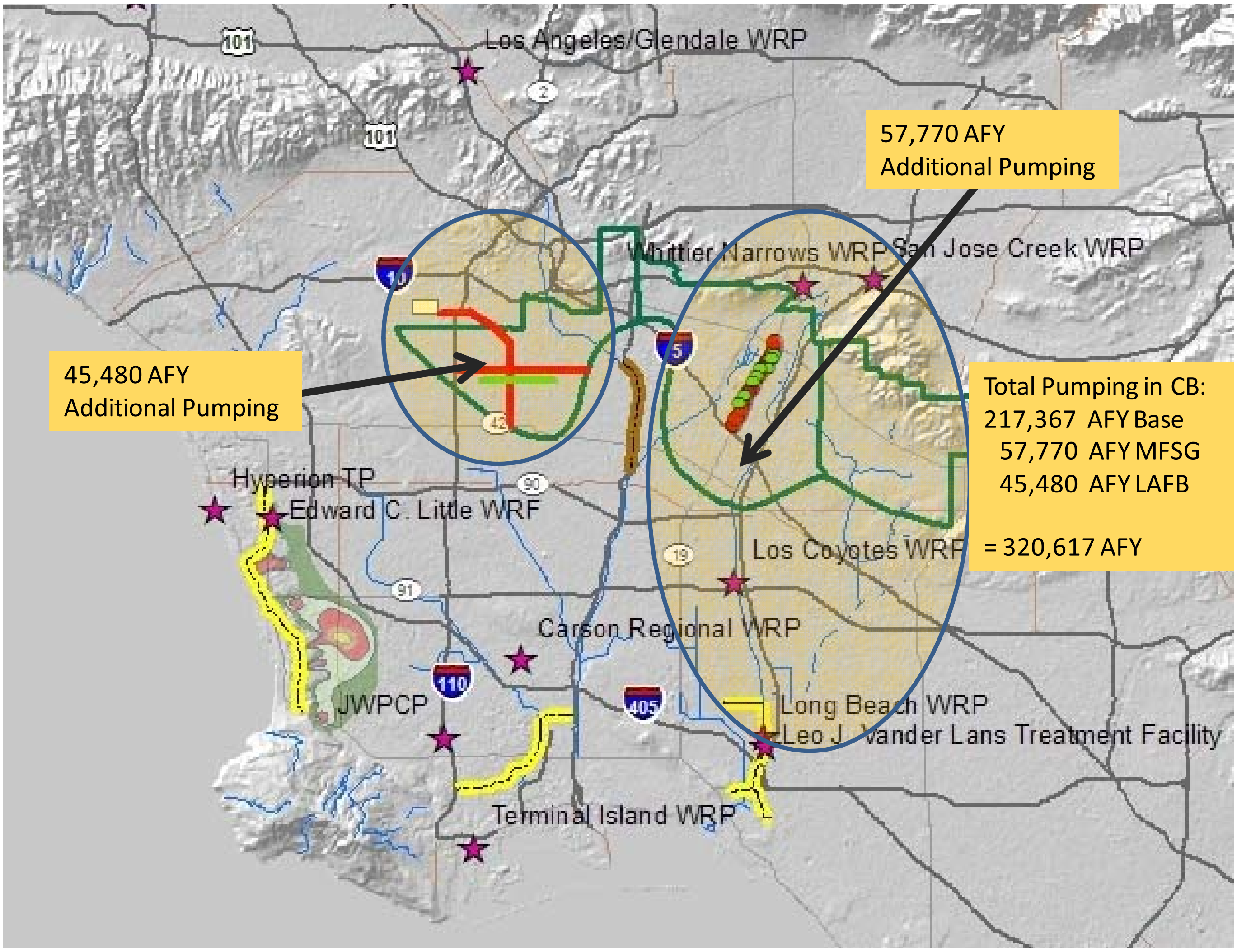


FIGURE 3-27
Total Pumping under Scenario CB-B2

Pumpers Increase Pumping in their Service Areas, plus 25,000 AFY of Pumping in Montebello Forebay and 29,000 AFY of Pumping in New Wellfield in Los Angeles Forebay Provides for 320,617 AFY of Total Pumping.



57,770 AFY
Additional Pumping

45,480 AFY
Additional Pumping

Total Pumping in CB:
217,367 AFY Base
57,770 AFY MFSG
45,480 AFY LAFB

= 320,617 AFY

Note:

LAFB = Los Angeles Forebay

TABLE 3-8
Redistribution of Pumping to Pumpers in the Central Basin for Maximizing Replenishment in the Montebello Forebay and Los Angeles Forebay Areas

Pumper	Total New Extraction (AFY)	Pumping from Montebello Forebay Extraction Wellfield (AFY)	Other	
			Assigned Additional Pumping (AFY)	Geographic Location
Golden State Water Company	6,770	6,770	0	
Park Water Company	9,000	9,000	0	
City of Santa Fe Springs	3,300	3,300	0	
City of Paramount	2,000	2,000	0	
Cal Water Service Company	12,500	4,700	7,800	Within pumper's service area
City of Long Beach	30,000	30,000	0	

TABLE 3-8
Redistribution of Pumping to Pumpers in the Central Basin for Maximizing Replenishment in the Montebello Forebay and Los Angeles Forebay Areas

Pumper	Total New Extraction (AFY)	Pumping from Montebello Forebay Extraction Wellfield (AFY)	Other	
			Assigned Additional Pumping (AFY)	Geographic Location
City of Compton	2,200	2,000	200	Within pumper's service area
City of Los Angeles	29,000		29,000	From the LA Forebay
City of Cerritos	300		300	Within pumper's service area
City of Vernon	1,150		1,150	Within pumper's service area
Bellflower Somerset Mutual Water Company	2,000		2,000	Within pumper's service area
City of Huntington Park	1,400		1,400	Within pumper's service area
La Habra Heights County Water District	800		800	Within pumper's service area
Suburban Water Systems	330		330	Within pumper's service area
City of Signal Hill	100		100	Within pumper's service area
City of Bell Gardens	500		500	Within pumper's service area
City of Norwalk	800		800	Within pumper's service area
City of Montebello	1,100		1,100	Within pumper's service area
Total	103,250	57,770	45,480	

3.4 Summary of the West Coast and Central Basin Scenarios

The GBMP planning scenarios established the hydraulic boundaries for basin utilization that were subsequently evaluated with the WRD/USGS updated and refined groundwater flow model. These scenarios were structured according to the initial conceptual options defined early in the planning process—Concept A (pump up to water rights in the West Coast Basin and up to the APA in the Central Basin) and Concept B (pump above the water rights and APA).

Scenarios were formulated for each basin to satisfy these conceptual options. Each scenario was constructed using combinations of supply, recharge and pumping components. Consideration of supply options (that is, recycled water sources in the West Coast Basin and combinations of recycled water and stormwater in the Central Basin) informed the range of scenarios that would be evaluated hydraulically to assess groundwater basin impacts.

Table 3-9 summarizes the GBMP planning scenarios presented in this section for both the basins. Combinations of the Central Basin and West Coast Basin Concept A and B scenarios were used for groundwater modeling of the interconnected basins, as described in Section 4.0. Viable scenarios were then further defined as distinct alternatives with specific supply sources and associated treatment, conveyance, recharge, and extraction for economic evaluation, described in Section 5.0.

TABLE 3-9
Summary of GBMP Planning Scenarios for the West Coast and Central Basins

Basin	Concept	Scenario	Description (Pumping/Replenishment)
West Coast Basin	A (Meet Water Rights)	Scenario WCB-A1	Pump full water rights by assumed distribution of additional pumping per three scenarios: WCB-A1a, WCB-A1b, WCB-A1c; Shift oil companies' non-potable demands from groundwater to recycled water and shift this groundwater pumping to municipal purveyors; Assume 100 percent RWC at injection barriers (WCBBP and DGBP)
		Scenario WCB-A1a	Distribute to Major Water Rights Holders (Torrance, CWSC, Golden State Water Company, Manhattan Beach, El Segundo, Inglewood, and Lomita) and City of Los Angeles Extracts their Adjudicated Rights
		Scenario WCB-A1b	Distribute to Major Water Rights Holders and to the City of Los Angeles
		Scenario WCB- A1c	Regional Partnership – Includes **remediation of saline plume** and minimizing impacts to barriers
		Scenario WCB-A2	Reduce or eliminate injection in Lower San Pedro aquifer by balancing pumping in Silverado aquifer
		Scenario WCB-A3	Inject surplus imported water only when available (2 out of 10 years) and reduce or eliminate injection into Lower San Pedro aquifer during the remaining (8) years
		Scenario WCB-A4	Pump and treat from Lower San Pedro aquifer
	B (Above Water Rights)	Scenario WCB-B1	Pump additional **30,000 AFY above water rights** by assumed distribution to CWSC, City of Torrance, and City of Los Angeles Increase injection at DGBP, WCBBP, and using new inland injection wells (assuming 100 percent RWC); Includes remediation of saline plume and pumping pattern Scenario WCB-A1c
Central Basin	A (Meet APA)	Scenario CB-A1	Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with high imported water usage; Assume 100 percent RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP** effluent for **spreading** at the MFSG*
		Scenario CB-A2	Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with high imported water usage; Assume 100 percent RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP and LCWRP** effluent for **spreading** at MFSG*
		Scenario CB-A3	Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with high imported water usage; Assume 100 percent RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP** effluent for **spreading** at MFSG and **LCWRP** FAT-treated effluent for **injection** in Montebello Forebay.*
		Scenario CB-A4	Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with high imported water usage;

TABLE 3-9
Summary of GBMP Planning Scenarios for the West Coast and Central Basins

Basin	Concept	Scenario	Description (Pumping/Replenishment)
			Assume 100 percent RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP** effluent for **spreading** at MFSG and **enhanced stormwater capture in Montebello Forebay.***
		Scenario CB-A5	Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with high imported water usage; Assume 100 percent RWC at injection barrier (ABP); *Increase replenishment by a total of 31,000 AFY using **SJCWRP** effluent for **spreading** 26,000 AFY at MFSG and **stormwater capture of 5,000 AFY in LAF***
	B (Above APA)	Scenario CB-B1	Maximizing use of stormwater capture from S**an Gabriel and Los Angeles Rivers** (22,000 AFY) and available recycled water from **SJCWRP and LCWRP** (66,770 AFY) in the Montebello Forebay allows for increased pumping of **57,770 AFY above the APA**
		Scenario CB-B2	Injection of 45,480 AFY of FAT-treated effluent from **new satellite AWTF** at new line of extraction wells in Los Angeles Forebay, in conjunction with maximizing stormwater capture and recycled water use (per Scenario CB-B1) allows for increased pumping in the Montebello and Los Angeles Forebays to a total of **103,270 AFY above the APA**

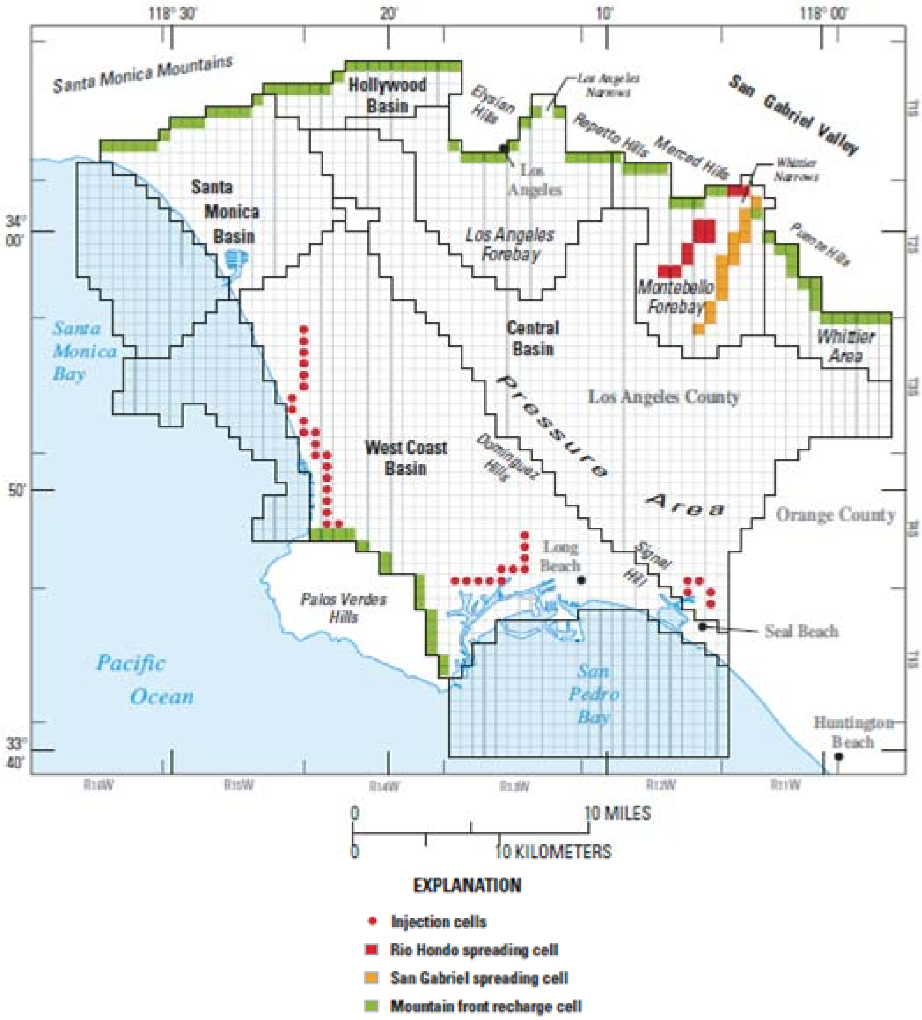
SECTION 4.0

Groundwater Modeling Assessments of Basin Operating Conditions

This section presents an update of the WRD/USGS groundwater flow model of the West Coast and Central Basins and application of this model to assess the various GBMP planning scenarios described in Section 3.0. WRD/USGS developed a groundwater simulation model of the Los Angeles Coastal Basin, including the West Coast and Central Basins, to serve as a tool to evaluate alternative groundwater management strategies. The model, which uses the USGS MODFLOW program (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996), is described in detail by the USGS (2003). Following is a brief summary of the features of the model:

- The extents of the model are shown in Figure 4-1, which covers the entire Los Angeles County portion of the Los Angeles Coastal Basin, including offshore extensions of the basins' aquifers.
- The grid consists of a uniform finite-difference grid (three-dimensional grid blocks), with each cell 0.5 miles by 0.5 miles on a side. The grid and boundaries of the model are shown in Figure 4-1.
- The hydrogeology, including variations in hydrogeologic properties (such as storage and transmissivity) of the West Coast and Central Basins are represented by four layers (from top to bottom), including the following aquifers as identified by the California Department of Water Resources (1961):
  - **Layer 1** – Semiperched and Gaspur aquifers
  - **Layer 2** – Ballona, Exposition, Artesia, and Gardena, Gage, and 200-Foot Sand aquifers
  - **Layer 3** – Hollydale, Jefferson, Lynwood, 400-Foot Gravel, and Silverado aquifers, which are the principal aquifers tapped by production wells in the West Coast and Central Basins
  - **Layer 4** – Sunnyside and Lower San Pedro aquifers
- Faults throughout the basin, such as the Newport-Inglewood Fault zone, are represented using the hydraulic flow barrier package, which acts to impede movement of groundwater flow across these faults.
- Boundary conditions include the following:
  - Constant heads, or constant groundwater levels, are used to represent inflow from the San Fernando Valley Basin through the Los Angeles Narrows, inflow from the Main San Gabriel Basin through Whittier Narrows and movement of water between the Orange County Groundwater Basin and Central Basin. Values of heads are constant for the Los Angeles and Whittier Narrows, but vary based on actual observed historical groundwater levels along the boundary with Orange County.
  - General head boundaries where aquifers are in contact with the Pacific Ocean, which also accounts for the density differences in freshwater and heavier ocean water.
  - Mountain Front (groundwater entering from the surrounding hills and mountains) and interior recharge (areal recharge over the surface of the basins) from precipitation and applied water, which varies based on precipitation at the Downey precipitation station (USGS, 2003).
- Recharge and discharge stresses including stormwater, recycled water, and imported water diverted to the spreading grounds in the MFSG, injection of imported water and advanced treated recycled water at the three injection barriers (ABP, WCBBP, and DGBP), and pumping by basin pumpers.
- Simulation period covers water years 1971 (October 1, 1970, through September 30, 1971) through 2000. The stress periods are for a full year (meaning all water budget terms are averaged over an entire year) resulting in 30 stress periods.

FIGURE 4-1
WRD/USGS Groundwater Flow Model – Grid and Boundary Conditions (USGS, 2003)



The WRD/USGS groundwater flow model was updated through water year 2010 as a part of this study, then used to project groundwater levels and storage conditions for various operating conditions in the West Coast and Central Basins over a 40-year period of water years 2011 through 2050, as described below.

4.1 Update of WRD/USGS Groundwater Flow Model (through Water Year 2010)

The WRD/USGS groundwater flow model was updated as a part of this study in order to use it to assess alternative operating conditions in the West Coast and Central Basins. The MODFLOW data sets were imported into Groundwater Vistas (GWV) offered by Environmental Simulations Inc. (www.groundwatermodels.com). GWV is a groundwater modeling environment that couples a model design system with graphical analysis tools. Model inputs and results can be exported for use in other programs, such as Microsoft Excel or ESRI, Inc., Geographical Information System (GIS) software. GWV was used, along with standard database tools, to update the WRD/USGS groundwater flow model through water year 2010.

The model update includes extending four principal stresses (recharge and discharge) and one boundary condition (refer to Figure 4-1 for locations of these stresses):

- Mountain front and interior recharge
- Recharge of stormwater, imported water, and recycled water at the MFSG

- Injection of imported water and advanced treated recycled water into the three injection barriers
- Inclusion of additional production wells installed since 2000 and pumping
- Constant heads along the Orange County boundary

Each of these stresses was updated for water years 2001 through 2010, which was the extent of available data for most of these data sets. The updated WRD/USGS groundwater flow model was run to create groundwater-level conditions at the end of water year 2010, which were used as the initial condition for subsequent modeling simulations.

4.1.1 Mountain Front and Interior Recharge

The USGS uses simple formulae to compute mountain front and interior recharge. The model area was broken into zones, and recharge values were estimated for each zone during calibration of a steady-state model. The transient recharge was estimated by multiplying the steady-state recharge values by a normalized precipitation value for a given year. LACDPW precipitation station 107D, located in Downey, was used as an indicator station of precipitation over the model area (USGS, 2003).

Precipitation data for the period 2000 through 2010 were obtained for station 107D from LACDPW to update mountain front and interior recharge over the modeled area using the approach described by USGS (2003). Table 4-1 shows the estimated mountain front and interior recharge applied to the model for the entire period of simulation for water years 1971 through 2010, which includes the updates for the last 10 years. This recharge was applied according to the zonal distribution as described by the USGS (2003).

4.1.2 Recharge of Stormwater, Imported Water, and Recycled Water at the MFSG

LACDPW monitors the source of water supplies and locations of recharge at the MFSG. Sources of supplies include stormwater, imported water from Metropolitan, and recycled water. Recycled water includes wastewater of tertiary quality from the Whittier Narrows WRP, Pomona WRP, and SJCWRP, all owned and operated by LACSD. Managed aquifer recharge occurs at the Whittier Narrows Dam, Rio Hondo Spreading Basins, and San Gabriel Coastal Spreading Basins, which includes unlined sections of the San Gabriel River. These data are reported to WRD. The San Gabriel River Watermaster also reports water conserved at the MFSG. The USGS (2003) used those data reported by the San Gabriel River Watermaster in their groundwater model simulations. Subsequent to the USGS (2003) published report, WRD reviewed those data reported by LACDPW and determined that these data should be used as the recharge quantities in this study (WRD, 2012).

Table 4-1 provides the reported quantities of water recharged at the MFSG, including an update through water year 2010 and a comparison of the 1971 through 2000 quantities as used in the original WRD/USGS groundwater flow model. On average, the updated recharge values are approximately 5,000 AFY more than those values used in the original WRD/USGS groundwater model. These recharge quantities were applied to the appropriate spreading basin as represented in the groundwater flow model.

4.1.3 Injection Barrier Operations

Two steps were required to update injection barrier operations since 2000. The first step was to assign injection to model layers corresponding to injection well screened intervals, and the second step was to update injection quantities through water year 2010. The original WRD/USGS model files contain the combined injection rates for all injection wells in a given model grid cell; and not for the individual injection well. To determine the grid and layer(s) for each injection well, the locations of each injection well were overlain on the model grid. The layer assignment was determined by comparing the screened interval of the injection well with the top and bottom layer elevations of the model layers at the location of the injection well. Flow from an injection well was partitioned to each layer penetrated by the screen interval based on a transmissivity-weighted value as was done for the original WRD/USGS model. So, a percentage of a given injection well flow was assigned to each model layer based on this transmissivity-weighted flow value.

WRD and LACDPW provided data on injection by well for all three seawater intrusion barriers. Table 4-2 shows the annual injection quantities to each barrier simulated for the period water years 2000 through 2010.

TABLE 4-1
Annual Precipitation at LACDPW Downey Station 107D, Mountain Front and Interior Recharge, and MFSG Spreading

Water Year	Precipitation (inches)	Normalized Precipitation	WRD/USGS Model Mountain Front and Interior Recharge (AFY)	Updated Mountain Front and Interior Recharge (AFY)	WRD/USGS Model Spreading Data (AFY)	Updated Spreading (AFY)
1971	11.46	1.00	64,400	64,345	121,700	126,629
1972	6.40	0.56	36,100	35,192	62,900	64,369
1973	18.63	1.63	83,700	83,236	147,100	146,769
1974	14.55	1.27	81,800	80,985	123,900	129,254
1975	15.01	1.31	83,700	83,236	105,700	117,283
1976	9.58	0.84	54,100	53,460	81,900	80,383
1977	11.24	0.98	63,100	62,562	69,900	65,229
1978	33.86	2.95	83,700	83,236	170,700	199,184
1979	18.69	1.63	83,700	83,236	151,800	144,277
1980	28.29	2.47	83,700	83,236	137,100	149,391
1981	8.74	0.76	48,900	48,638	128,400	134,923
1982	13.41	1.17	75,300	74,356	110,100	107,774
1983	30.32	2.65	83,700	83,236	165,200	150,869
1984	11.99	1.05	67,600	67,048	114,500	108,766
1985	12.45	1.09	70,200	69,530	110,200	103,491
1986	19.47	1.70	83,700	83,236	117,400	110,323
1987	6.49	0.57	36,700	35,501	101,000	117,273
1988	11.47	1.00	64,400	64,365	100,300	114,100
1989	7.82	0.68	43,800	43,810	123,900	110,621
1990	7.87	0.69	44,400	44,030	132,700	124,900
1991	12.22	1.07	68,900	67,618	138,700	144,659
1992	16.07	1.40	83,700	83,236	152,800	224,891
1993	26.56	2.23	83,700	83,236	174,500	211,649
1994	9.26	0.81	52,200	51,210	113,600	129,385
1995	26.17	2.28	83,700	83,236	151,700	154,235
1996	10.68	0.93	59,900	59,870	130,500	133,694
1997	13.95	1.22	78,600	78,400	128,300	126,833
1998	32.45	2.83	83,700	83,236	133,200	133,840
1999	7.29	0.64	41,200	39,986	80,400	78,801
2000	9.21	0.80	51,500	51,001	108,900	108,400
2001	15.6	1.36		83,236		108,042
2002	2.8	0.24		14,486		120,212

TABLE 4-1
Annual Precipitation at LACDPW Downey Station 107D, Mountain Front and Interior Recharge, and MFSG Spreading

Water Year	Precipitation (inches)	Normalized Precipitation	WRD/USGS Model Mountain Front and Interior Recharge (AFY)	Updated Mountain Front and Interior Recharge (AFY)	WRD/USGS Model Spreading Data (AFY)	Updated Spreading (AFY)
2003	16.93	1.48	-	83,236	-	121,884
2004	9.37	0.82	-	51,560	-	101,987
2005	24.86	2.17	-	83,236	-	201,840
2006	11.36	0.99	-	62,803	-	134,507
2007	2.85	0.25	-	16,180	-	96,458
2008	17.11	1.49	-	83,236	-	94,322
2009	9.49	0.83	-	53,132	-	74,021
2010	13.02	1.14	-	72,225	-	116,120`

TABLE 4-2
Injection Values for Seawater Intrusion Barriers

Water Year	Dominguez Gap (AFY)	West Coast Basin (AFY)	Alamitos Barrier (AFY)	Total Injection (AFY)
1971	-	-	-	36,200
1972	-	-	-	41,000
1973	-	-	-	41,800
1974	-	-	-	42,700
1975	-	-	-	36,900
1976	-	-	-	44,800
1977	-	-	-	49,300
1978	-	-	-	40,200
1979	-	-	-	34,500
1980	-	-	-	37,200
1981	-	-	-	34,400
1982	-	-	-	34,300
1983	-	-	-	45,200
1984	-	-	-	39,500
1985	-	-	-	37,500
1986	-	-	-	31,700
1987	-	-	-	39,400
1988	-	-	-	37,500
1989	-	-	-	33,500

TABLE 4-2
Injection Values for Seawater Intrusion Barriers

Water Year	Dominguez Gap (AFY)	West Coast Basin (AFY)	Alamitos Barrier (AFY)	Total Injection (AFY)
1990	-	-	-	32,100
1991	-	-	-	29,700
1992	-	-	-	34,800
1993	-	-	-	31,300
1994	-	-	-	25,100
1995	-	-	-	23,200
1996	-	-	-	23,300
1997	-	-	-	29,300
1998	-	-	-	25,400
1999	-	-	-	27,300
2000	-	-	-	30,400
2001	4,203	20,518	5,837	30,558
2002	5,178	17,954	5,368	28,500
2003	6,752	13,513	5,206	25,471
2004	6,151	10,711	4,973	21,834
2005	6,613	7,540	4,929	19,082
2006	4,745	10,088	4,845	19,678
2007	3,822	14,875	4,688	23,385
2008	4,913	14,050	4,570	23,533
2009	4,706	13,624	4,447	22,777
2010	1,304	21,046	4,332	26,682

4.1.4 Groundwater Production

WRD maintains information on wells and groundwater production records for the West Coast and Central Basins. These data were obtained to update the groundwater flow model through water year 2010. Sixty-six new wells were installed in the basins since 2000, as shown in Figure 4-2. Grid and proportional assignment of flow rates to each layer of the model was done using the same procedure used for the injection wells. Groundwater production by basin is shown in Table 4-3.

FIGURE 4-2
Location of New Extraction Wells Installed Since 2000 Location of New Extraction Wells Installed Since 2000

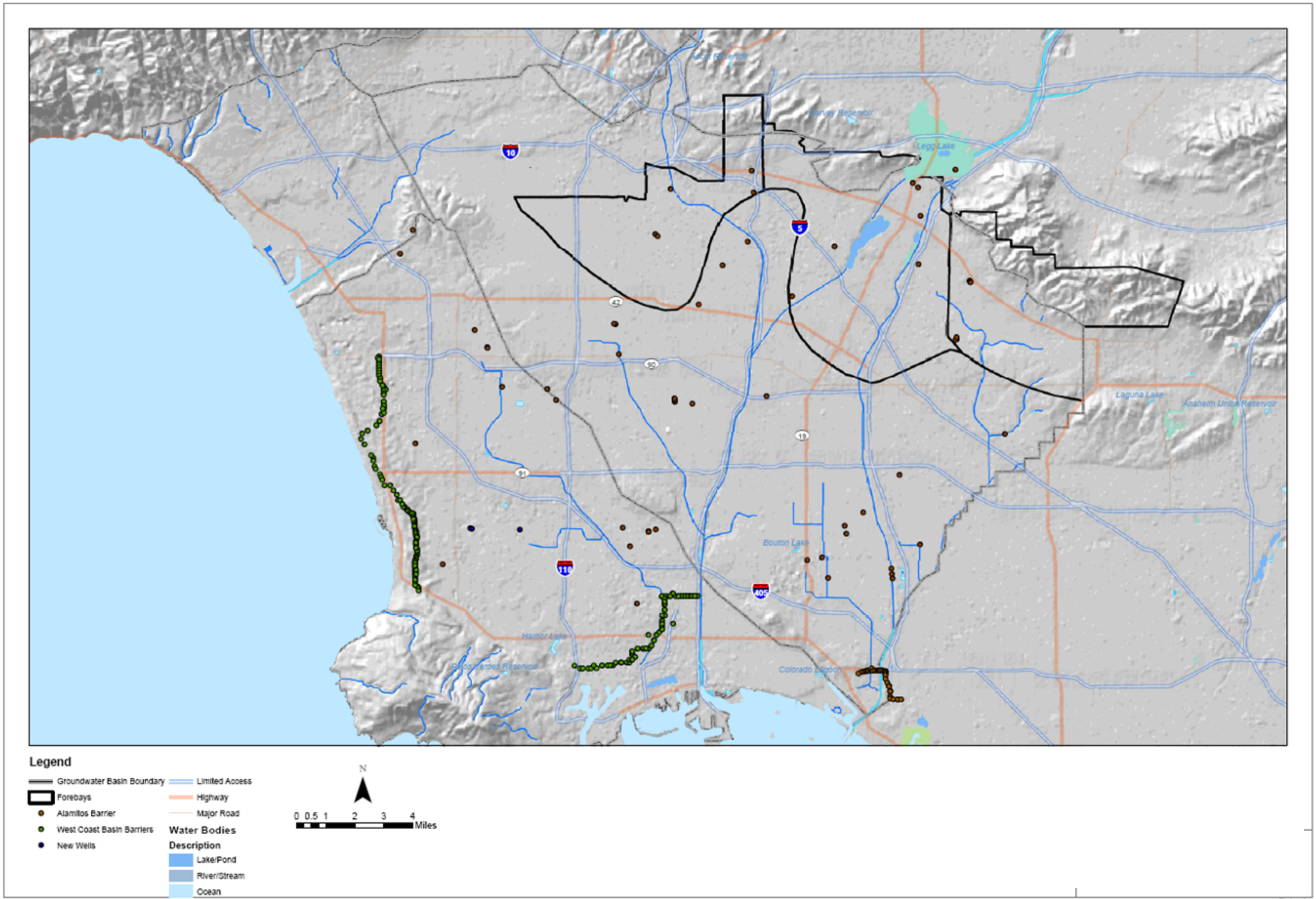


TABLE 4-3
Pumping for the West Coast and Central Basins

Water Year	West Coast Basin (AFY)	Central Basin (AFY)	Total Pumping (AFY)
1971	-	-	186,730
1972	-	-	184,108
1973	-	-	189,888
1974	-	-	192,591
1975	-	-	197,758
1976	-	-	191,636
1977	-	-	184,811
1978	-	-	202,135
1979	-	-	205,185
1980	-	-	213,092
1981	-	-	221,639
1982	-	-	209,611
1983	-	-	202,484
1984	-	-	204,487
1985	-	-	213,123
1986	-	-	204,228
1987	-	-	201,936
1988	-	-	210,111
1989	-	-	204,962
1990	-	-	209,815
1991	-	-	222,783
1992	-	-	188,200
1993	-	-	146,381
1994	-	-	196,542
1995	-	-	204,948
1996	-	-	233,545
1997	-	-	237,178
1998	-	-	252,241
1999	-	-	247,416
2000	53,087	194,946	248,034
2001	53,962	195,361	249,323
2002	50,155	200,168	250,323
2003	51,754	190,268	242,022

TABLE 4-3
Pumping for the West Coast and Central Basins

Water Year	West Coast Basin (AFY)	Central Basin (AFY)	Total Pumping (AFY)
2004	47,775	200,365	248,140
2005	41,143	188,783	229,926
2006	36,642	191,123	227,764
2007	37,484	198,249	235,732
2008	38,304	206,296	244,600
2009	45,367	197,163	242,530
2010	43,906	197,386	241,291

4.1.5 Boundary with Orange County Groundwater Basin

The modeled groundwater flow boundary with the Orange County Groundwater Basin is simulated as a constant head boundary, using fixed groundwater levels based on observed historical groundwater levels as contoured from observation wells along this boundary. OCWD compiles groundwater levels throughout the Orange County Groundwater Basin and prepares groundwater level contour maps for each of the principal aquifers in the basin. These annual contour maps (2000 through 2010) were obtained from OCWD and used to assign groundwater levels to constant head grid cells of the three layers simulated along the boundary (see Figure 4-1 for location of constant head boundary grid cells). Appendix G contains the maps provided by OCWD.

4.1.6 Simulation Update Results Through Water Year 2010

Figure 4-3 shows simulated groundwater levels at the end of water year 2010 for all four layers represented in the model. Figure 4-4 shows hydrographs for selected locations in the West Coast and Central Basins for the historical period of water years 1971 through 2010. Additional groundwater level contour maps and hydrographs for more locations are provided in Appendix H. Generally, groundwater levels in the Central Basin were relatively stable from 2000 through 2004, rose somewhat in response to wetter than normal conditions in 2005, then declined in response to drier than normal conditions through the end of the simulation. Groundwater levels in the West Coast Basin are generally steady to slightly rising over the simulation period.

Figure 4-5 shows a summary of average groundwater fluxes by zone throughout the modeled area over the period of simulation (water years 1971 through 2010). These fluxes show flow between 10 zones that were used in the original WRD/USGS groundwater flow model discussed below.

The groundwater levels in each layer at the end of water year 2010 were used as the starting groundwater levels for each of the simulations of the alternative basin operational conditions.

4.2 Simulation of Groundwater Basins Master Plan Planning Scenarios

The updated WRD/USGS groundwater flow model was used to evaluate a number of alternative basin operating conditions represented by the GBMP planning scenarios for both the West Coast and Central Basins presented in Section 3.0. These alternative operating conditions included scenarios in which the basins are pumped within the APA of the Central Basin and adjudicated water rights of the West Coast Basin (Concept A scenarios) and scenarios where the Central Basin is pumped above the APA and West Coast Basin is pumped above water rights (Concept B scenarios), with variations in sources of replenishment supplies. These scenarios can provide insights into how the groundwater basins would respond to management actions that might be implemented under various recharge programs.

The forecast period for modeled scenarios was 2011 through 2050. The model was used to simulate groundwater levels and cumulative groundwater storage in the groundwater basins in response to changes in water replenishment and pumping conditions. The simulation conditions included combinations of operating conditions wherein one basin is pumped within or above its APA/water rights, while the other basin is being pumped within or above its APA/water rights.

4.2.1 Modeling Combinations

Provided below is a summary of the combinations developed under each of the operating conditions in both the basins that were used for model simulations. The operating conditions for each of the scenarios used for developing the modeling combinations are discussed in Section 3.0.

4.2.1.1 APA-Central Basin and Water Rights-West Coast Basin

The following combinations were modeled with pumping at APA levels in the Central Basin and at water rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions.

- **Combination 1:** This is a baseline model run using the updated model for a 40-year forecast period using the APA of 217,367 AFY in the Central Basin and water rights of 64,468 AFY in the West Coast Basin. This represents a combination of GBMP Scenarios WCB–A1a and CB–A1 for the two basins. The conditions used in this combination serve as the baseline condition that was used as a starting point for subsequent model run combinations. Generally, pumping is assigned to each pumper according to their adjudicated rights (see Table 3-5). Replenishment to support this pumping is provided at the existing seawater intrusion barriers and spreading grounds.
- **Combination 2:** In this combination, the APA of 217,367 AFY is pumped in the Central Basin and water rights of 64,468 AFY are pumped in the West Coast Basin. This represents a combination of GBMP Scenarios WCB-A1a and CB-A4. Total pumping for this combination is identical to Combination 1. However, 25,000 AFY of pumping by the City of Long Beach, Golden State Water Company, City of Paramount, and City of Santa Fe Springs is shifted from their current well locations to the Montebello Forebay. Replenishment at the spreading grounds is thereby enhanced by this pumping shift allowing for additional stormwater recharge of 17,000 AFY and reducing the recycled water used for recharge.
- **Combination 3:** In this combination, the APA of 217,367 AFY is pumped in the Central Basin and water rights of 64,468 AFY are pumped in the West Coast Basin. This represents a combination of GBMP Scenarios WCB-A1c and CB–A1. For this combination, pumping in the West Coast Basin is redistributed with the goal of containing/removing saline plume in Silverado aquifer. 15,000 AFY is extracted from the Silverado aquifer for desalting. Pumping for three pumpers (CWSC, City of Torrance, and City of Los Angeles) is shifted from their current well locations to the saline plume. Recharge for the West Coast Basin is the same as in Combination 1. Pumping and recharge for the Central Basin are also the same as in Combination 1.

FIGURE 4-3
Groundwater Level Contours for Historical Conditions at the end of the Simulation Period (September 30, 2010)

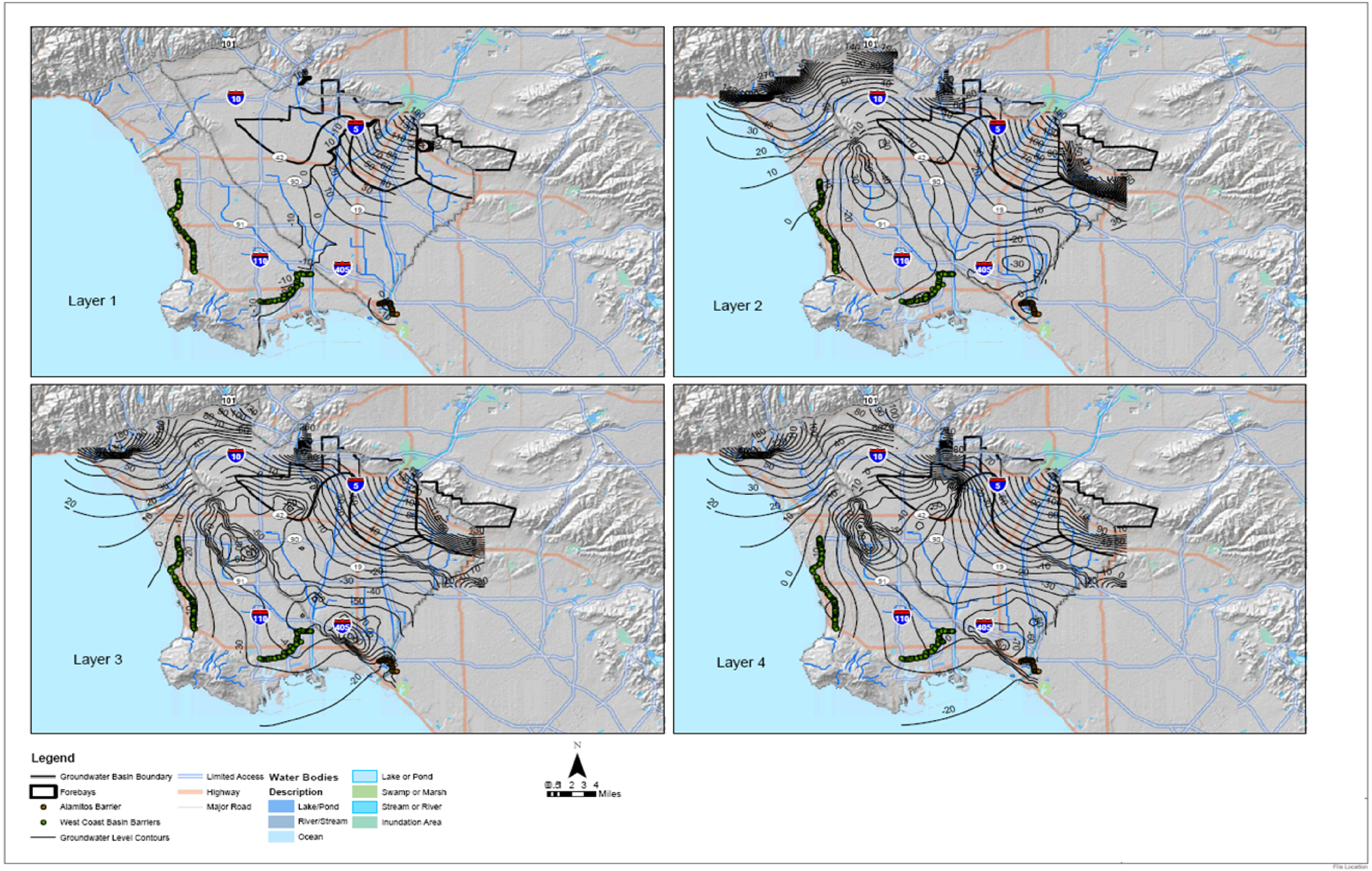


FIGURE 4-4
Selected Hydrographs Showing Simulated Historical Groundwater Levels

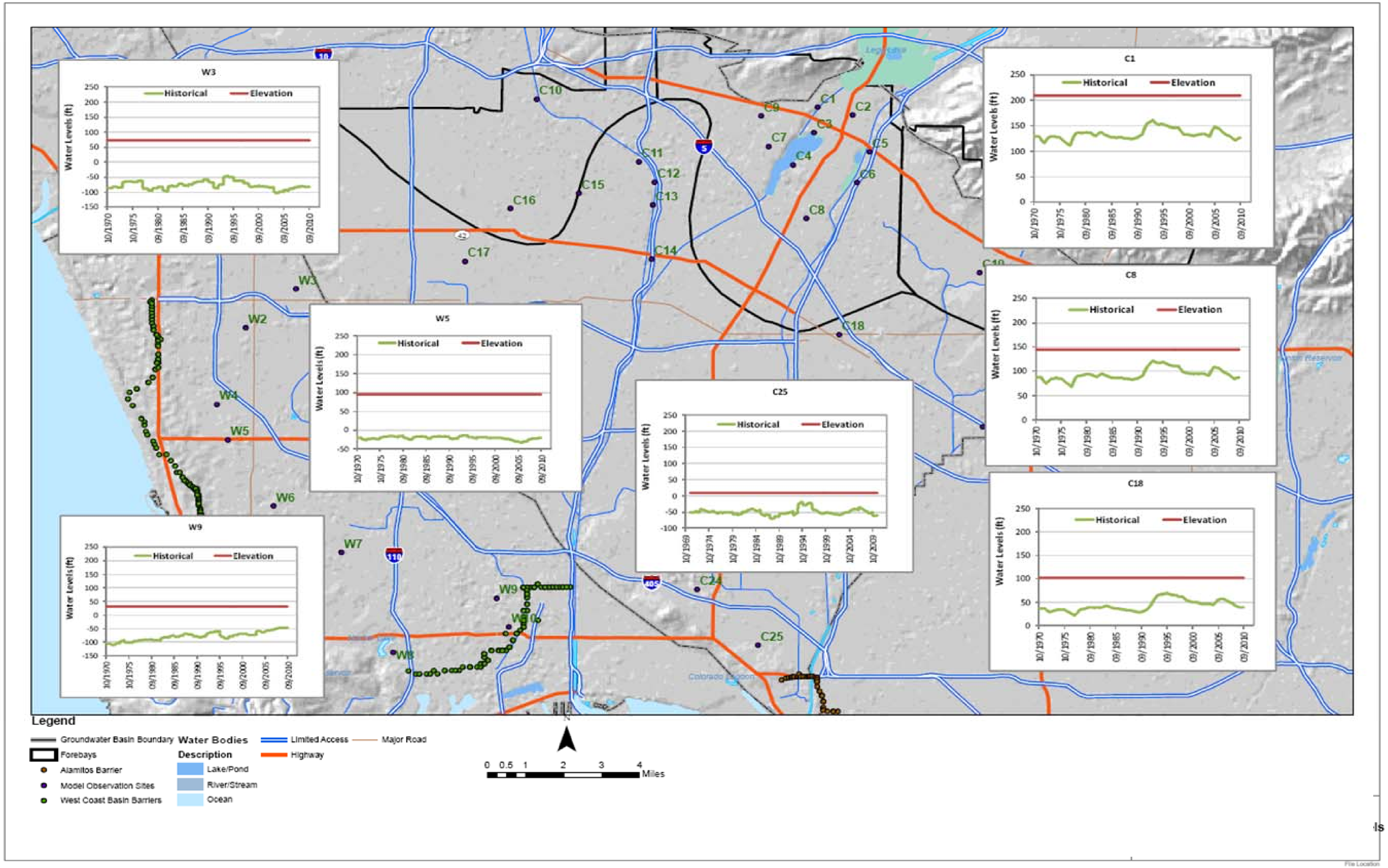
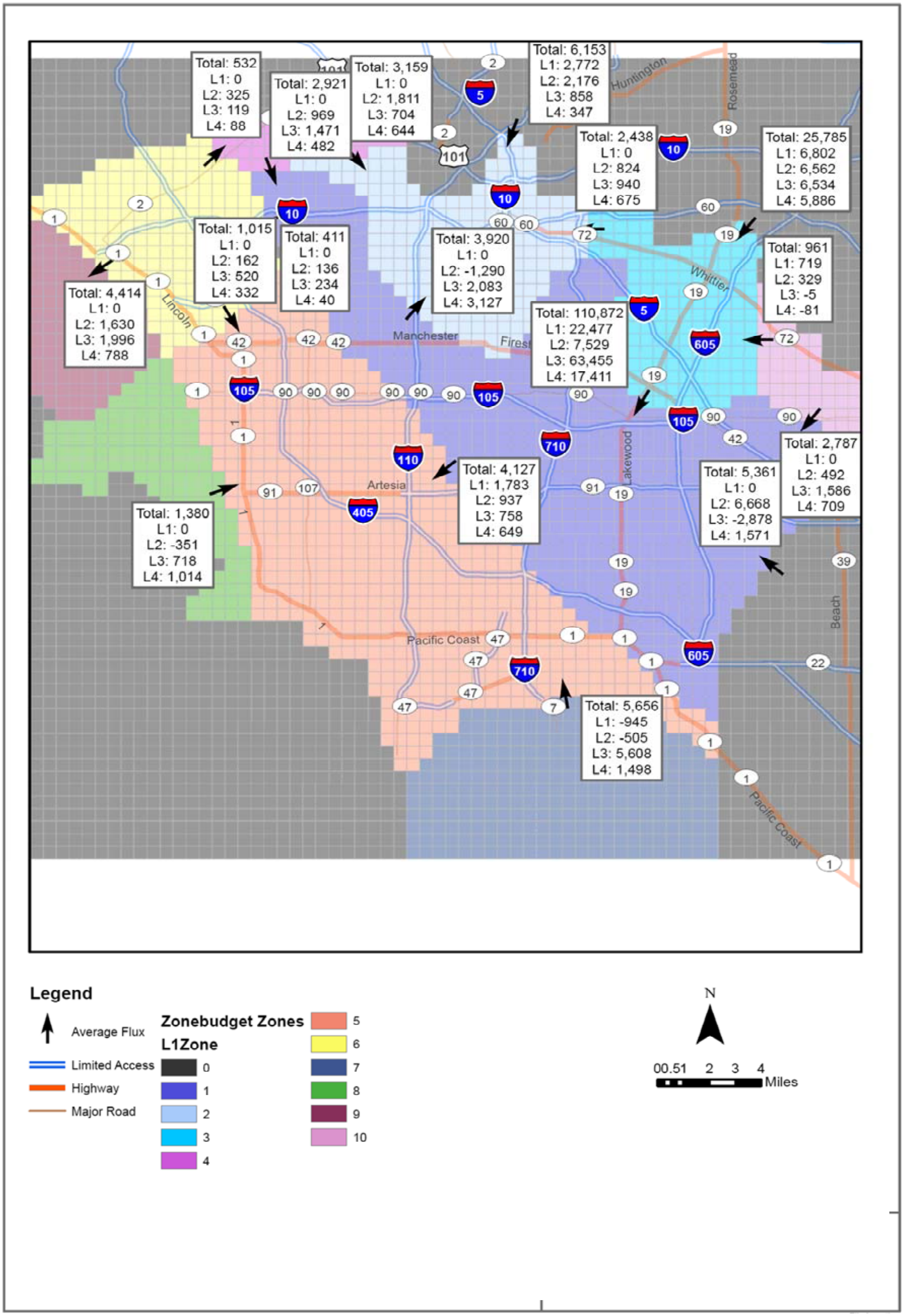


FIGURE 4-5
Zonebudget Summary for 10 Zones for Simulation Period (Water Years 1971 through 2010)



4.2.1.2 Above APA-Central Basin and Water Rights-West Coast Basin

The following combinations were conducted with pumping above APA levels in the Central Basin and at water rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions:

- **Combination 4:** In this combination, pumping is above the APA to 275,137 AFY in the Central Basin and at the water rights of 64,468 AFY in the West Coast Basin. This represents a combination of GBMP Scenarios WCB-A1a and CB–B1. Under this combination, pumping and replenishment are the same as in Combination 1 in the West Coast Basin. In the Central Basin, an additional 57,770 AFY is pumped by major imported water users from the MFSG, and additional recharge is provided in both the MFSG and the Los Angeles Forebay. Additional replenishment is provided through spreading and injection of recycled water and enhanced stormwater capture.
- **Combination 5:** In this combination, pumping is above the APA to 320,617 AFY in the Central Basin and at the water rights of 64,468 AFY in the West Coast Basin. This represents a combination of GBMP Scenarios WCB-A1a and CB–B2. Under this combination, pumping and replenishment are the same as in Combination 1 in the West Coast Basin. In the Central Basin, additional extraction occurs in the Los Angeles Forebay and MFSG. To support pumping for this combination, additional recharge of stormwater and recycled water to the MFSG and Los Angeles Forebay is assumed.

4.2.1.3 APA-Central Basin and Above Water Rights-West Coast Basin

The following combination was conducted with pumping at APA levels in the Central Basin and above water rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions:

- **Combination 6:** In this combination, pumping is at the APA of 217,367 AFY in the Central Basin and above the water rights at 94,468 AFY in the West Coast Basin. This represents a combination of GBMP Scenarios WCB-B1 and CB–A1. Under this combination, pumping in the West Coast Basin is redistributed with the goal of containing or removing the saline plume in Silverado aquifer. Extraction of an additional 30,000 AFY beyond the water rights for the West Coast Basin was allocated to three pumpers: CWSC, City of Torrance, and City of Los Angeles. To balance the pumping, additional water replenishment in the West Coast basin occurs at the existing barriers and a new line of inland injection wells.

4.2.1.4 Above APA-Central Basin and Above Water Rights-West Coast Basin

The following combination was conducted with pumping above APA levels in the Central Basin and above water rights levels in the West Coast Basin, with sufficient replenishment to support these pumping conditions:

- **Combination 7:** In this combination, pumping is above the APA to 275,137 AFY in the Central Basin and above the water rights to 94,468 AFY in the West Coast Basin. This represents a combination of GBMP Scenarios WCB-B1 and CB–B1. Pumping and replenishment for the West Coast Basin is the same as in Combination 6. Pumping and replenishment for the Central Basin is the same as in Combination 4.

Table 4-4 summarizes the basin operating conditions in each basin used for the modeling combinations described above.

TABLE 4-4
Basin Operating Conditions for Modeling Assessments

Basin Operating Conditions (Model Run)**	Basin	Description	GBMP Planning Scenario (see Table 3-9)	Pumping						Artificial Replenishment									
										Subsurface Injection					Surface Spreading				TOTAL - Both Basins
				WCB	CB	Additional Pumping by Pumpers	New Extraction Wells	TOTAL - per Basin	TOTAL - Both Basins	WCBBP	DGBP	ABP	New Injection Wells	TOTAL per Basin	Storm-water	Incidental RW Recharge*	RW	TOTAL - per Basin	
Combination 1 (Base Case Model Run)	WCB	Pumping within water rights	WCB-A1a	64,468				64,468	281,835	32,500	7,500			40,000					186,001
	CB	Pumping within APA	CB-A1		217,367			217,367				8,000		8,000	57,032	9,047	71,922	138,001	
Combination 2 (Model Run 5c)	WCB	Pumping within water rights	WCB-A1a	64,468				64,468	281,835	32,500	7,500			40,000					185,990
	CB	Pumping within APA	CB-A4		192,367		25,000	217,367				8,000		8,000	73,983	8,690	55,317	137,990	
Combination 3 (Model Run 2)	WCB	Pumping within water rights	WCB-A1c	49,468			15,000	64,468	281,835	32,500	7,500			40,000					186,001
	CB	Pumping within APA	CB-A1		217,367			217,367				8,000		8,000	57,032	9,047	71,922	138,001	
Combination 4 (Model Run 6)	WCB	Pumping within water rights	WCB-A1a	64,468				64,468	339,605	32,500	7,500			40,000					243,423
	CB	Pumping above APA	CB-B1		217,367		57,770	275,137				8,000	23,200	31,200	73,983	8,690	89,550	172,223	
Combination 5 (Model Run 7-3)	WCB	Pumping within water rights	WCB-A1a	64,468				64,468	385,085	32,500	7,500			40,000					288,903
	CB	Pumping above APA	CB-B2		217,367	16,480	86,770	320,617				8,000	68,680	76,680	73,983	8,690	89,550	172,223	
Combination 6 (Model Run 2-1)	WCB	Pumping above water rights	WCB- B1	49,468			45,000	94,468	311,835	40,000	15,000		15,000	70,000					318,890
	CB	Pumping within APA	CB-A1		217,367			217,367				8,000		8,000	57,032	9,047	71,922	138,001	
Combination 7 (Model Run 8)	WCB	Pumping above water rights	WCB- B1	49,468			45,000	94,468	369,605	35,000	10,000		25,000	70,000					250,223
	CB	Pumping above APA	CB-B1		217,367		57,770	275,137				8,000		8,000	73,983	8,690	89,550	172,223	

*Incidental RW recharge occurs from discharge of RW by Whittier Narrows WRP to the Rio Hondo and Pomona WRPs to San Jose Creek, a tributary of the San Gabriel River.

**indicates the model run number used in simulations for a specific model Combination. Some figures In this Section reference model run numbers.

4.3 Combination 1 (Baseline Operating Conditions)

WRD is required to meet the replenishment needs of the West Coast and Central Basins so that pumpers can extract groundwater up to the APA in the Central Basin and up to their water rights in the West Coast Basin. The APA in the Central Basin is 217,367 AFY, and water rights in the West Coast Basin are 64,468 AFY. Given the drivers described in Section 1.0, it is anticipated that pumping will increase up to the APA and water rights as water purveyors look to meet their water demands in the most reliable and economic manner. Therefore, WRD desires to develop the GBMP assuming pumping at the APA in the Central Basin and water rights in the West Coast Basin as the baseline operational condition.

4.3.1 Combination 1 – Assumptions and Model Input

To assess the potential replenishment requirements for Combination 1, the updated WRD/USGS groundwater flow model was extended through water year 2050, for a 40-year simulation period by repeating the hydrology from 1971 through 2010. This period (1971 through 2010) is a reasonably good period to use for planning purposes as it (1) is a relatively long period, (2) includes severe wet and dry periods, (3) includes variations in pumping, (4) covers the period of the WRD/USGS groundwater flow model simulations, and (5) contains a relatively complete data set. Following are the assumptions used for this planning period from water year 2011 through 2050:

- The historical hydrology of water years 1971 through 2010 are repeated into the future, beginning with water year 2011. This assumption also implies that the mountain front and interior recharge are repeated as in the updated groundwater flow model.

- Stormwater will be available in the same quantities in the future as it was in the past for each equivalent water year into the future. So, stormwater runoff in 1971 available for capture and recharge is the same in the equivalent water year 2012, and for 2013 it is the same as 1972, and so on. This also means that any non-captured stormwater in years when stormwater was wasted to the ocean (Figure 3-18), that this excess stormwater is available for capture and use for recharge. This is case for both the Rio Hondo/San Gabriel River and Los Angeles River. Table 4-5 provides a summary of stormwater captured and recharged at the Whittier Narrows Dam, Rio Hondo and San Gabriel River Coastal Spreading Grounds for water years 2011 through 2050.

- Use of imported water for replenishment at the MFSG is replaced with either increased capture of stormwater or recycled water given that the WIN program goal is to replace the use of imported water. It is important to note that the groundwater flow model does not distinguish between sources of water, so any distinction between water sources is tracked separately outside of the model. Table 4-5 shows the supplemental replenishment water recharged at the Whittier Narrows Dam, Rio Hondo and San Gabriel River Coastal Spreading Grounds for water years 2011 through 2050.

- Groundwater production is increased to the APA in the Central Basin and water rights in the West Coast Basin. It is assumed that pumpers who also use imported water will likely lease or acquire water rights to increase pumping to the levels assumed herein. This distribution of pumping is not certain, but it is assumed for purposes of analysis. In addition, each pumper’s monthly pumping is varied based on their average monthly pumping over water years 2000 through 2010 to account for seasonal variations in water demands. Tables 3-2 and Table 3-5 provide the distribution of annual pumping by pumper in the West Coast and Central Basins, respectively. Other pumping patterns are possible as pumpers determine their actual pumping plan; however, these alternative pumping distributions are not likely to significantly change the modeling results unless there is substantially different geographical redistribution of pumping than assumed herein.

- Injection into the seawater intrusion barriers is increased to 32,500 AFY for the WCBBP, 7,500 AFY for the DGBP, and 8,000 AFY for the ABP. WRD is in the final design stage of expanding the LVLWTF to provide 8,000 AFY of advanced treated wastewater for injection to the ABP.

- In addition, the groundwater flow model stress periods are reduced from annual to monthly durations over the 40-year simulation period. This finer stress period resolution allows for simulation of more representative groundwater levels in response to recharge events, especially high-rate recharge of stormwater events at the MFSG. This allows for an assessment of whether groundwater levels could potentially rise to (or above) land surface during these high-rate recharge events. Also, this finer stress period allows for assessment of groundwater fluctuations due to seasonal pumping patterns.

TABLE 4-5
Summary of Surface Water and Supplemental Replenishment Water at MFSG

Water Year	Base Stormwater (AFY)	Supplemental Recycled Water (AFY)	Total (AFY)
2011	40,833	93,983	134,816
2012	25,064	92,071	117,135
2013	49,009	78,408	127,417
2014	32,003	89,805	121,808
2015	25,924	94,737	120,661
2016	28,099	95,095	123,194
2017	17,713	97,512	115,225
2018	133,186	58,172	191,358
2019	71,467	69,762	141,229
2020	107,667	59,040	166,707
2021	45,261	85,437	130,698
2022	57,917	84,117	142,034
2023	100,010	61,309	161,319
2024	58,963	79,783	138,746
2025	53,979	79,246	133,225
2026	78,210	65,213	143,423
2027	24,670	96,106	120,776
2028	50,068	94,292	144,360
2029	19,587	95,114	114,701
2030	18,680	96,941	115,621
2031	41,481	87,169	128,650
2032	94,881	61,875	156,756
2033	147,699	48,502	196,201
2034	55,896	80,612	136,508
2035	100,578	65,965	166,543
2036	62,920	79,674	142,594
2037	58,262	77,665	135,927
2038	96,706	67,924	164,630

TABLE 4-5
Summary of Surface Water and Supplemental Replenishment Water at MFSG

Water Year	Base Stormwater (AFY)	Supplemental Recycled Water (AFY)	Total (AFY)
2039	32,013	96,688	128,701
2040	27,104	87,690	114,794
2041	45,470	85,937	131,407
2042	18,279	98,297	116,576
2043	59,337	75,450	134,787
2044	35,317	88,909	124,226
2045	148,674	47,265	195,939
2046	61,398	77,564	138,962
2047	13,693	97,520	111,213
2048	55,343	86,039	141,382
2049	44,251	84,764	129,015
2050	43,658	77,086	120,744

4.3.2 Combination 1 – Model Simulation Results

The groundwater flow model was used to determine the supplemental replenishment requirements at the MFSG and injection barriers to maintain an overall water balance in the West Coast and Central Basins. That is, over the simulation period, the goal is that the cumulative change in storage is near zero at the end of the simulation period, so that all inflows and outflows are relatively balanced over the simulation period. This balancing approach also results in groundwater levels that fluctuate, but in general end at levels that are comparable to their beginning levels. Given the large storage capacity of these basins and the fact that WRD would review actual replenishment requirements annually, the ending cumulative storage goal of the model simulations are considered satisfactory if they are within about 1 percent of the annual pumping cumulative over the simulation period, which is about 3,000 AFY or about 120,000 AF over the 40-year simulation period.

A trial and error approach was used to determine the supplemental replenishment water required at the MFSG to result in a balanced model over the 40-year simulation period. The total recharge required, including supplemental replenishment water, is approximately an average of 138,000 AFY. The historical quantity of stormwater conserved over this period is approximately 57,000 AFY, which leaves a requirement of 81,000 AFY of supplemental replenishment water to meet APA pumping requirements in the Central Basin.

Figure 4-6 shows a few selected hydrographs at locations throughout the West Coast and Central Basins. The hydrographs for locations in the Montebello Forebay show groundwater-level fluctuations in Layer 1 (to capture groundwater responses in the shallowest layer). The remainder of the hydrographs are for Layer 3 (which represents the layer with the most pumping) of the model. Simulated historical groundwater levels (water years 1971 through 2010 by adding 40 years to the date) are plotted, as well as the projected groundwater levels under this baseline modeling combination for comparison purposes. This comparison shows groundwater level responses to identical hydrological conditions in the basins, with the addition of supplemental replenishment in the MFSG, increased injection into the injection barriers, and pumping at APA and water rights. Additional hydrographs are provided in Appendix I.

These hydrographs show an overall water balance in these basins. Groundwater level fluctuations in the Montebello Forebay area are slightly muted compared to historical fluctuations. This is a result of a projected more consistent replenishment of recycled water compared to historical imported water, which was recharged based on the availability of low-cost surplus supplies. Figure 4-7 shows groundwater level contours for each model layer at the end of water year 2050.

Figure 4-8 shows the baseline Combination 1 cumulative groundwater storage for the modeled area. Groundwater in storage fluctuates in response to local hydrological conditions, with storage increasing during wet years and decreasing during dry years. The ending balance is about +50,000 AF, which is about 1,250 AFY of surplus inflow compared to outflow—less than 0.5 percent of the annual pumping in these basins.

Figure 4-9 shows a summary of the average annual fluxes between zones over the simulation period.

Pumping in the West Coast Basin is distributed to pumpers assuming that they would acquire pumping rights (through leases or purchase) and pump this water from their wells or wells in or near their service areas (see Table 3-2, Scenario A1a). Therefore, under this operating condition, there is no plan to address the large saline plumes; these plumes of salty water would continue to migrate unabated, in response to injection and pumping as described for this operating condition. Figure 4-10 shows a plot of path lines in the Silverado aquifer (model Layer 3) from the western extent of the saline plume (as characterized by WRD) over the 40-year simulation period. These path lines show the eastward advancement that the saline water would make under the injection and pumping pattern assumed for this baseline operating condition.

FIGURE 4-6
Selected Hydrographs Showing Simulated Baseline Groundwater Levels under Combination 1

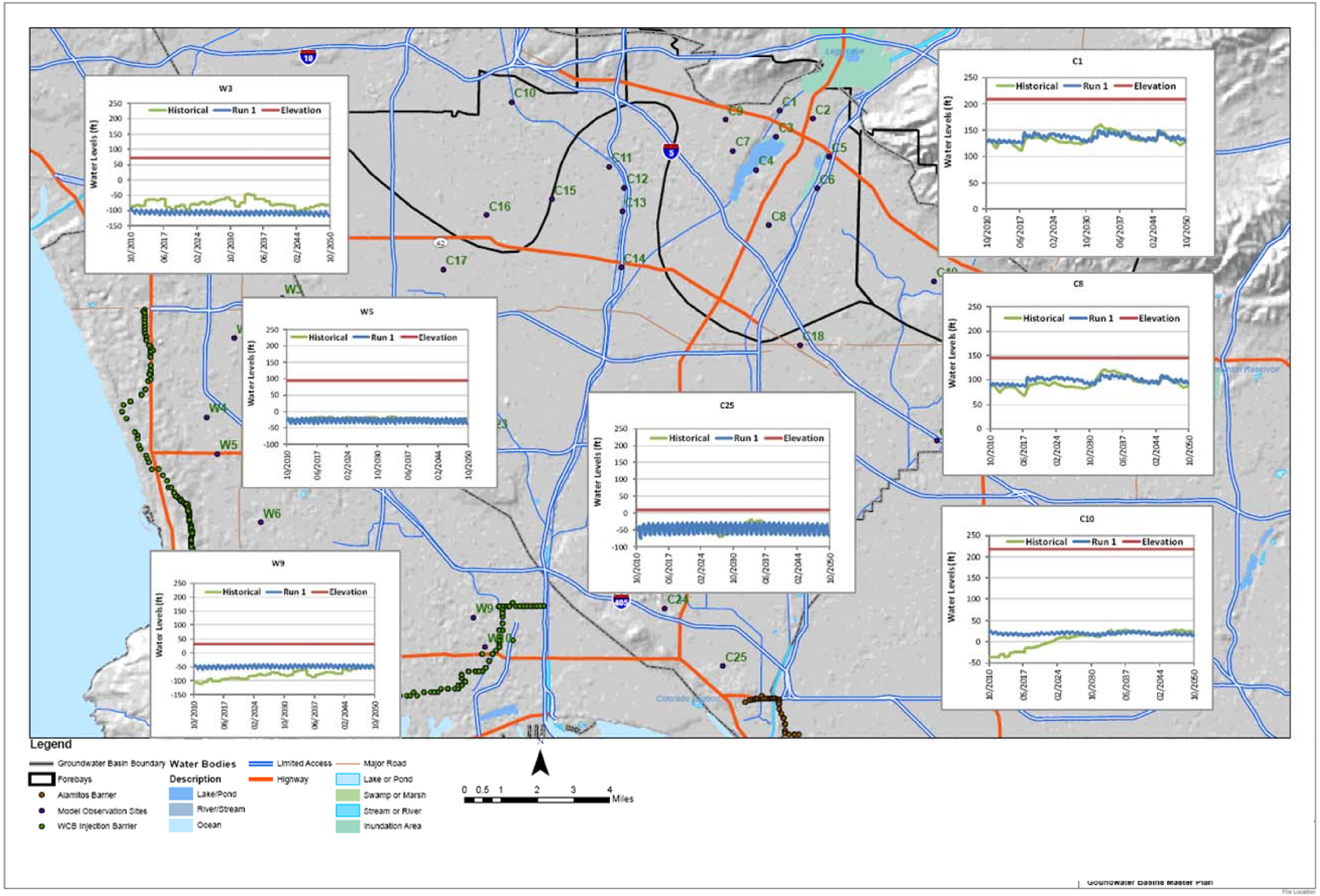


FIGURE 4-7
Groundwater Level Contours at the End of the Simulation Period (September 30, 2050) under Combination 1

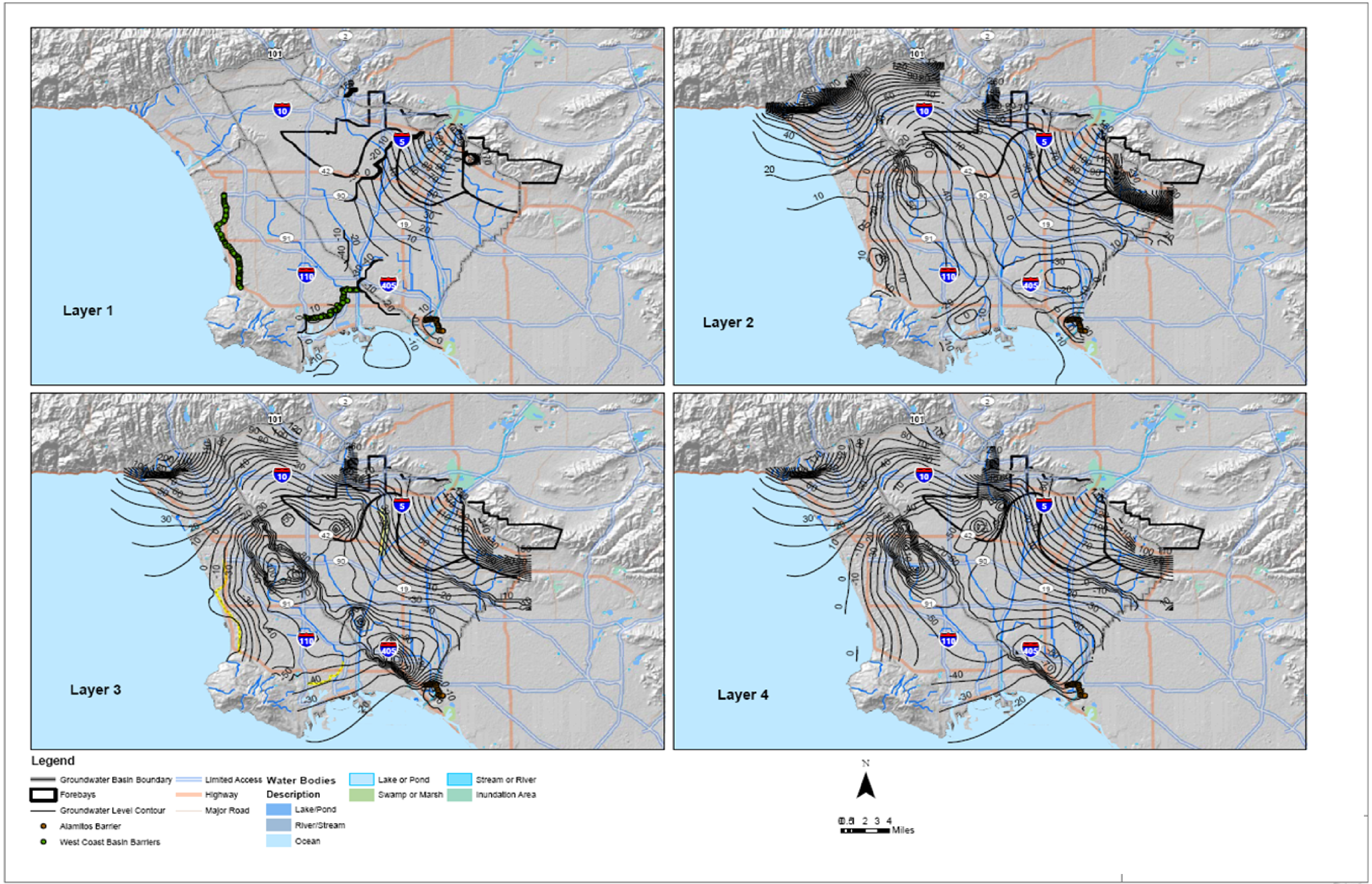


FIGURE 4-8
Cumulative Groundwater in Storage for the West Coast and Central Basins under Combination 1

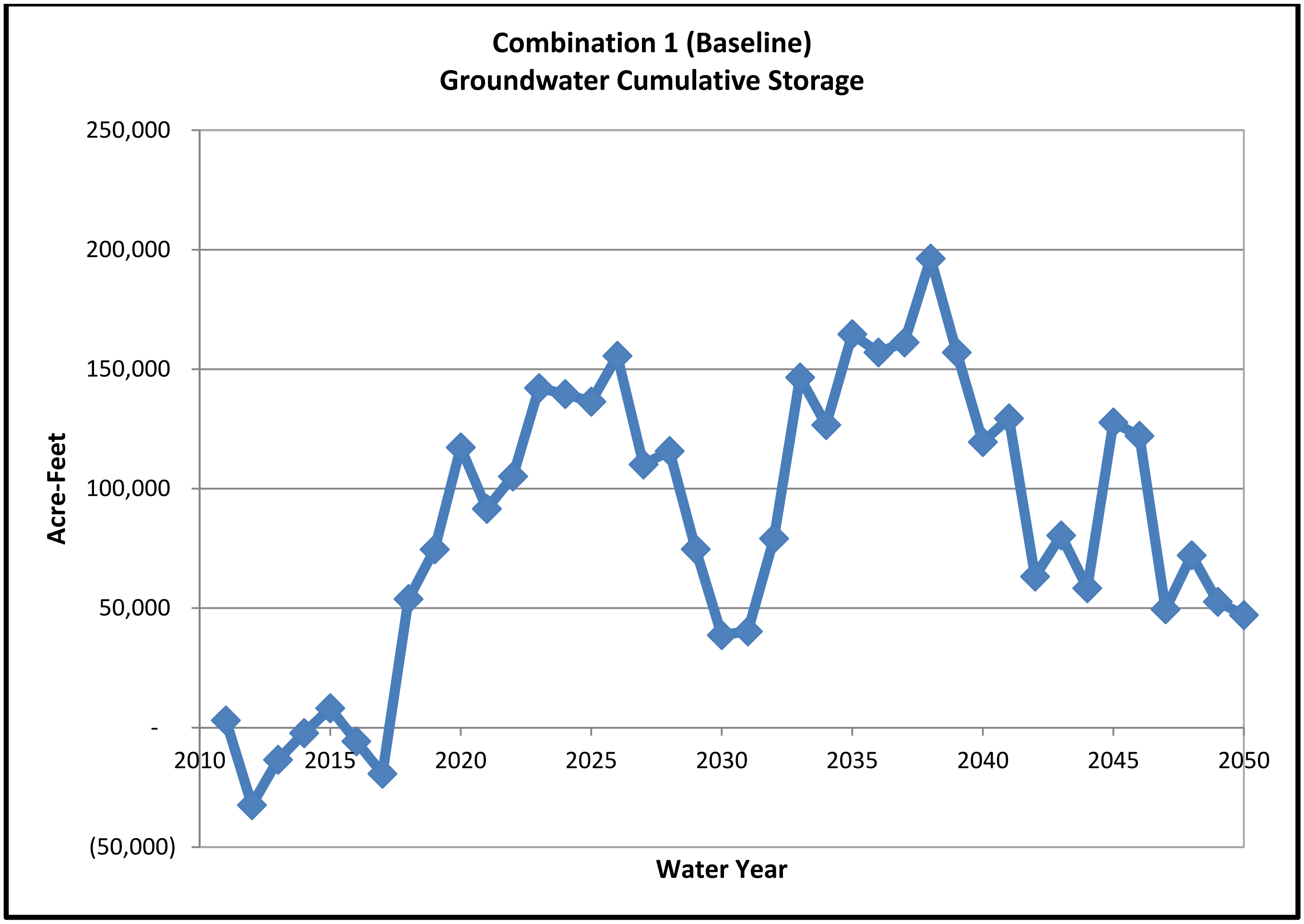


FIGURE 4-9
Zonebudget Summary of 10 Zones for Simulation Period (Water Years 2010 through 2050) under Combination 1

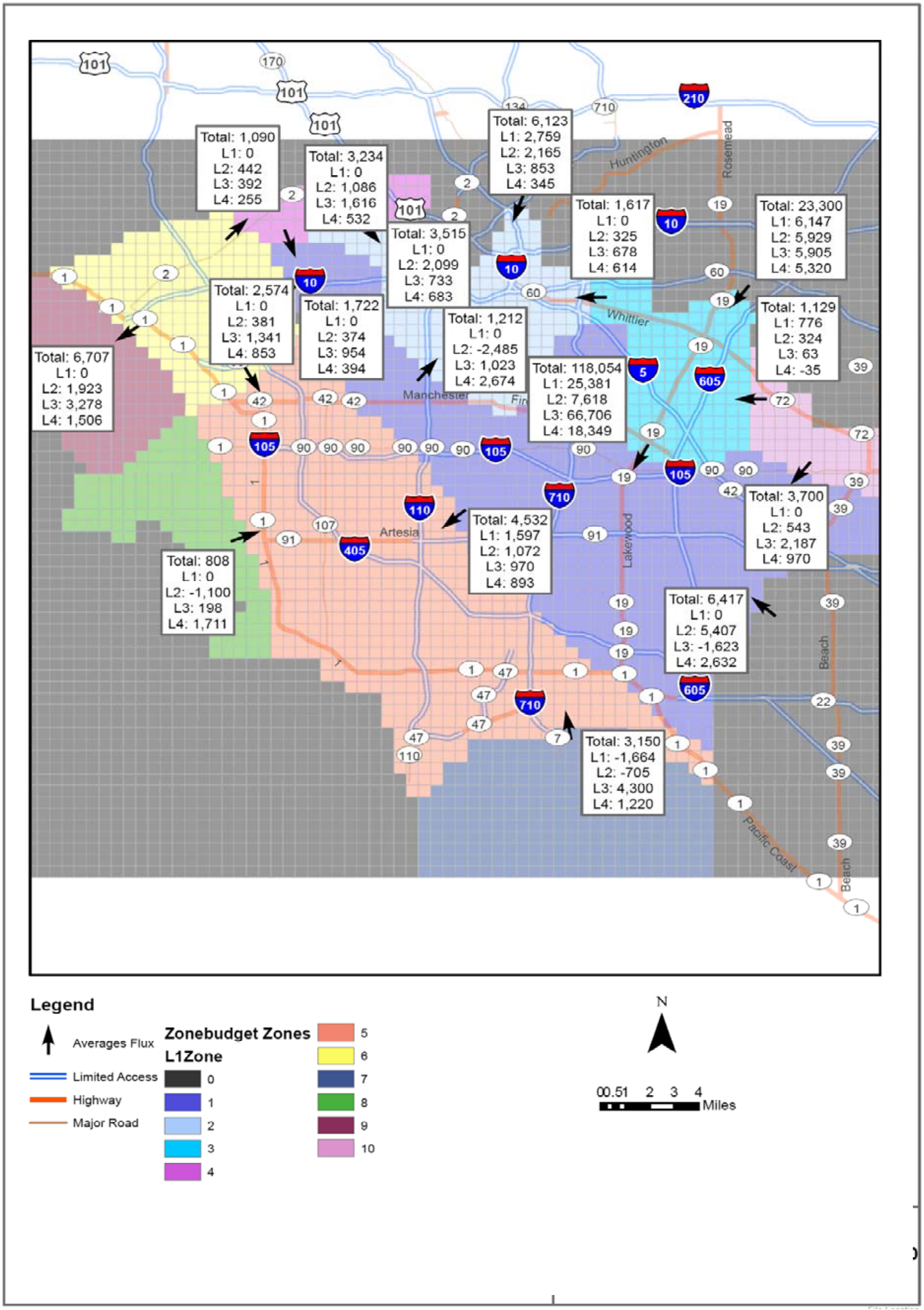
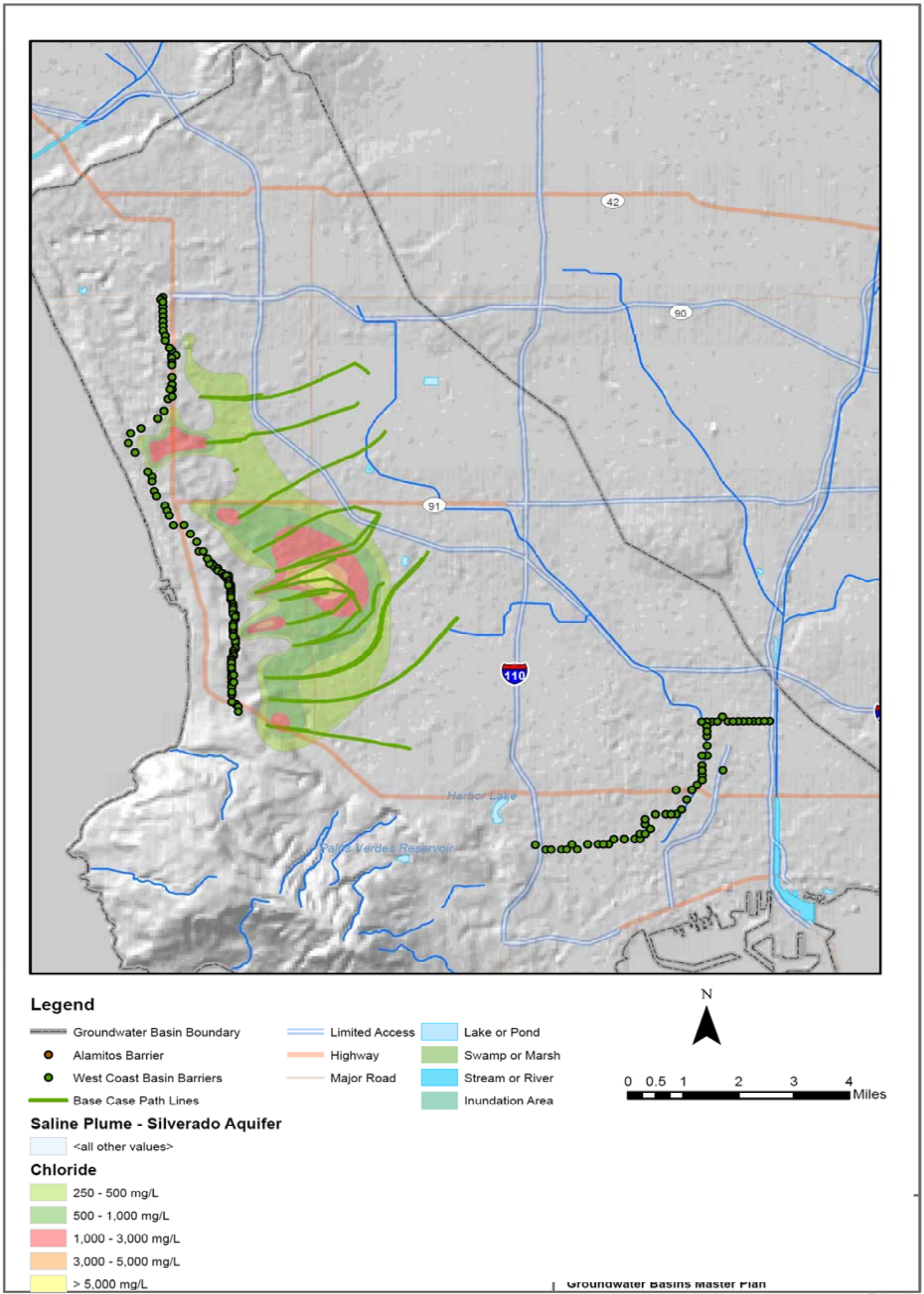


FIGURE 4-10
Baseline (Combination 1) – Groundwater Path Lines Through Saline Plume in Silverado Aquifer



4.4 Combination 2

Combination 2 modifies Combination 1 with the assumption of additional stormwater capture and recharge in the MFSG. The potential to capture more stormwater for recharge at the MFSG requires that (1) the capacity to recharge additional stormwater exists, and (2) additional stormwater is available to divert into the spreading basins.

4.4.1 Combination 2 – Assumptions and Model Input

This operating scenario is based on the assumption that additional stormwater is available for capture and recharge at the MFSG. As discussed in Section 3.0, a portion of stormwater wasted to the ocean can be diverted and captured for additional recharge at the MFSG (refer Section 3.3.2.3). Figure 3-20 shows a projected condition for capturing additional stormwater, using the projected operational capacity of the MFSG and availability of additional stormwater for capture and recharge.

Figure 4-11 shows a projected scenario for capturing additional stormwater, using the projected operational capacity of the MFSG and availability of additional stormwater for capture and recharge. Table 4-6 summarizes the annual quantity of water recharged at the MFSG, which totals 138,000 AFY as in the baseline modeling Combination 1. It is assumed that additional stormwater was available in those years where LACDPW did not report water wasted to the ocean based on general wet-year hydrological conditions. This assumption will have to be investigated further to confirm the availability of this supply; for example, by developing more detailed stormwater models of the watershed to simulate runoff over the study period, for various assumed hydrological conditions and flood control/water conservation operating conditions. The projected recharge at the MFSG is used for this master plan to assess impacts on groundwater levels and basin storage conditions, assuming this operation was in place.

FIGURE 4-11
Projected Monthly Volumes of Stormwater and Recycled Water Replenished at the Montebello Forebay Spreading Basins with Additional Stormwater Capture

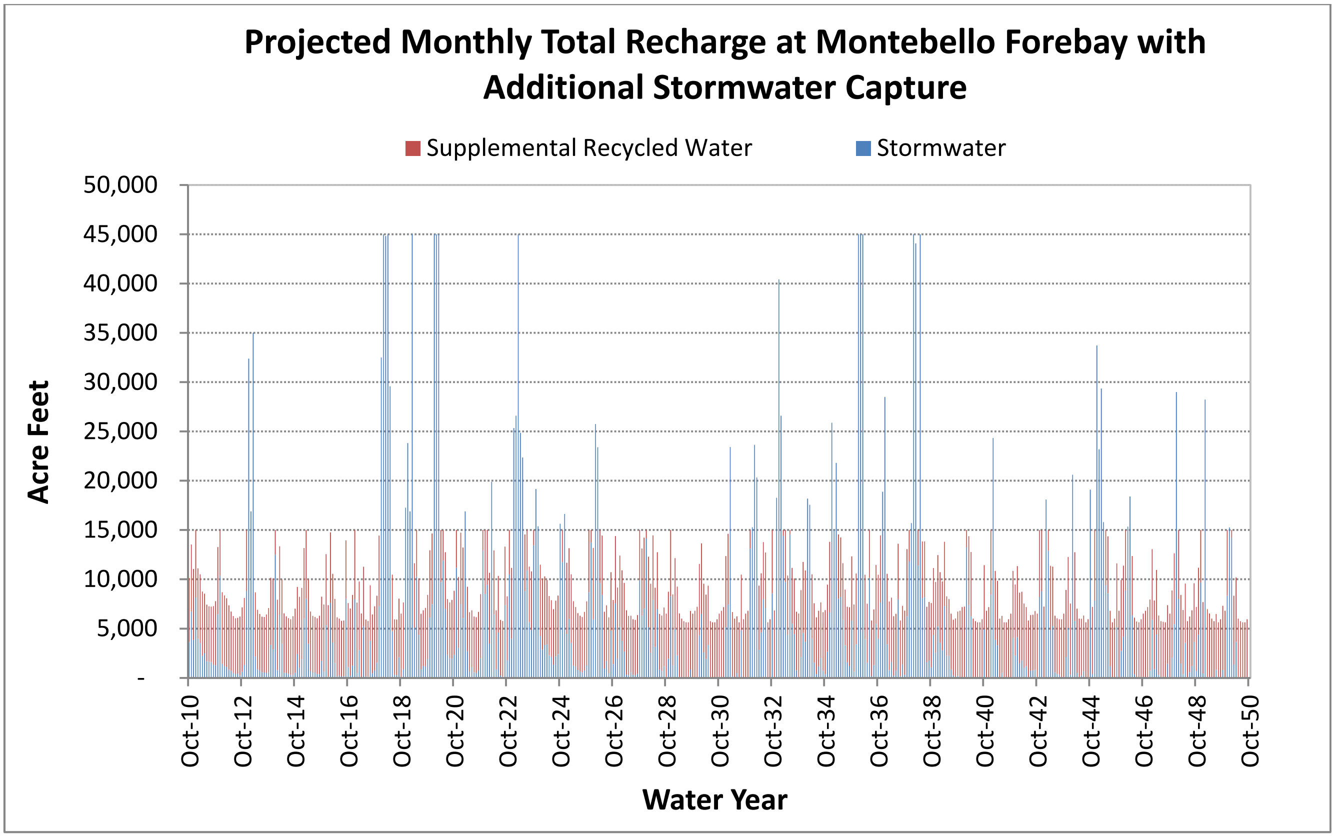


TABLE 4-6
Summary of Annual Water Recycled at the Montebello Forebay

	Surface Water		Recycled Water	
Water Year	Baseline (AFY)	Additional Stormwater Captured (AFY)	Supplemental Recycled Water (AFY)	Total (AFY)
1971	40,833	0	77,008	117,841
1972	25,064	0	74,825	99,889
1973	49,009	51,388	55,040	155,437
1974	32,003	0	72,652	104,655
1975	25,924	0	77,397	103,321
1976	28,099	1,163	77,397	106,659
1977	17,713	5,869	77,195	100,777
1978	133,186	80,652	43,484	257,322
1979	71,467	55,335	47,527	174,329
1980	107,667	77,796	51,865	237,328
1981	45,261	8,026	67,455	120,742
1982	57,917	17,940	63,315	139,172
1983	100,010	90,582	39,652	230,244
1984	58,963	13,219	58,456	130,638
1985	53,979	9,178	60,150	123,307
1986	78,210	26,534	55,722	160,466
1987	24,670	0	77,397	102,067
1988	50,068	15,815	69,586	135,469
1989	19,587	0	76,927	96,514
1990	18,680	0	77,397	96,077
1991	41,481	0	70,430	111,911
1992	94,881	0	50,739	145,620
1993	147,699	0	42,789	190,488
1994	55,896	0	63,265	119,161
1995	100,578	0	56,033	156,611
1996	62,920	104,516	55,123	222,559
1997	58,262	17,017	62,981	138,260
1998	96,706	102,461	43,081	242,248
1999	32,013	533	77,397	109,943
2000	27,104	0	71,994	99,097
2001	45,470	0	69,544	115,014
2002	18,279	0	77,397	95,676
2003	59,337	0	64,413	123,750
2004	35,317	0	70,232	105,549
2005	148,674	0	42,518	191,191
2006	61,398	0	62,886	124,284

TABLE 4-6
Summary of Annual Water Recycled at the Montebello Forebay

	Surface Water		Recycled Water	
Water Year	Baseline (AFY)	Additional Stormwater Captured (AFY)	Supplemental Recycled Water (AFY)	Total (AFY)
2007	13,693	0	77,397	91,090
2008	55,343	0	69,992	125,334
2009	44,251	0	68,371	112,622
2010	43,658	0	63,242	106,900

Pumping is redistributed under this modeling combination to provide for 25,000 AFY of additional pumping in the Montebello Forebay. A new extraction wellfield is assumed to be installed between the Rio Hondo and San Gabriel Coastal Spreading Grounds to accomplish this additional extraction. A portion of the APA of a number of pumpers will be shifted to this extraction wellfield, so these participating pumpers would get this pumped water delivered to them via the FIX-IT pipeline described in Sections 3 and 5. Table 3-6 summarizes the pumping by pumper that would be shifted to this wellfield. A like amount of pumping is assumed to be reduced by each pumper as compared to the baseline modeling Combination 1. For example, the City of Long Beach is assumed to pump 30,000 AFY from wells within the city in Combination 1. The City would shift 14,000 AFY to the Montebello Forebay wellfield and reduce pumping by 14,000 AFY in their wells within the city. The net difference in pumping would be zero, and only the location of pumping would shift to the Montebello Forebay extraction wellfield.

The redistribution of pumping as described for this modeling combination is for planning purposes only. The redistribution is based on feedback received from pumpers at workshops during the course of this study. The actual redistribution, if any, would be determined in the future. In general, the effects on simulated groundwater levels and groundwater storage as a result of different redistributions of pumping than the one used here are not expected to be significantly different, except for the case of the City of Long Beach. Long Beach is near the Los Angeles/Orange County boundary line, so shifting more or less of Long Beach's pumping could result in significantly different impacts on groundwater levels and groundwater storage. Therefore, additional model simulations are expected to be completed for any specific projects that may be proposed to reassess the project-specific impacts on groundwater levels and storage. Nonetheless, the simulations conducted using the present pumping redistribution assumptions provide insights into the feasibility of such shifting of pumping to accomplish enhanced stormwater recharge in the Montebello Forebay.

4.4.2 Combination 2 – Model Simulation Results

Figure 4-12 shows simulated groundwater levels at the end of the simulation period (September 30, 2050) for the four layers of the model under Combination 2 operating conditions. Figure 4-13 shows selected hydrographs for locations throughout the basin. In general, groundwater-level fluctuations in the Montebello Forebay are not significantly different from historical groundwater-level fluctuations, even though there is enhanced capture of stormwater with high-rate recharge in some years and 25,000 AFY of additional pumping in this area. The lack of significant variations is due to the overall balance that is maintained in the recharge and pumping conditions. However, there is an overall sight decline in groundwater levels in the Central Basin compared to the Combination 1 operating condition. Groundwater levels in the West Coast Basin remain largely unaffected by this difference in operations in the Central Basin.

Figure 4-14 shows the overall cumulative change in groundwater storage over the simulation period. The ending storage is about 100,000 AF lower than the beginning storage. This translates to a deficit of approximately 2,500 AFY, which is within the acceptable limits for planning purposes as described above. In practice, this deficit would be made up through purchase of additional recycled water or other supplies if this operational condition were implemented and if a deficit actually developed.

FIGURE 4-12
Groundwater Level Contours at the end of the Simulation Period (September 30, 2050) Combination 2 Operating Conditions

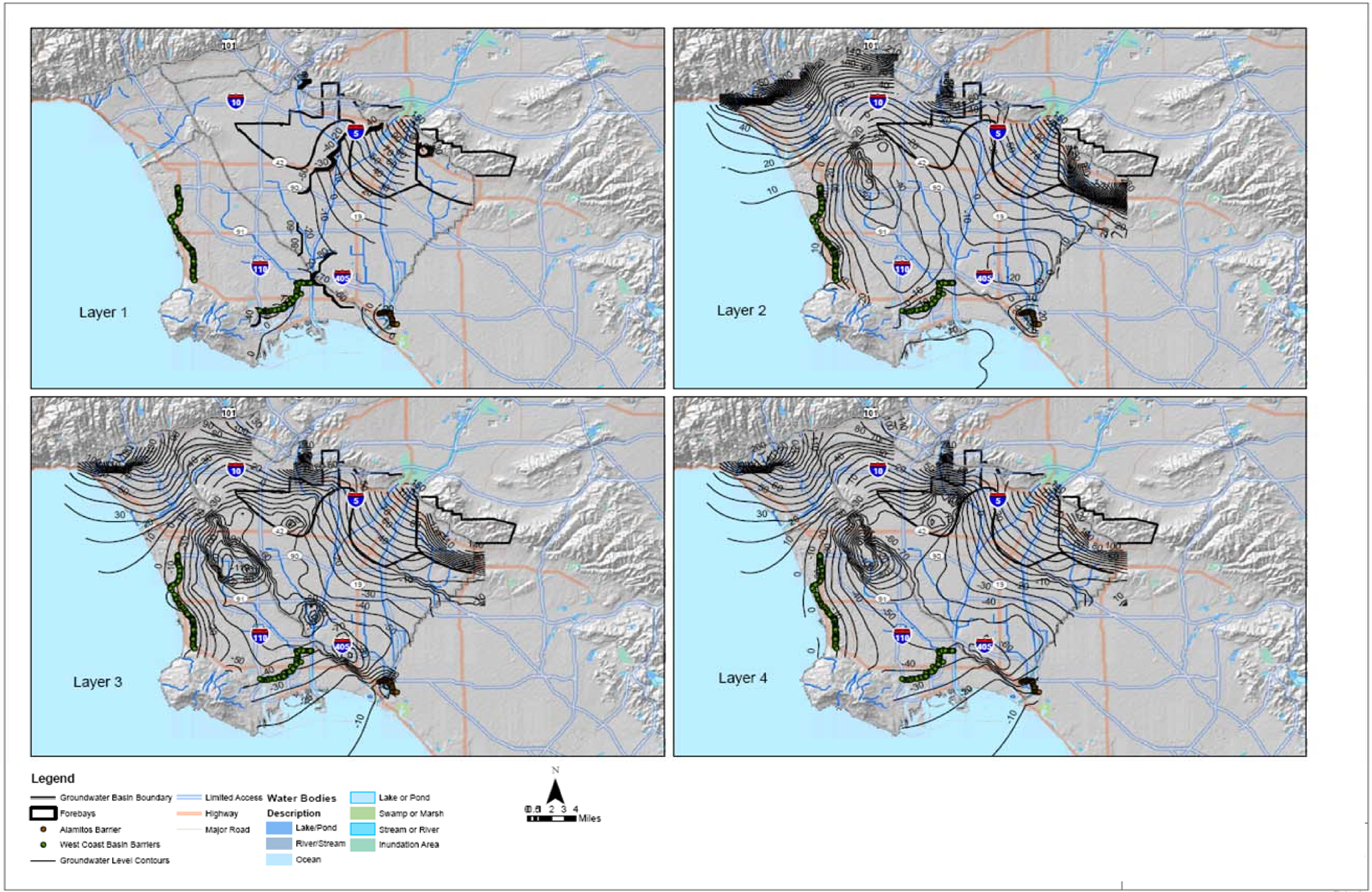


FIGURE 4-13
Selected Hydrographs Showing Simulated Groundwater Levels for Combination 2 Operating Conditions

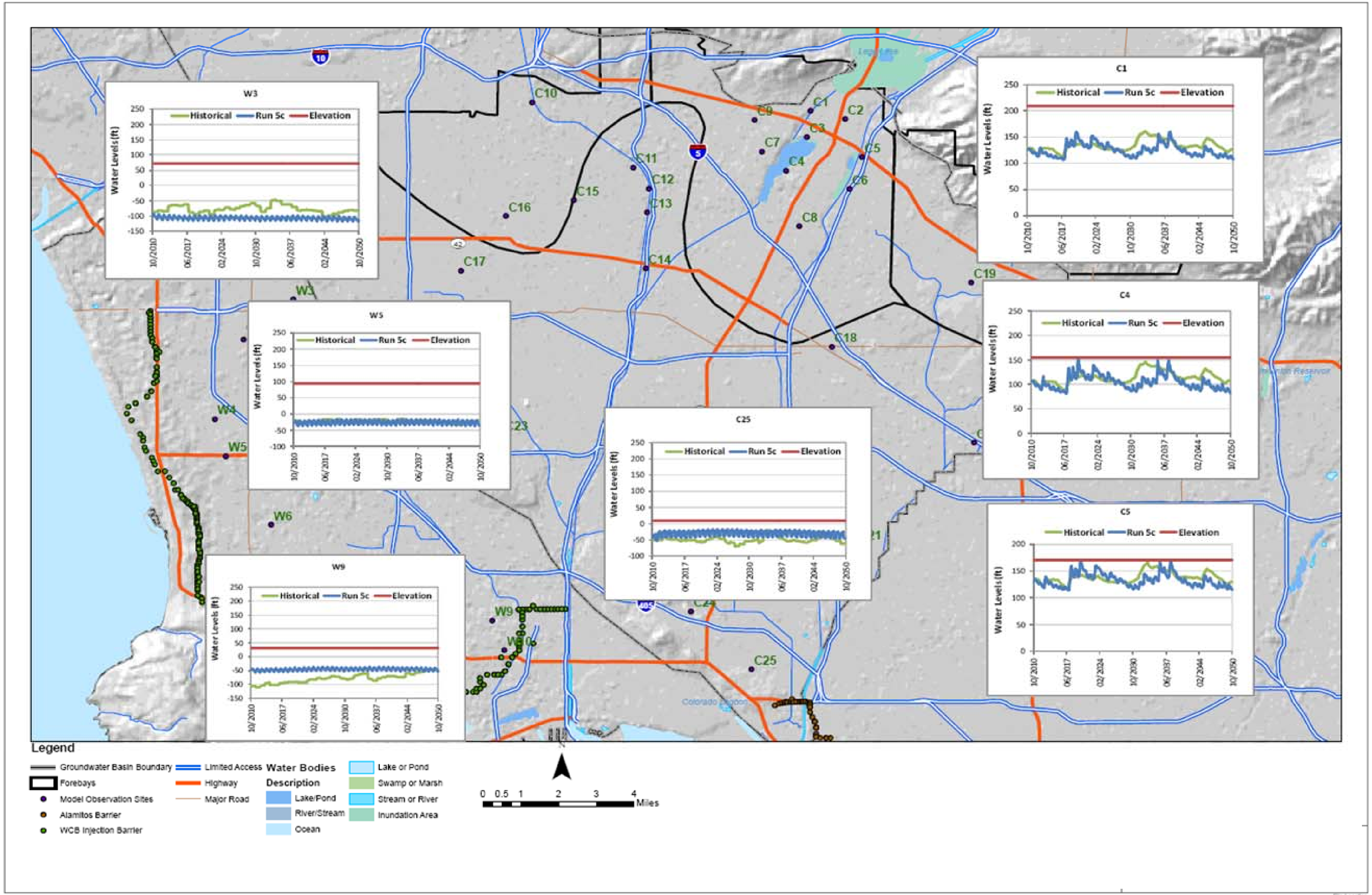
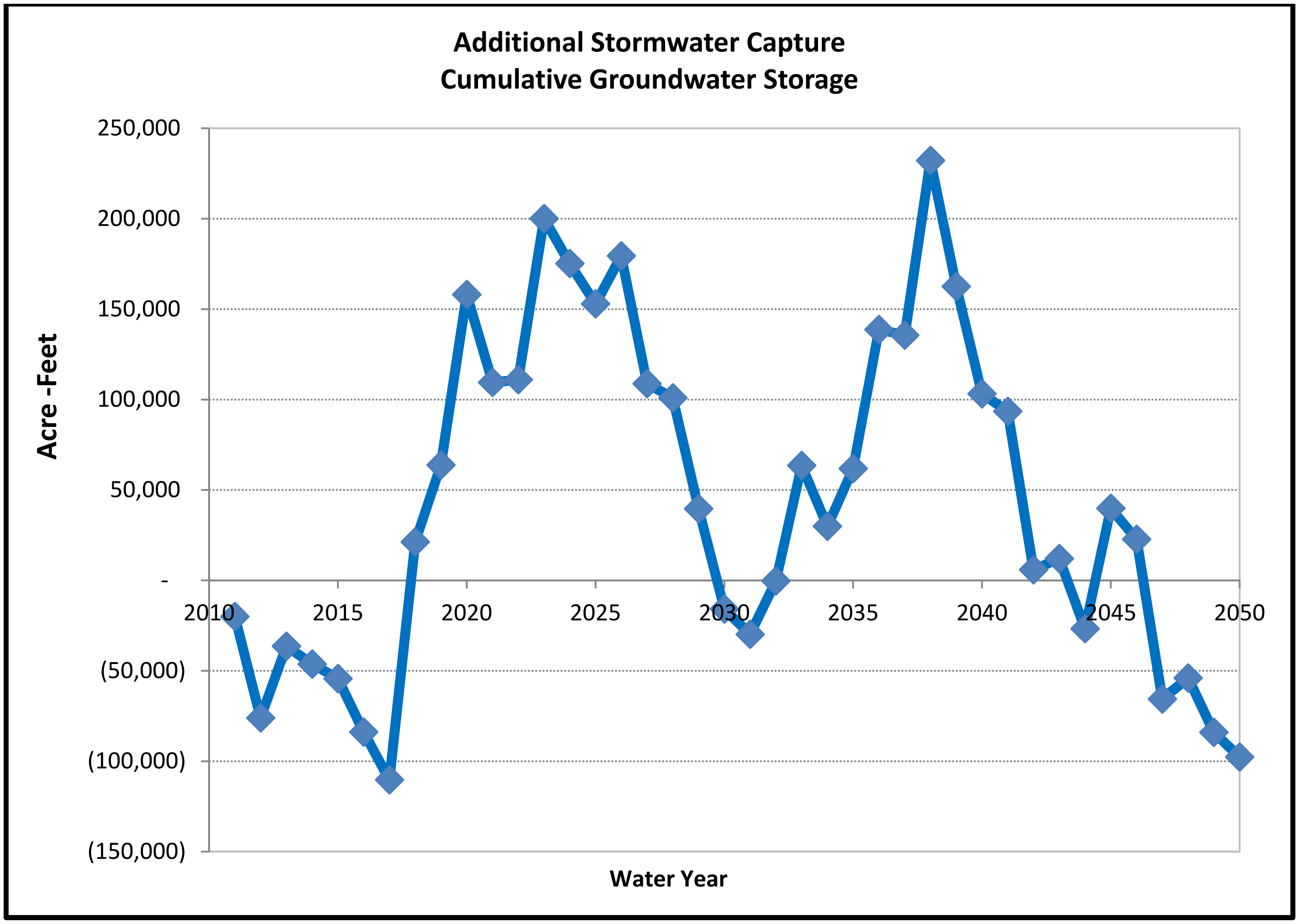


FIGURE 4-14
Cumulative Groundwater in Storage for the West Coast and Central Basins under Combination 2



4.5 Combination 3

Combination 3 is the operating condition for the West Coast Basin simulated with the updated WRD/USGS groundwater flow model. It reflects a strategic redistribution of pumping to contain/remove salty groundwater from the saline plume. In this modeling combination, pumping by selected pumpers is reduced so that 15,000 AFY of water rights water is moved to wells that will intercept and extract brackish/saline groundwater in the Silverado aquifer. This extracted water would be delivered to and treated by desalination facilities, then delivered to water purveyors for distribution in their potable water delivery systems.

4.5.1 Combination 3 – Assumptions and Model Input

The recharge conditions under this combination are the same as in Combinations 1 and 2. However, the pumping distribution is changed. Table 3-2 shows the redistribution of pumping to pumpers in the West Coast Basin under this combination (that is, for GBMP planning Scenario WCB-A1c) to contain/remediate saline plume. This redistribution of pumping is the only change made to the updated WRD/USGS groundwater flow model used for the baseline simulation described under Combination 1.

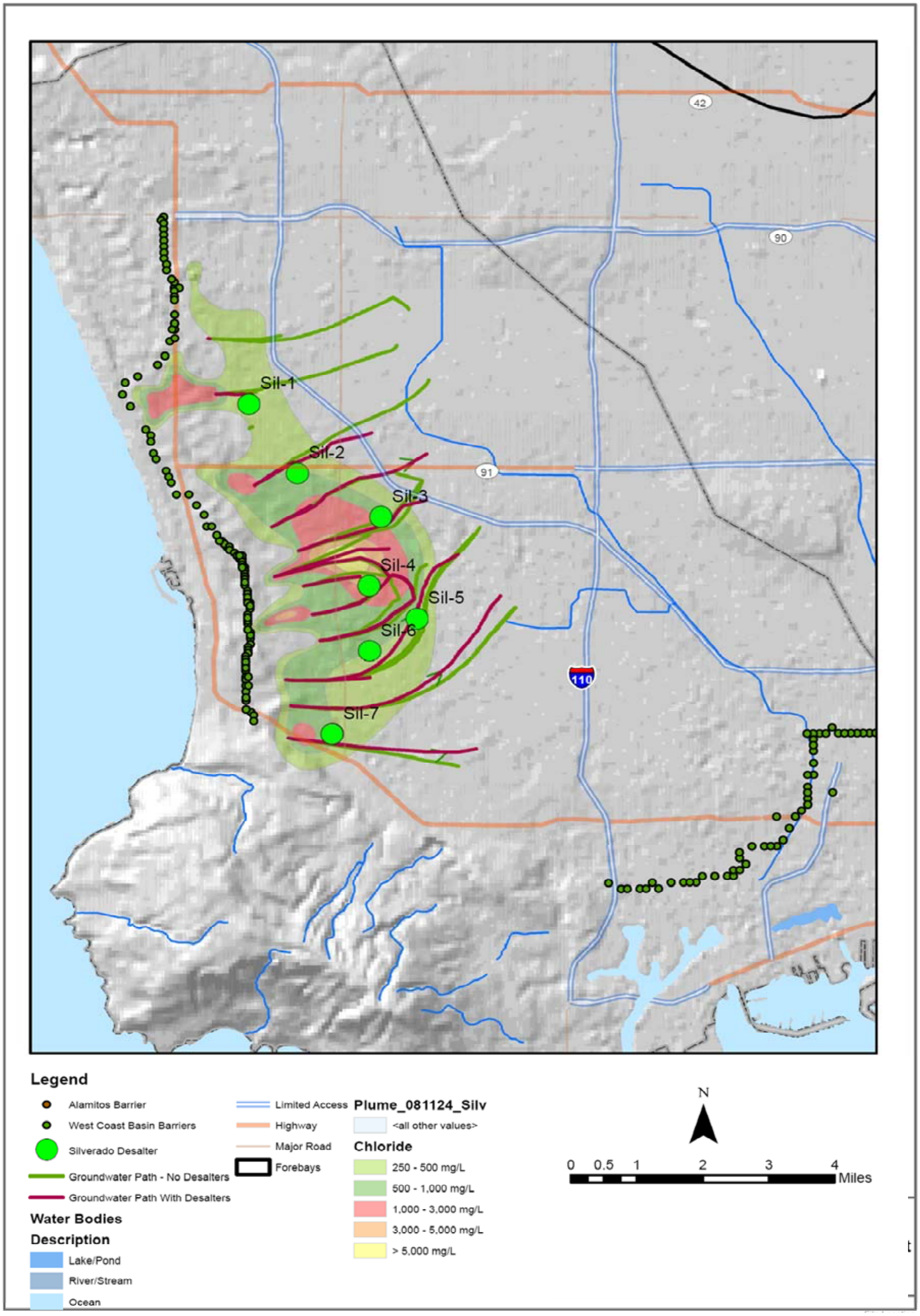
4.5.2 Combination 3 – Model Simulation Results

Figure 4-15 shows groundwater flow paths through the saline plume for this extraction condition. Groundwater path lines are terminated by some of the saline plume extraction wells and other path lines are shortened or deflected from their flow paths compared to the baseline, Combination 1 extraction condition. This change in flow path indicates that more mass of salts will likely be removed compared to the Combination 1 condition.

Appendix I contains groundwater level contour maps and hydrographs for the model simulation observation sites distributed throughout the basins. Groundwater levels and storage are not significantly different for this operating condition compared to the baseline Combination 1 condition.

Use of the West Coast Basin groundwater flow and solute transport model maintained by WBMWD is recommended to simulate this operating condition. WBMWD and WRD are in the process of having this groundwater flow and solute transport model calibrated for simulations of the saline plume. As described above, preliminary simulations of saline plume containment/removal were conducted with the current WBMWD groundwater flow and solute transport model. These preliminary simulations indicated significant improvement in basin water quality. Once the groundwater flow and solute transport model is recalibrated for the saline plume, these simulations should be repeated to refine this operating condition.

FIGURE 4-15
Comparison of Travel Paths Through Silverado Saline Plume With and Without Desalters



4.6 Combination 4

Combination 4 assumes additional recycled water and stormwater are recharged in the MFSG, allowing for extraction of up to 57,700 AFY above the APA. The West Coast Basin was operated at water rights, as in the baseline, Combination 1, operating condition.

4.6.1 Combination 4 – Assumptions and Model Input

This operating scenario is based on the assumption that additional stormwater is available for capture and recharge at the MFSG. In addition, Los Angeles River stormwater is available for recharge along the Los Angeles River. Stormwater capture and available recycled water use was maximized in the Montebello Forebay to increase replenishment under this modeling combination in order to increase pumping above APA in the Central Basin. It is assumed that enhanced stormwater capture can be accomplished as described in Section 3.3.2.6, so that approximately 22,000 AFY of additional stormwater would be captured (from the San Gabriel and Los Angeles Rivers) compared to historical capture and recharge of stormwater. It is assumed that improvements would be made at the SJCWRP (for example, Diversions 1 and 2) to allow for increased availability of recycled water. This would allow for an annual average of approximately 108,200 AFY of recycled water (which includes 8,690 AFY of incidental recharge of tertiary recycled water from the Whittier Narrows WRP and Pomona WRP) to be spread at the MFSG or injected into injection wells in the Montebello Forebay area. It is assumed that 9,500 AFY will be available from the LCWRP for injection into wells in the Montebello Forebay. In addition to the MFSG recharge, 5,000 AFY are recharged via an ARRF along the Los Angeles River as described in Section 3.3.2.7. An ARRF is proposed to capture stormwater for recharge along the Los Angeles River between Atlantic Boulevard and Firestone Boulevard.

Tertiary and advanced treated recycled water will be replenished at the MFSG. To maximize the use of available recycled water from the SJCWRP, FAT-treated recycled water will be injected into new injection wells located between the Rio Hondo and San Gabriel Coastal Spreading Grounds. In addition, FAT-treated recycled water from the LCWRP will be injected into these injection wells. Figure 4-16 shows the locations of these injection wells. Figure 4-17 shows the projected monthly spreading and injection of stormwater, tertiary recycled water, and advanced treated recycled water from SJCWRP (including Whittier Narrows and Pomona Water Reclamation Plants) and LCWRP in the Montebello Forebay area.

The replenishment that results from maximizing stormwater from the Rio Hondo/San Gabriel River and Los Angeles River, and recycled water from the SJCWRP and LCWRP is sufficient to provide for 57,770 AFY of additional pumping above the APA in the Central Basin. This pumping is assumed to take place from new extraction wells in the Montebello Forebay, as shown in Figure 4-16. These wells would be connected to the FIX-IT pipeline as described in Sections 3 and 5 and delivered to purveyors in the Central Basin to offset their imported water demands. Table 3-7 shows the distribution of the pumping that would be conveyed to these pumpers via the FIX-IT pipeline in the Central Basin. This distribution is based on feedback from pumpers during workshops; however, as described previously, this distribution is for planning purposes only and should not be considered a definitive plan.

FIGURE 4-16

Location of Injection and Extraction Wells – Montebello Forebay Area for Additional Pumping Considered Under Combination 4

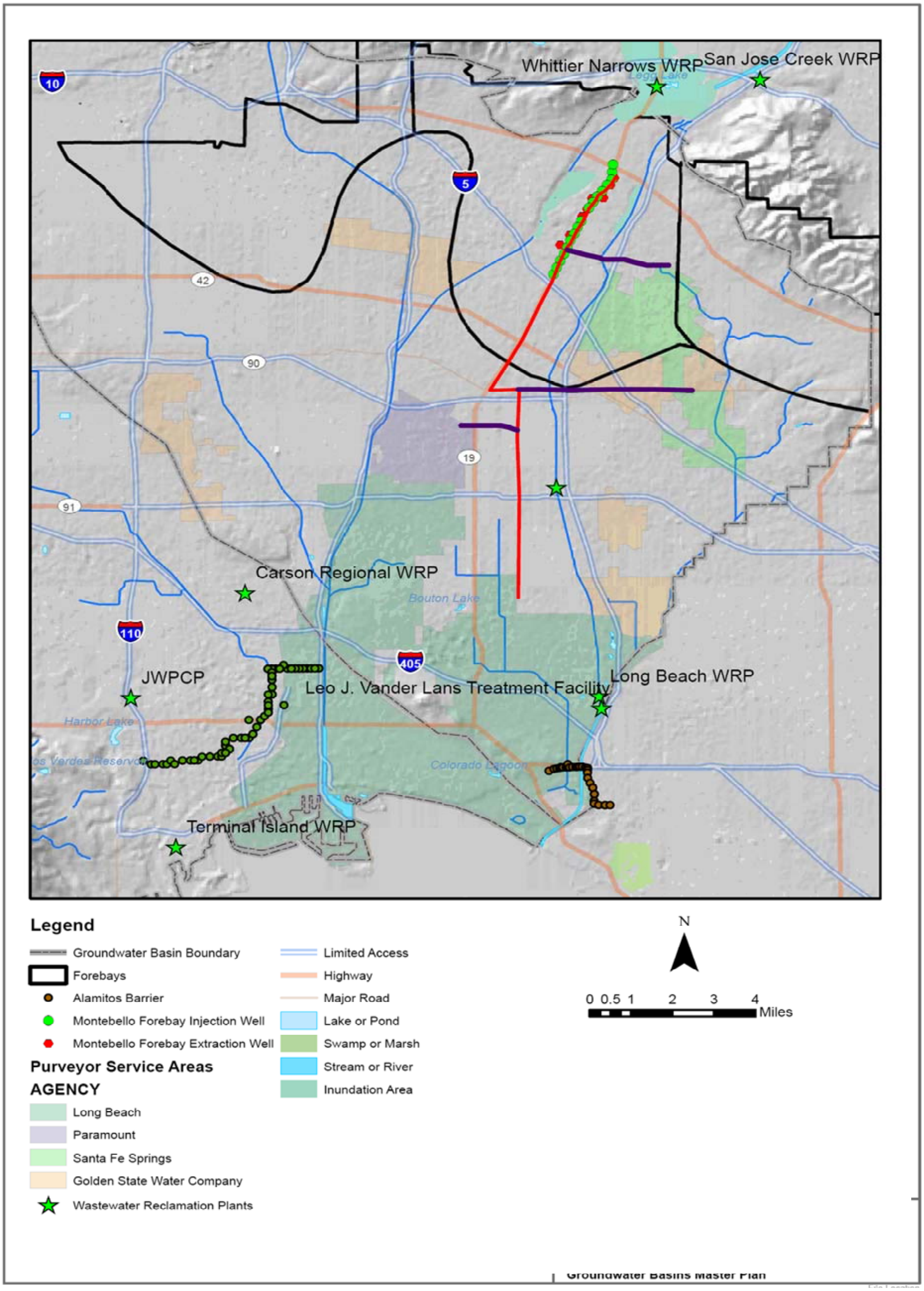
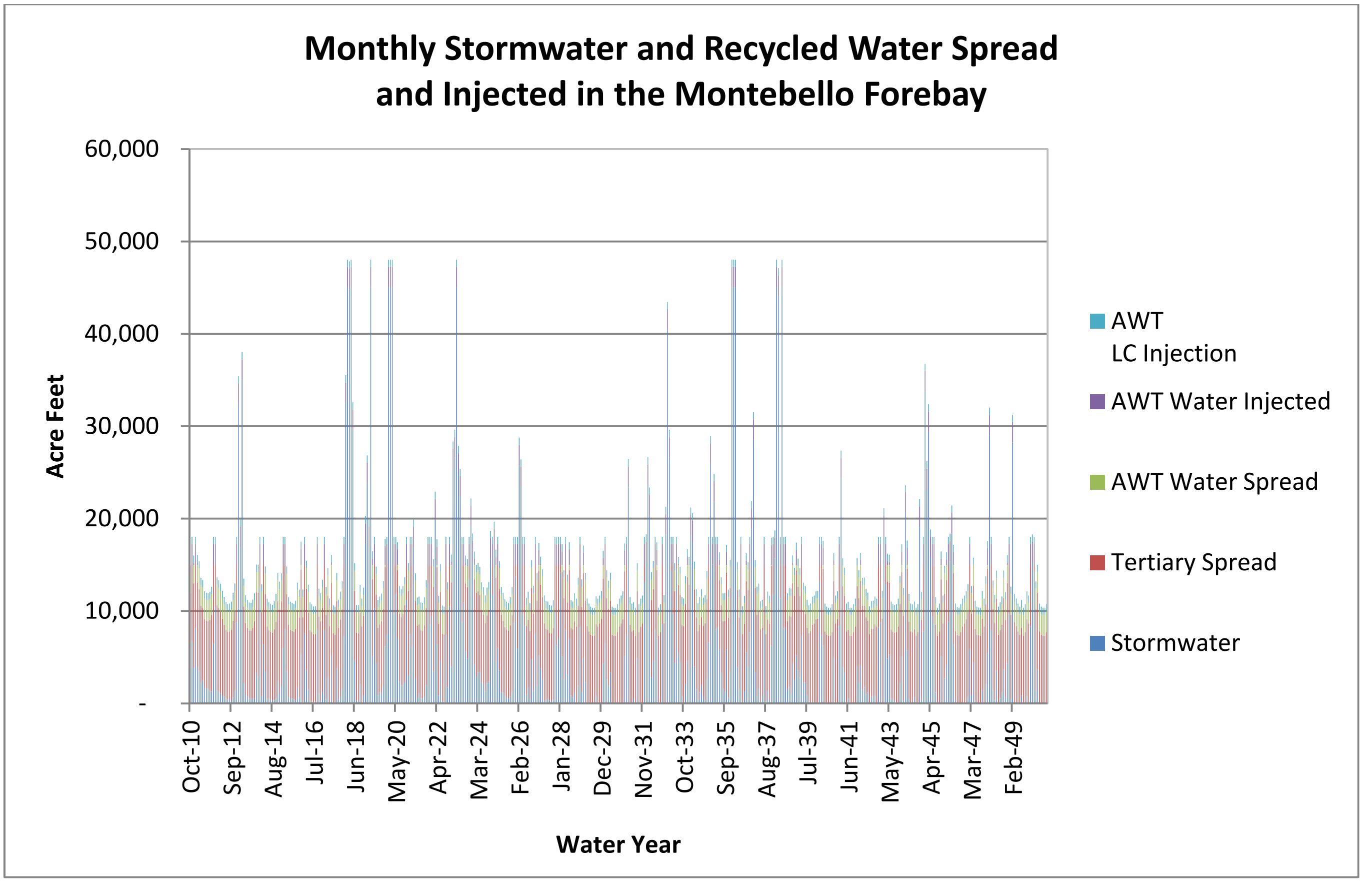


FIGURE 4-17
Projected Monthly Spreading and Injection in the Montebello Forebay Area – Scenario to Maximize Stormwater and Recycled Water Spread and Injected In the Montebello Forebay



4.6.2 Combination 4 – Model Simulation Results

Figure 4-18 shows selected hydrographs for model simulated groundwater levels in the Central Basin. Figure 4-19 shows groundwater-level contours for each of the four model layers. Hydrographs in the Montebello Forebay show groundwater levels in wells near the Rio Hondo spreading grounds rise to and slightly above land surface during high-rate recharge events in wet years. To reduce the rise of groundwater levels above ground surface, additional pumping would be required above the pumping assumed in this modeling combination. This additional pumping potentially could be accomplished by individual pumpers increasing pumping in the Montebello Forebay area, or increasing pumping from the Montebello Forebay extraction wells.

Figure 4-20 shows the cumulative change in storage in the West Coast and Central Basins under this combination. Figure 4-21 shows the Zonebudget summary for flow between the 10 zones of the West Coast and Central Basins. Figure 4-20 shows the basins are balanced over the simulation period in that there is not a surplus or deficit in storage at the end of the simulation period. This is also indicated by the groundwater level hydrographs, which end very close to the levels from which they started.

FIGURE 4-18
Selected Hydrographs Showing Simulated Groundwater Levels for Combination 4 Operating Conditions

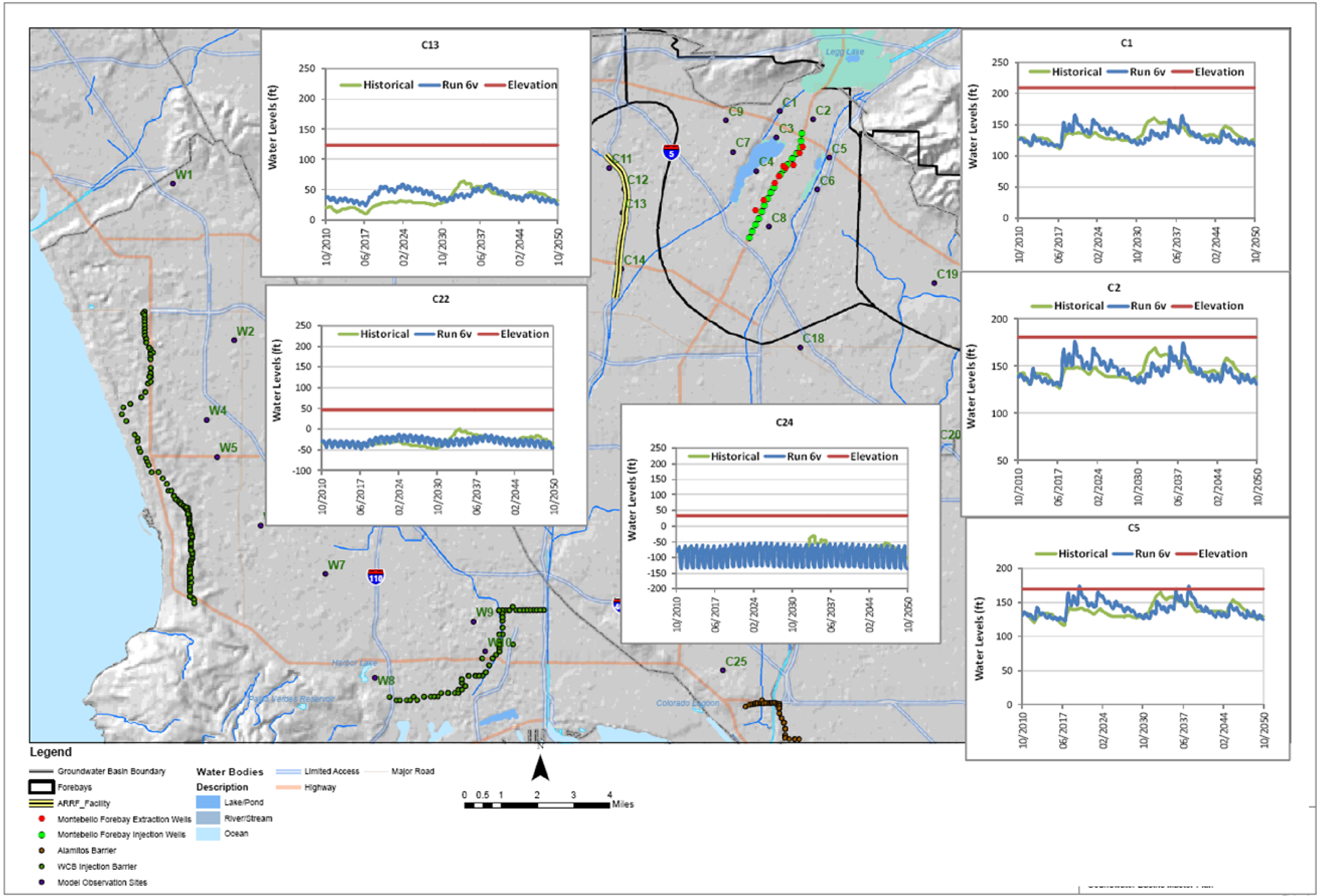


FIGURE 4-19
Groundwater Level Contours at the End of the Simulation Period (September 30, 2050) Under Combination 4

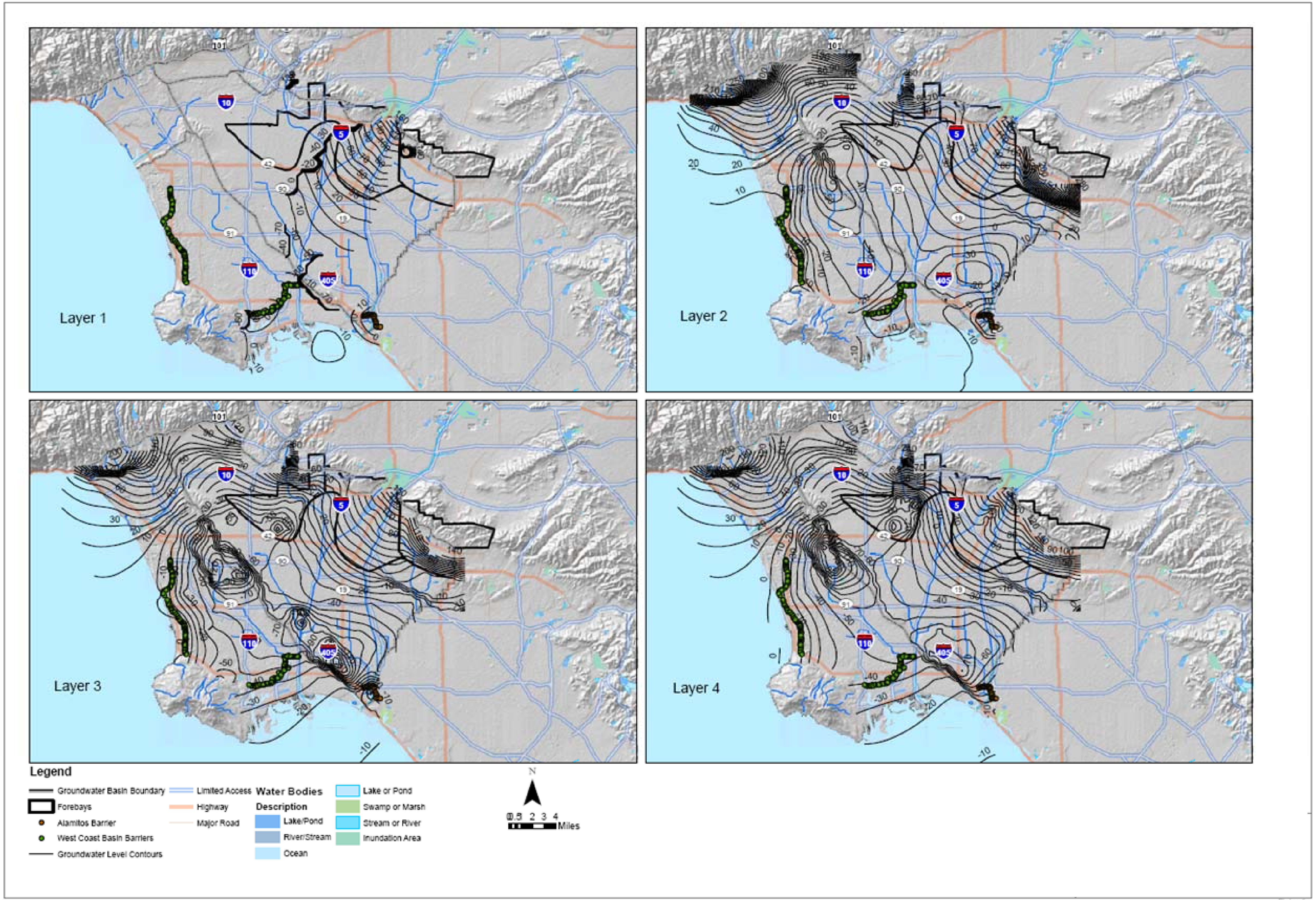


FIGURE 4-20
Cumulative Groundwater in Storage for the West Coast and Central Basins under Combination 4

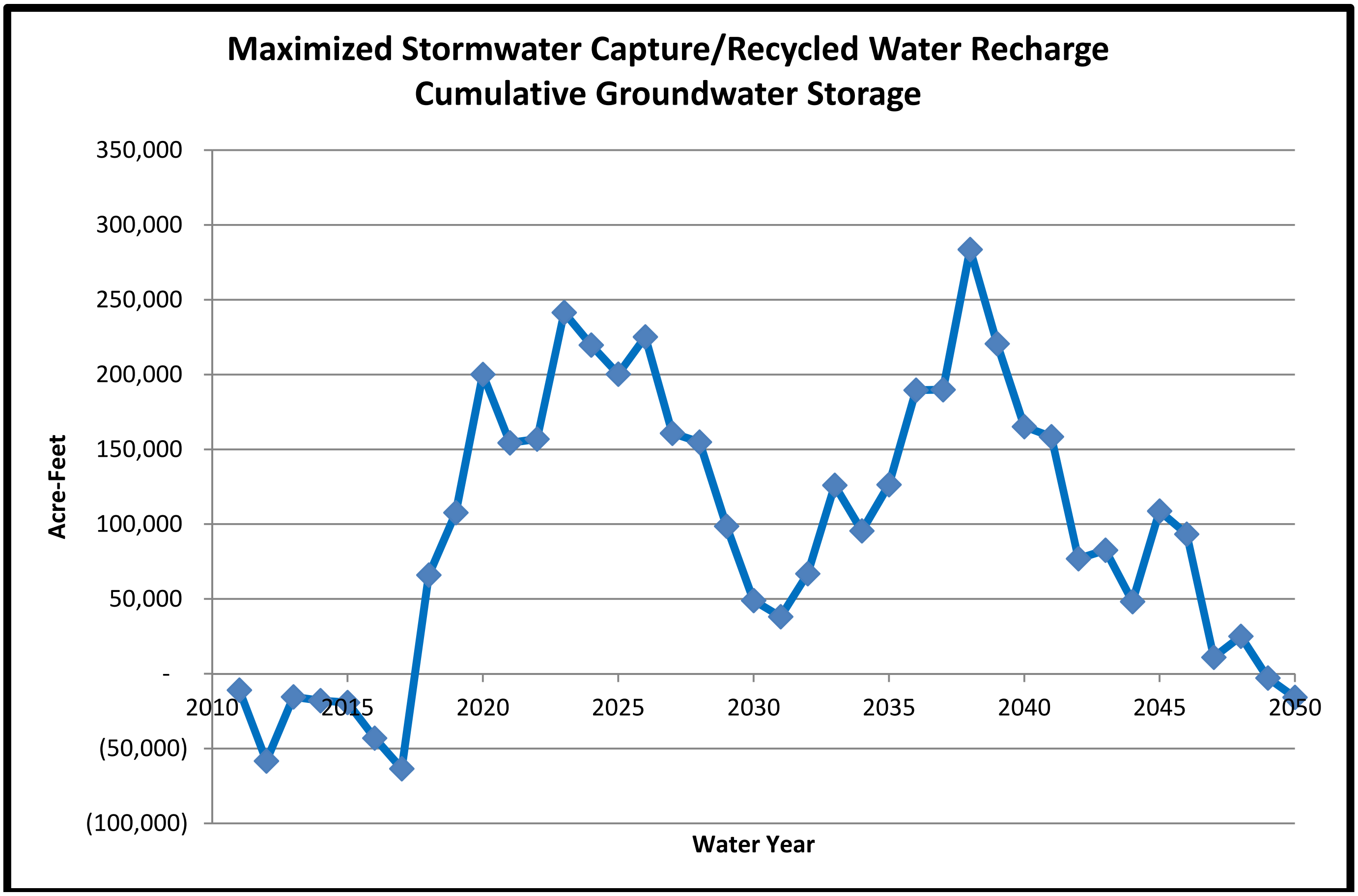
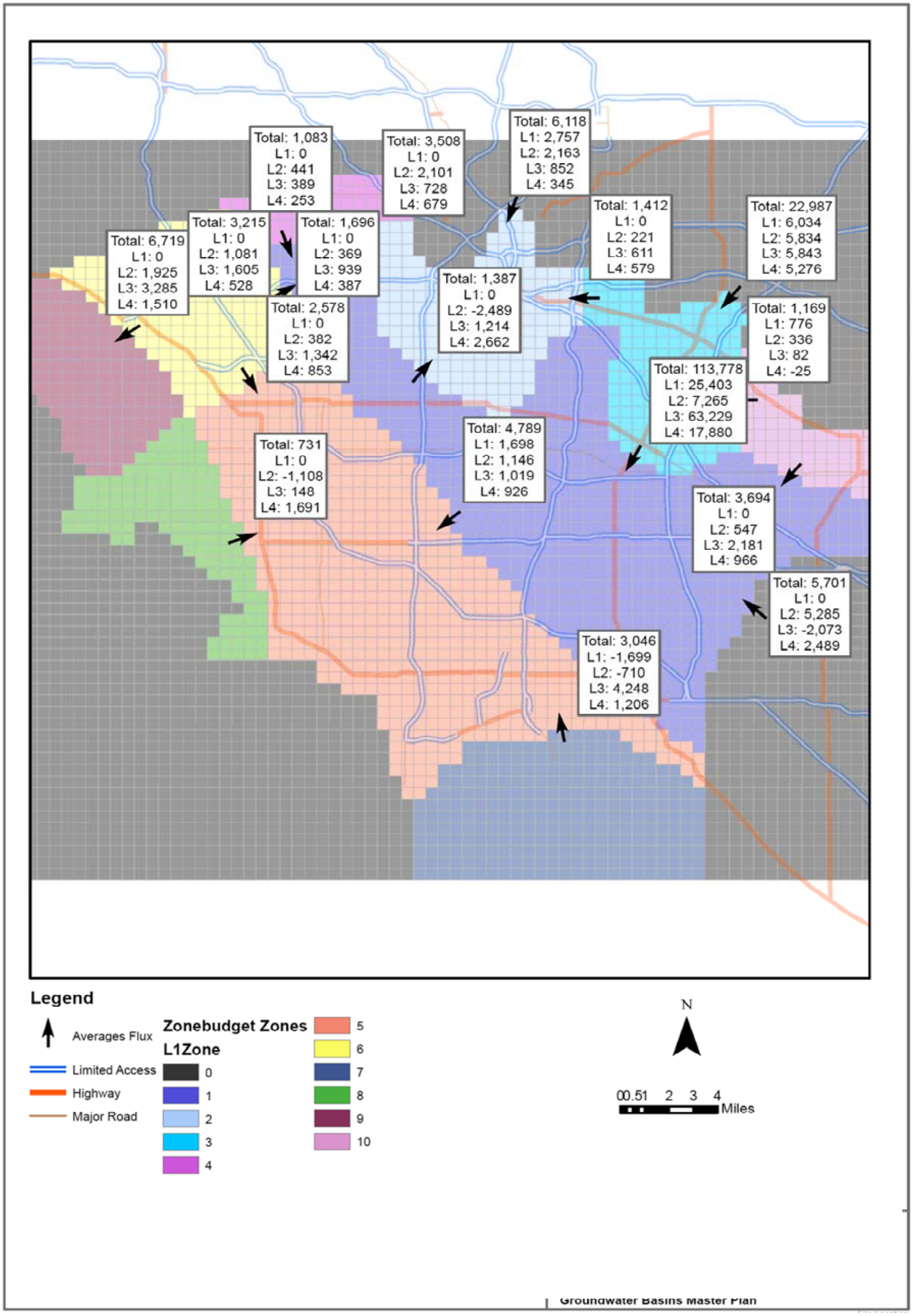


FIGURE 4-21
Zonebudget Summary of 10 Zones for Simulation Period (Water Years 2010 through 2050) Under Combination 4



4.7 Combination 5

Combination 5 modified Combination 4 by simulating even more recharge and extraction in the Los Angeles Forebay. This effectively provided sufficient groundwater extraction to replace nearly all of the imported water use in the Central Basin. The West Coast Basin was operated at water rights, as in the baseline Combination 1 operating condition.

4.7.1 Combination 5 – Assumptions and Model Input

This operating condition builds on Combination 4. Additional replenishment in the Los Angeles Forebay is sufficient to provide for an additional 45,480 AFY of pumping, for a total of 103,250 AFY of pumping above the Central Basin APA. This modeling combination assumes development of a satellite treatment facility in the Los Angeles Forebay that will intercept sewer flows to City of Los Angeles's HTP. A line of 50 injection wells would distribute 45,480 AFY of FAT-treated recycled water for recharge into the Los Angeles Forebay as shown in Figure 4-22.

A line of extraction wells would be developed in Los Angeles Forebay to extract 29,000 AFY for delivery to City of Los Angeles Manhattan and 99th Street wellfields, where water would be distributed to City of Los Angeles water system. The remaining quantity of recharged water not used by City of Los Angeles (16,480 AFY) would be redistributed to Central Basin pumpers. Table 3-8 shows the distribution of pumping to pumpers assumed under this operating condition. This distribution is made to offset imported water, so that nearly all imported water use in the Central Basin is eliminated under this modeling combination. All other recharge and extraction would be same as in the previous operating condition as described above in Combination 4.

4.7.2 Combination 5 – Model Simulation Results

Figure 4-23 shows selected hydrographs for model simulated groundwater levels in the Central Basin. Figure 4-24 shows groundwater level contours for each of the four model layers. Hydrographs in the Montebello Forebay show groundwater levels in wells near the Rio Hondo spreading grounds rise close to land surface during high-rate recharge events in wet years.

Figure 4-25 shows the cumulative change in storage in the West Coast and Central Basins under this modeling combination. Figure 4-26 shows the Zonebudget summary for flow between the 10 zones of the West Coast and Central Basins. Figure 4-25 shows the basins end with a significant surplus at the end of the simulation period. This surplus is largely contained in the Los Angeles Forebay, which indicates that replenishment is not equally balanced with pumping in this area. Figure 4-25 indicates that there is additional inflow from the basin boundaries, so that the pumping assigned to pumpers is not "pulling" water from the replenishment in the Los Angeles Forebay, but from adjacent areas to the Central Basin. This is also indicated by the groundwater level hydrographs.

FIGURE 4-22
Location of Injection and Extraction Facilities in the Los Angeles Forebay Area

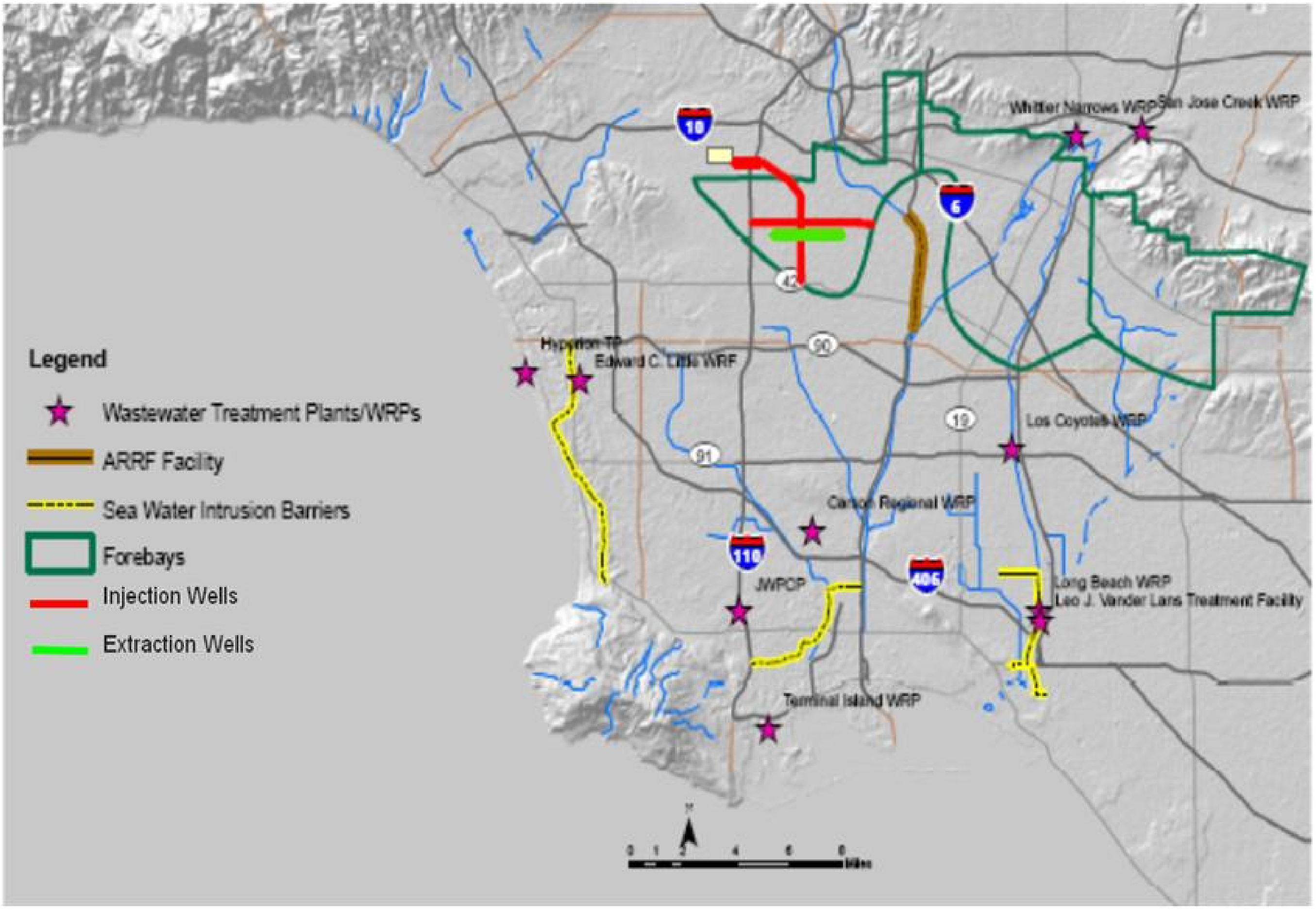


FIGURE 4-23
Selected Hydrographs Showing Simulated Groundwater Levels for Combination 5 Operating Conditions

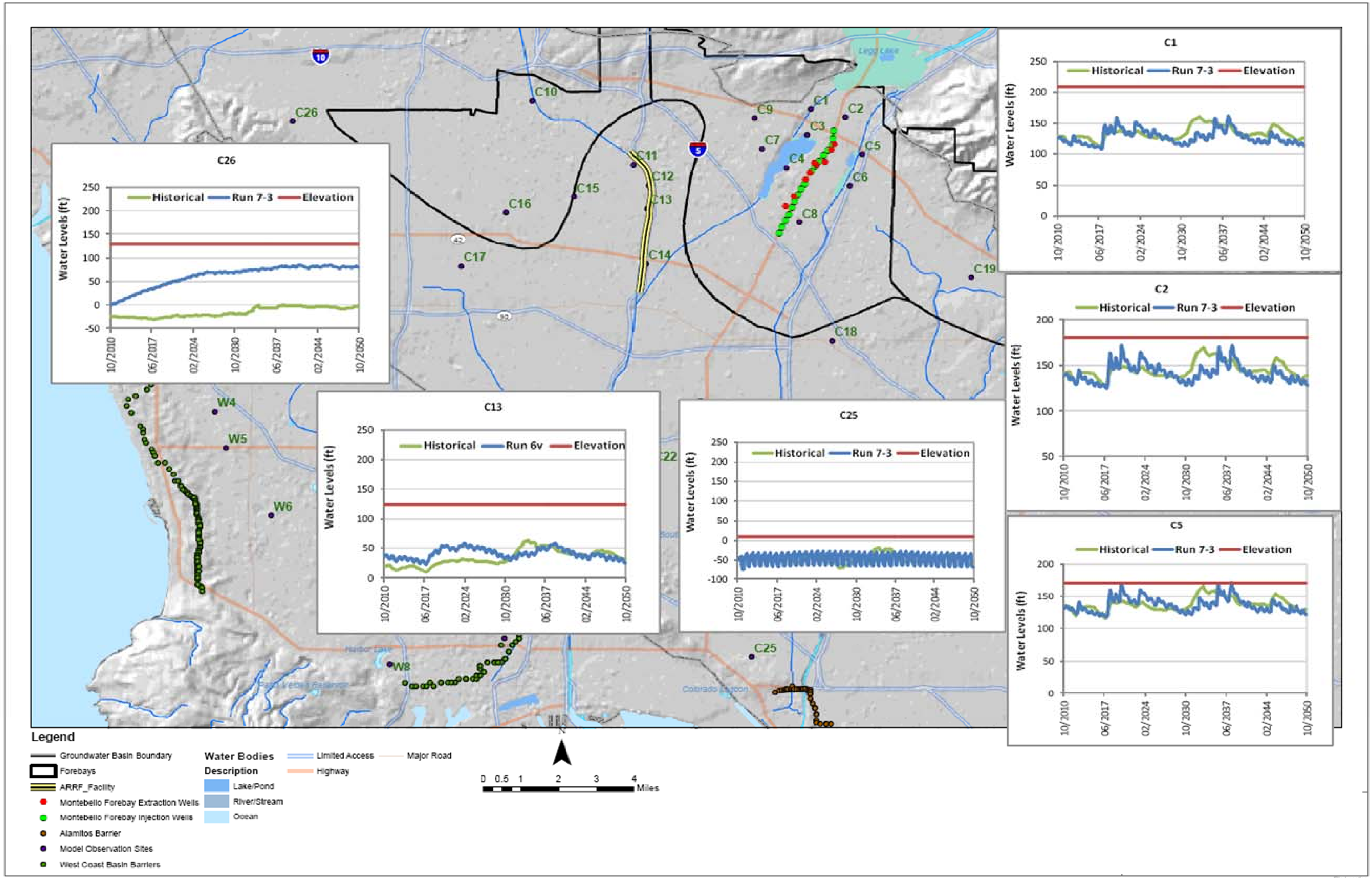


FIGURE 4-24
Groundwater Level Contours at the End of the Simulation Period (September 30, 2050) Under Combination 5

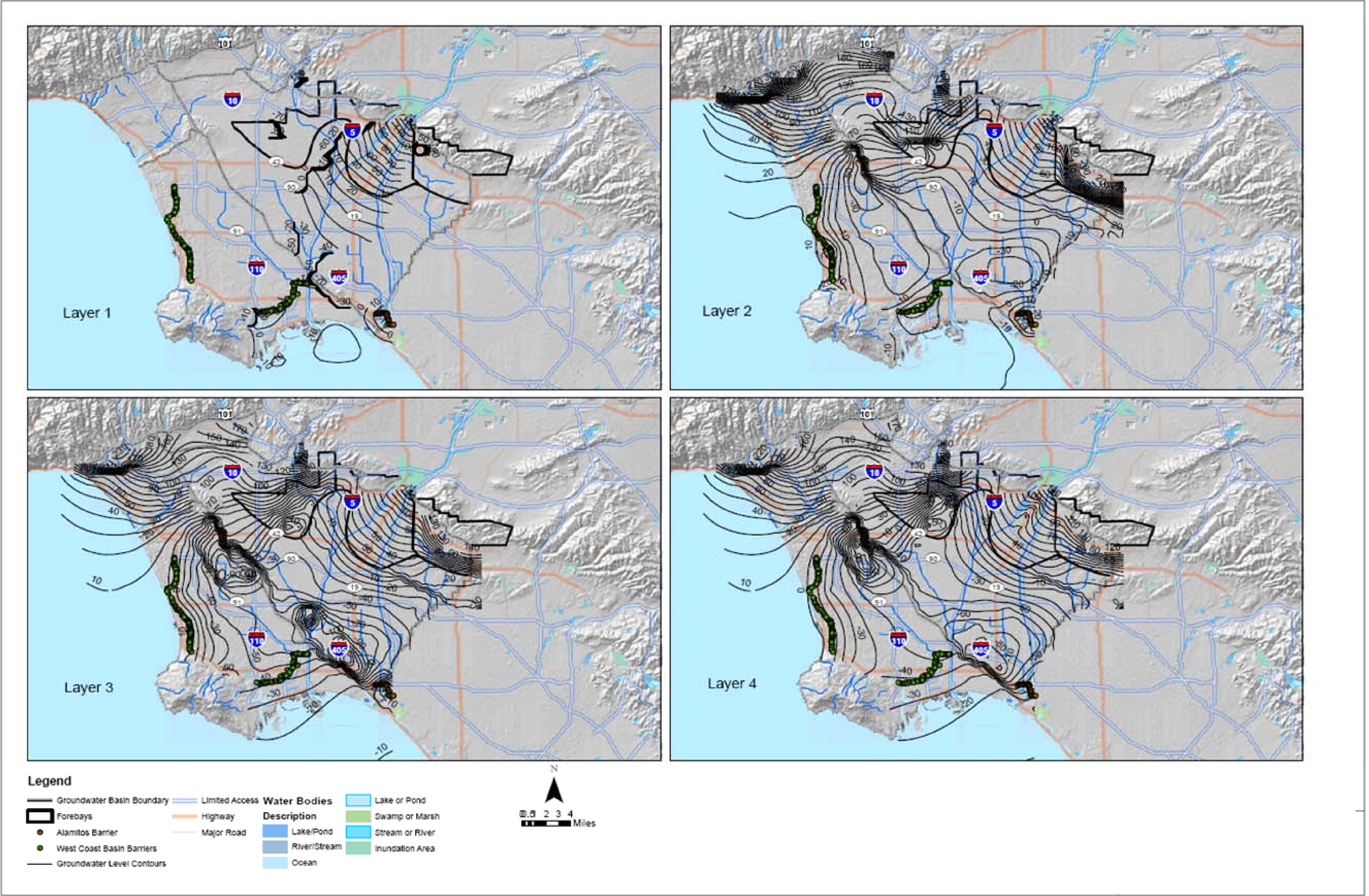


FIGURE 4-25
Cumulative Groundwater in Storage for the West Coast and Central Basins Under Combination 5

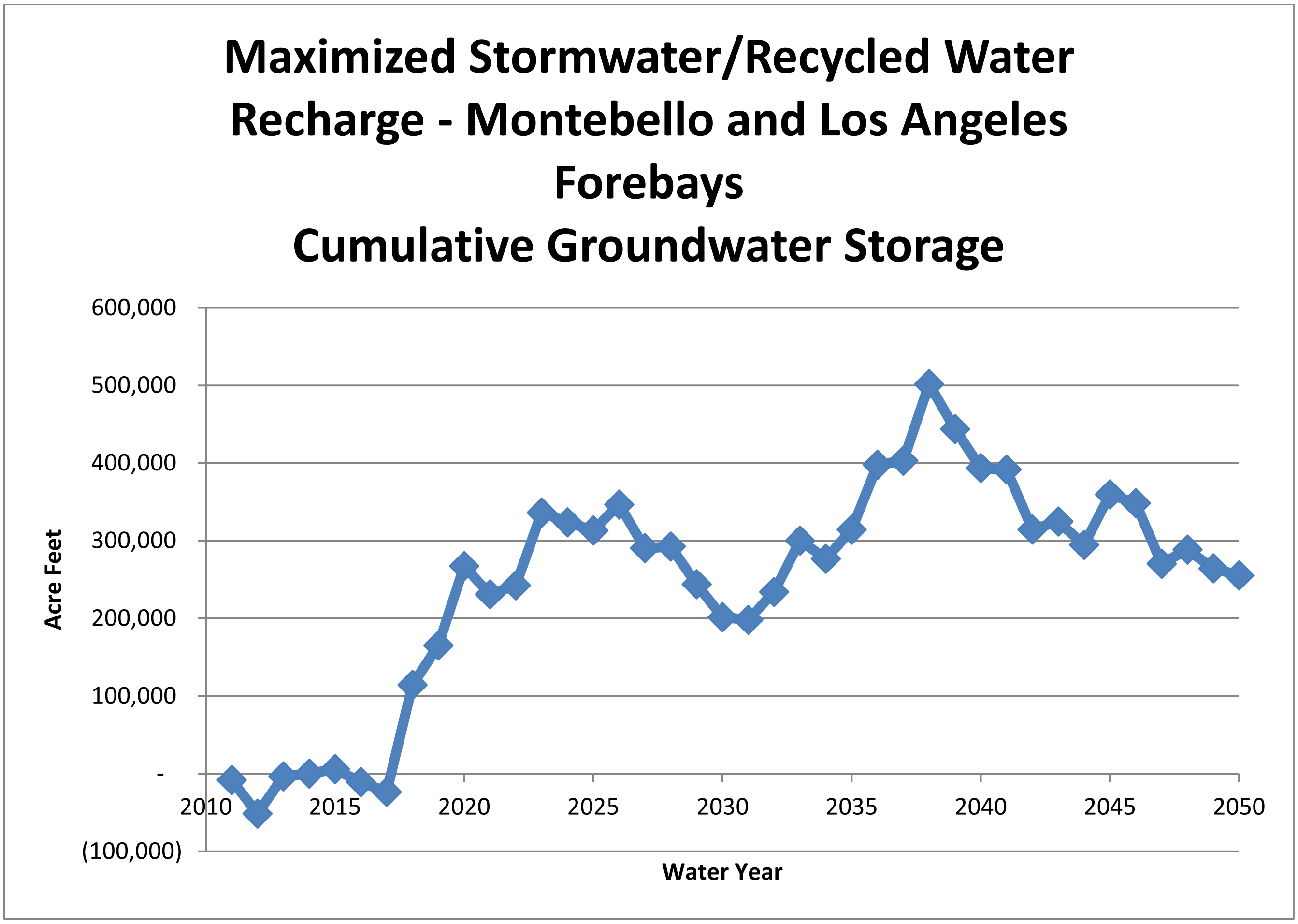
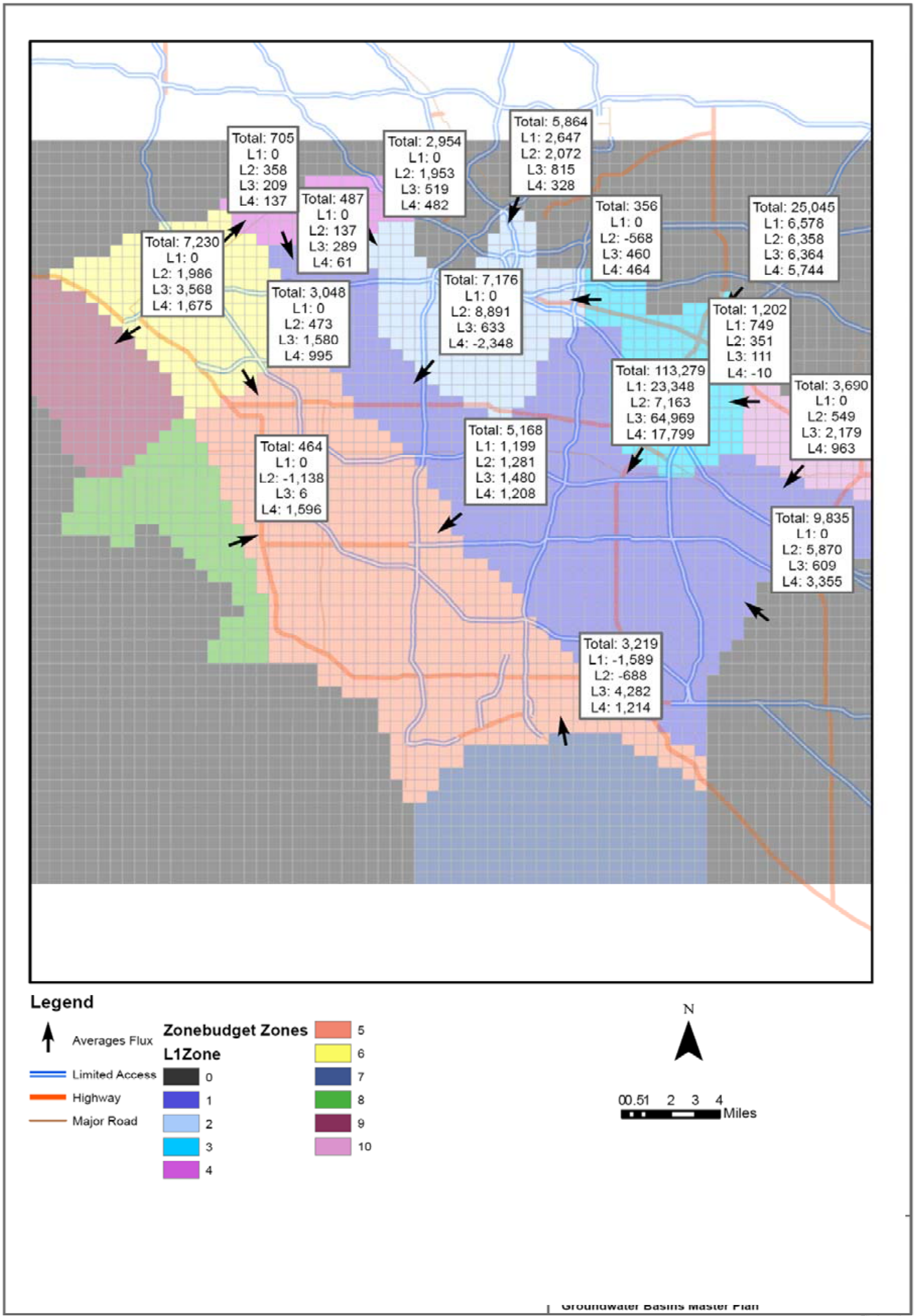


FIGURE 4-26
Zonebudget Summary of 10 Zones for Simulation Period (Water Years 2010 through 2050) under Combination 5



4.8 Combination 6

Combination 6 is the second operating condition simulated with the updated WRD/USGS groundwater flow model for the West Coast Basin. It assumes additional extraction of an additional 30,000 AFY above the West Coast Basin water rights. Replenishment is provided with additional recycled water injected at the existing sweater intrusion barriers, as well as a new line of inland injection wells. The Central Basin was operated at the APA, as in the baseline, Combination 1, operating condition.

4.8.1 Combination 6 – Assumptions and Model Input

In the Carson/Torrance area along Normandie Boulevard there is a potential capacity to inject between 15,000 to 25,000 AFY of recycled water. Under this modeling combination, 15,000 AFY of recycled water was considered for injection in this area using a series of new inland injection wells. In addition, injection to the WCBBP would be increased by 7,500 AFY and injection to the DGBP would be increased by 6,500 to 7,500 AFY, so that the overall additional replenishment would be increased by 30,000 AFY over the West Coast Basin water rights (that is, up to 94,468 AFY). The source of this replenishment supply would likely be a new AWTF at the LACSD JWPCP in Carson. Section 5.0 (Fig 5-4) shows the line of 14 injection wells that would be installed under this operating condition. As mentioned in Section 3.1.1.1 (Scenario WCB-B1), it is assumed that City of Torrance, CWSC, and the City of Los Angeles would pump a total of 30,000 AFY from wells at or near their existing wells to offset their imported water demands. All other pumping is the same as in the baseline Combination 1 operating condition, including the saline plume containment/removal pumping for the West Coast Basin.

4.8.2 Combination 6 – Model Simulation Results

Figure 4-27 shows selected hydrographs for model simulated groundwater levels in the Central Basin. Figure 4-28 shows groundwater level contours for each of the four model layers. Hydrographs show that groundwater levels are very similar to groundwater levels in the baseline Combination 1 operating condition, so that the distribution of injection and pumping are balanced.

Figure 4-29 shows the cumulative change in storage in the West Coast and Central Basins under this modeling combination. Figure 4-30 shows the Zonebudget summary for flow between the 10 zones of the West Coast and Central Basins. Figure 4-29 shows the basins are balanced over the simulation period in that there is not a surplus or deficit in storage at the end of the period. This is also indicated by the groundwater level hydrographs, which end very close to the levels from which they started.

FIGURE 4-27
Selected Hydrographs Showing Simulated Groundwater Levels for Combination 6 Operating Conditions

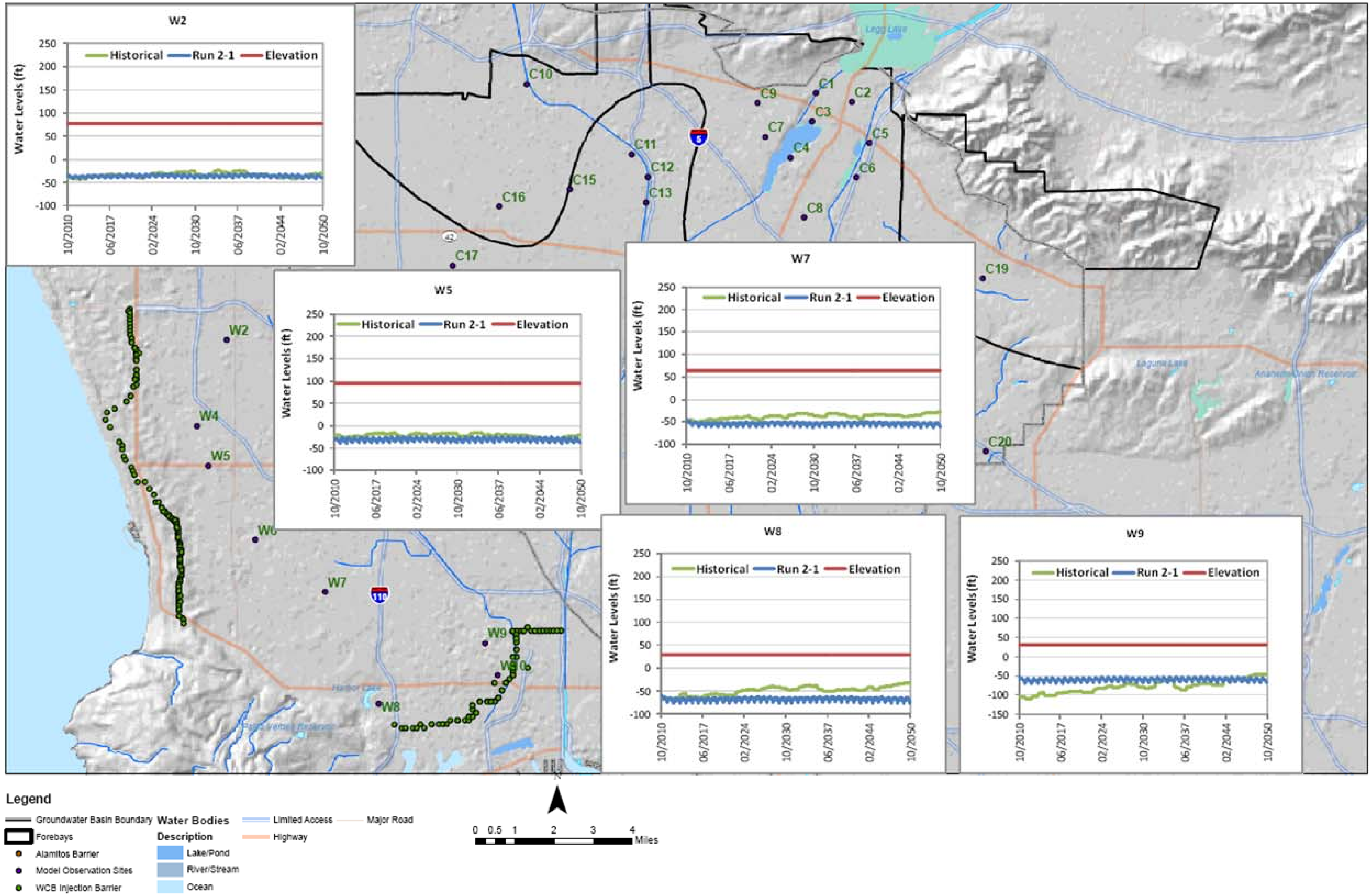


FIGURE 4-28
Groundwater Level Contours at the End of the Simulation Period (September 30, 2050) Under Combination 6

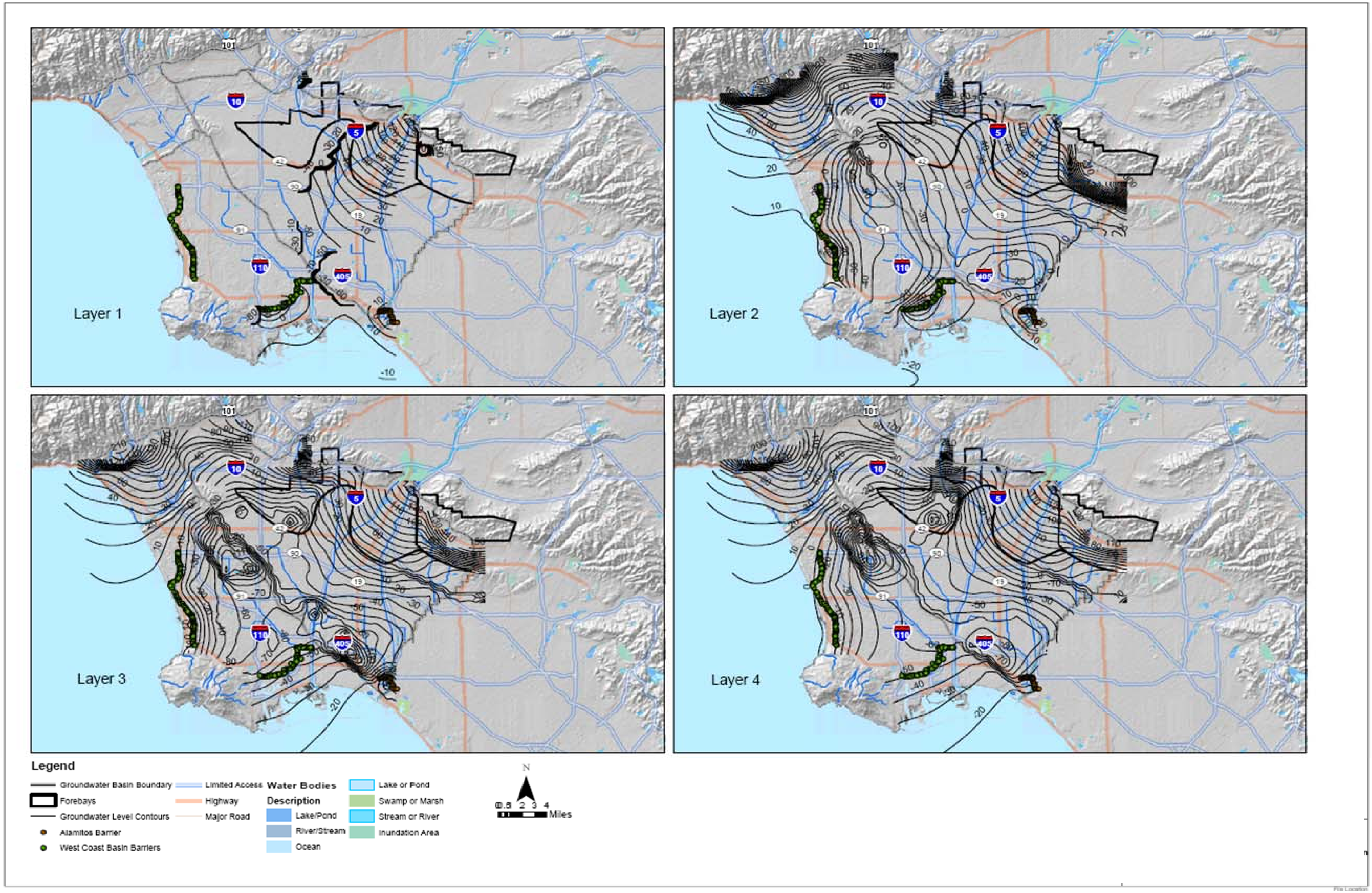


FIGURE 4-29
Cumulative Groundwater in Storage for the West Coast and Central Basins Under Combination 6

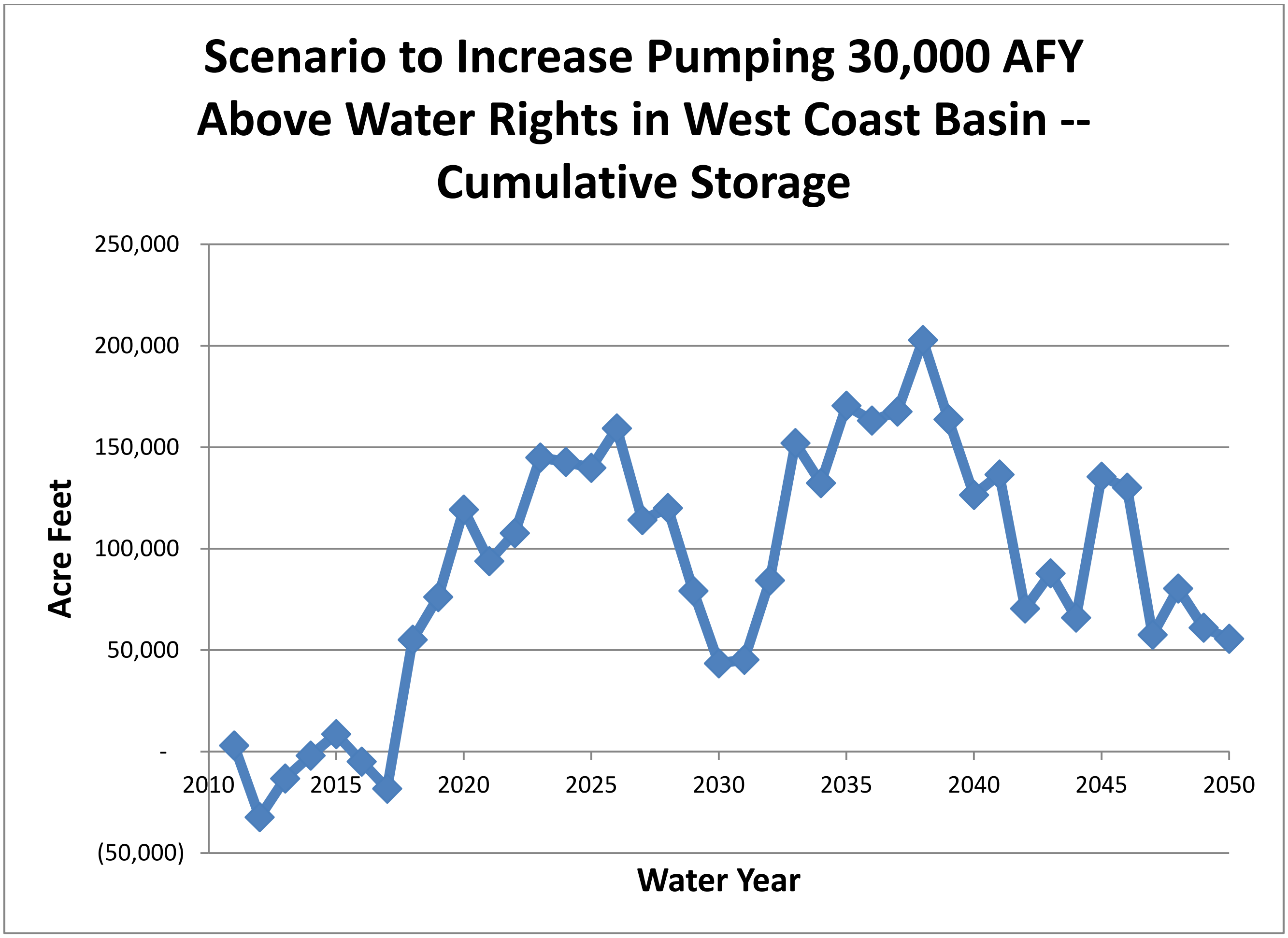
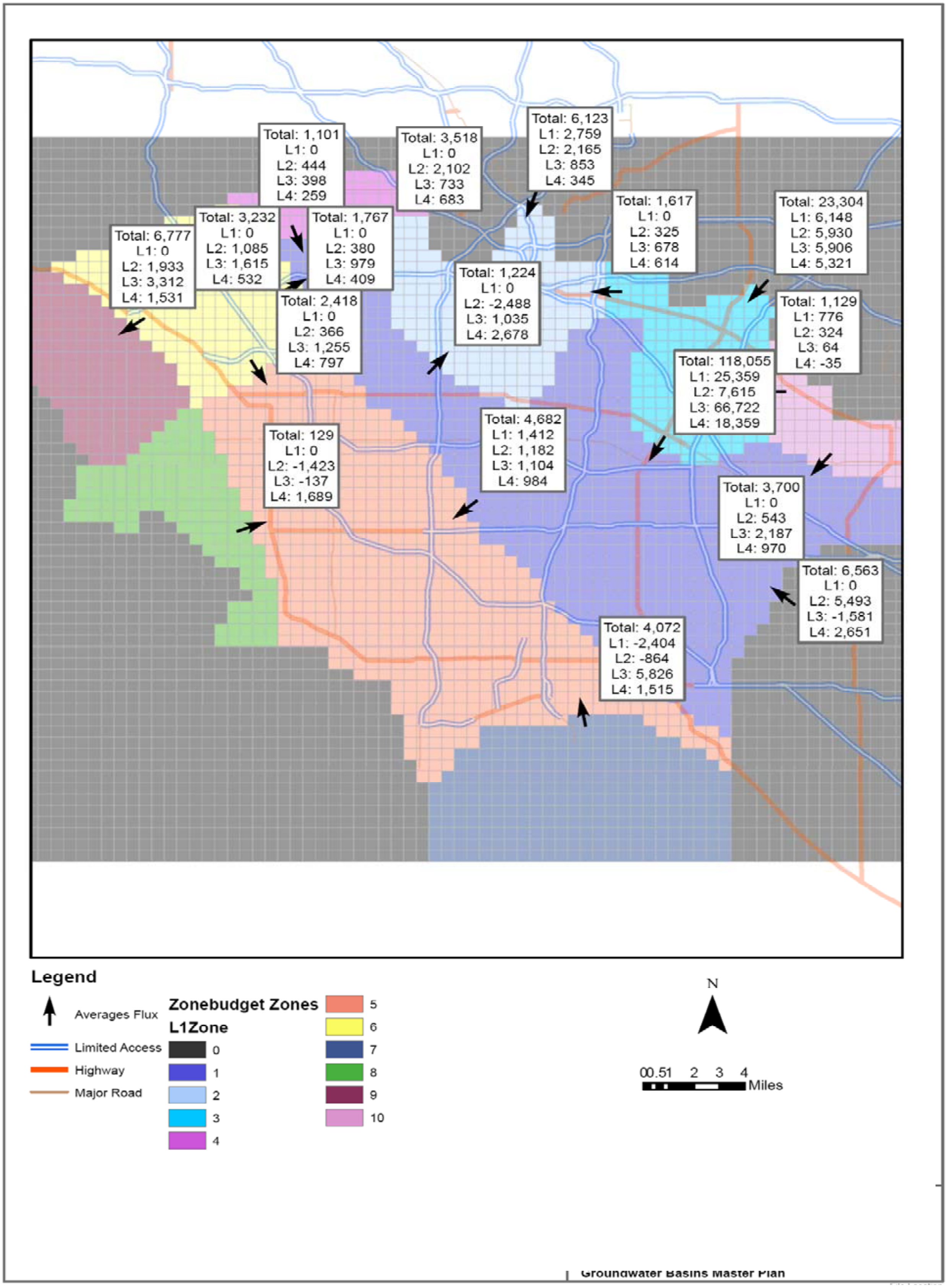


FIGURE 4-30
Zonebudget Summary of 10 Zones for Simulation Period (Water Years 2010 through 2050) Under Combination 6



4.9 Combination 7

Combination 7 is for an operating condition in which both the West Coast and Central Basins are pumped at levels above the water rights and APA, respectively.

4.9.1 Combination 7 – Assumptions and Model Input

This operating condition was a combination of pumping 57,700 AFY over APA in the Central Basin (which is the same as the conditions used in Combination 4) and 30,000 AFY over water rights in the West Coast Basin. Replenishment of West Coast Basin is accomplished in a similar manner as described in Combination 6 (under Scenario WCB-B1), but varied by increasing the amount of water replenished at the new inland injection wells to a total of 25,000 AFY, while injecting 35,000 AFY into the WCBBP and 10,000 AFY into the DGBP. Replenishment for the Central Basin is accomplished in the same manner as described Combination 4 (Scenario CB-B1).

4.9.2 Combination 7 – Model Simulation Results

Figure 4-31 shows selected hydrographs for model simulated groundwater levels in the Central Basin. Figure 4-32 shows groundwater level contours for each of the four model layers at the end of the simulation. Hydrographs show that groundwater levels are very similar to groundwater levels in for the two Central Basin and West Coast Basin operating conditions on which this modeling combination is based.

Figure 4-33 shows the cumulative change in storage in the West Coast and Central Basins under this modeling combination. Figure 4-34 shows the Zonebudget summary for flow between the 10 zones of the West Coast and Central Basins. Figure 4-33 shows the basins are balanced over the simulation period in that there is not a surplus or deficit in storage at the end of the period. This is also indicated by the groundwater level hydrographs, which end very close to the levels from which they started.

FIGURE 4-31
Selected Hydrographs Showing Simulated Groundwater Levels for Combination 7 Operating Conditions

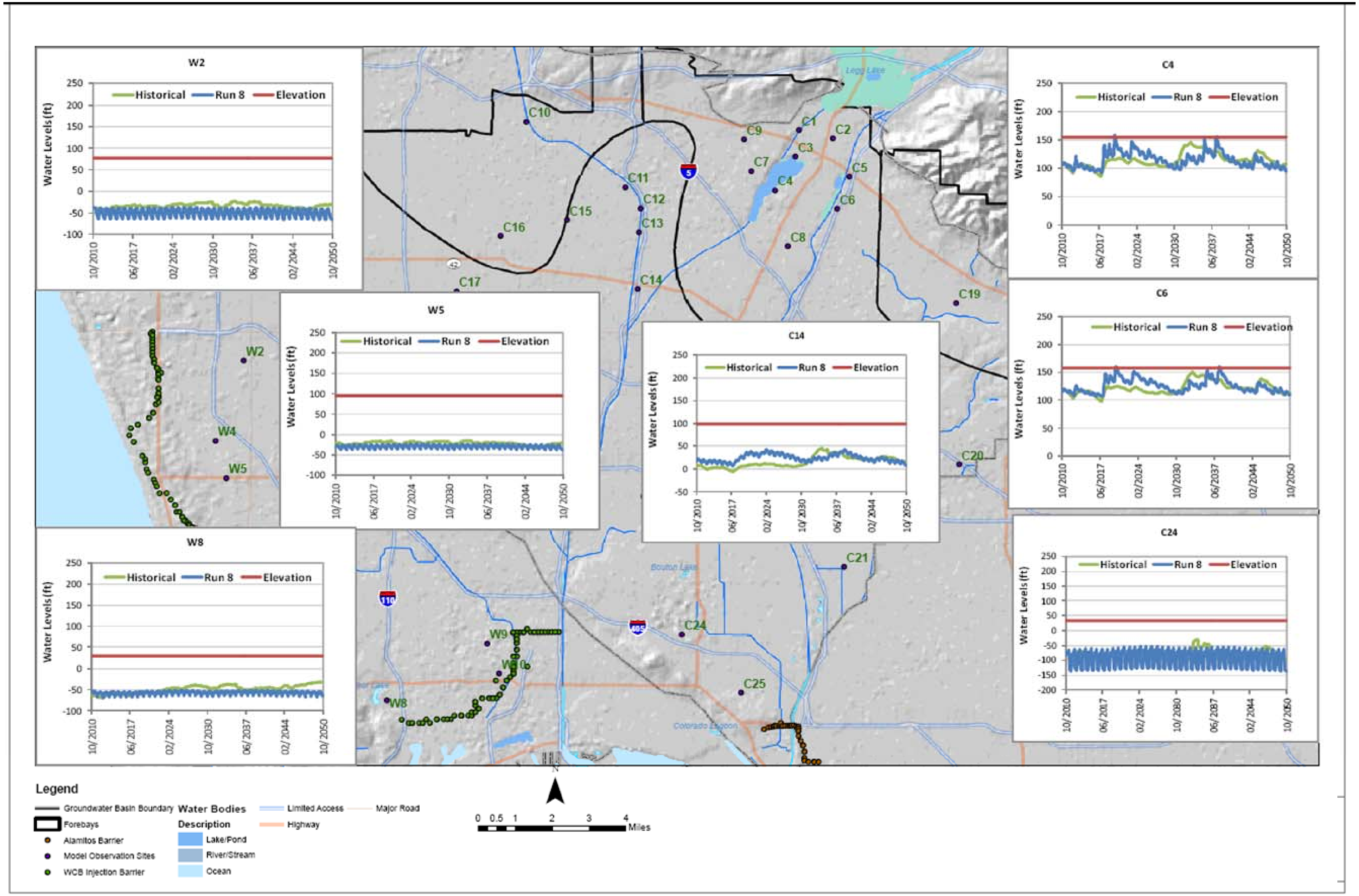


FIGURE 4-32
Groundwater Level Contours at the End of the Simulation Period (September 30, 2050) Under Combination 7

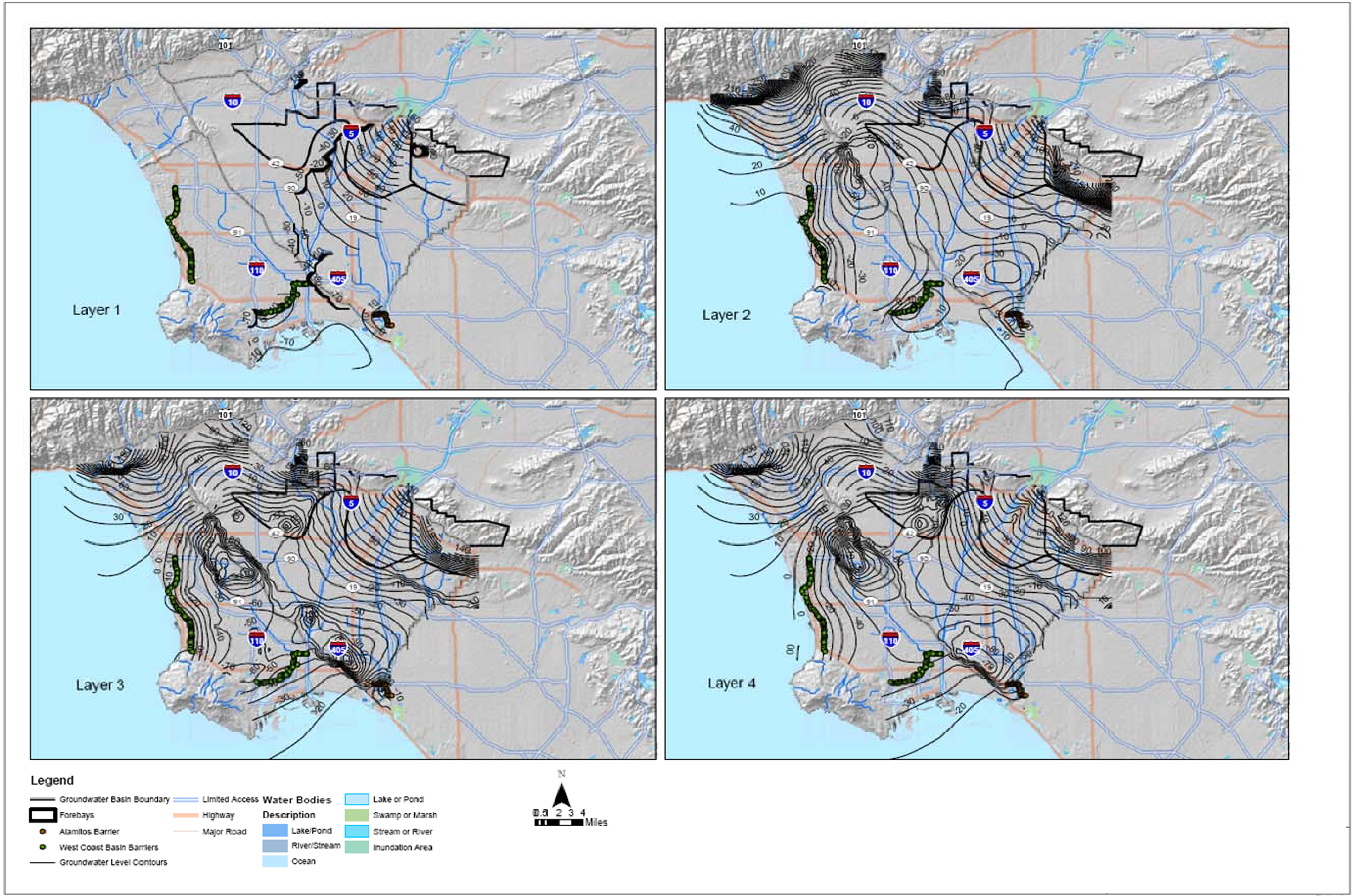


FIGURE 4-33
Cumulative Groundwater in Storage for the West Coast and Central Basins Under Combination 7

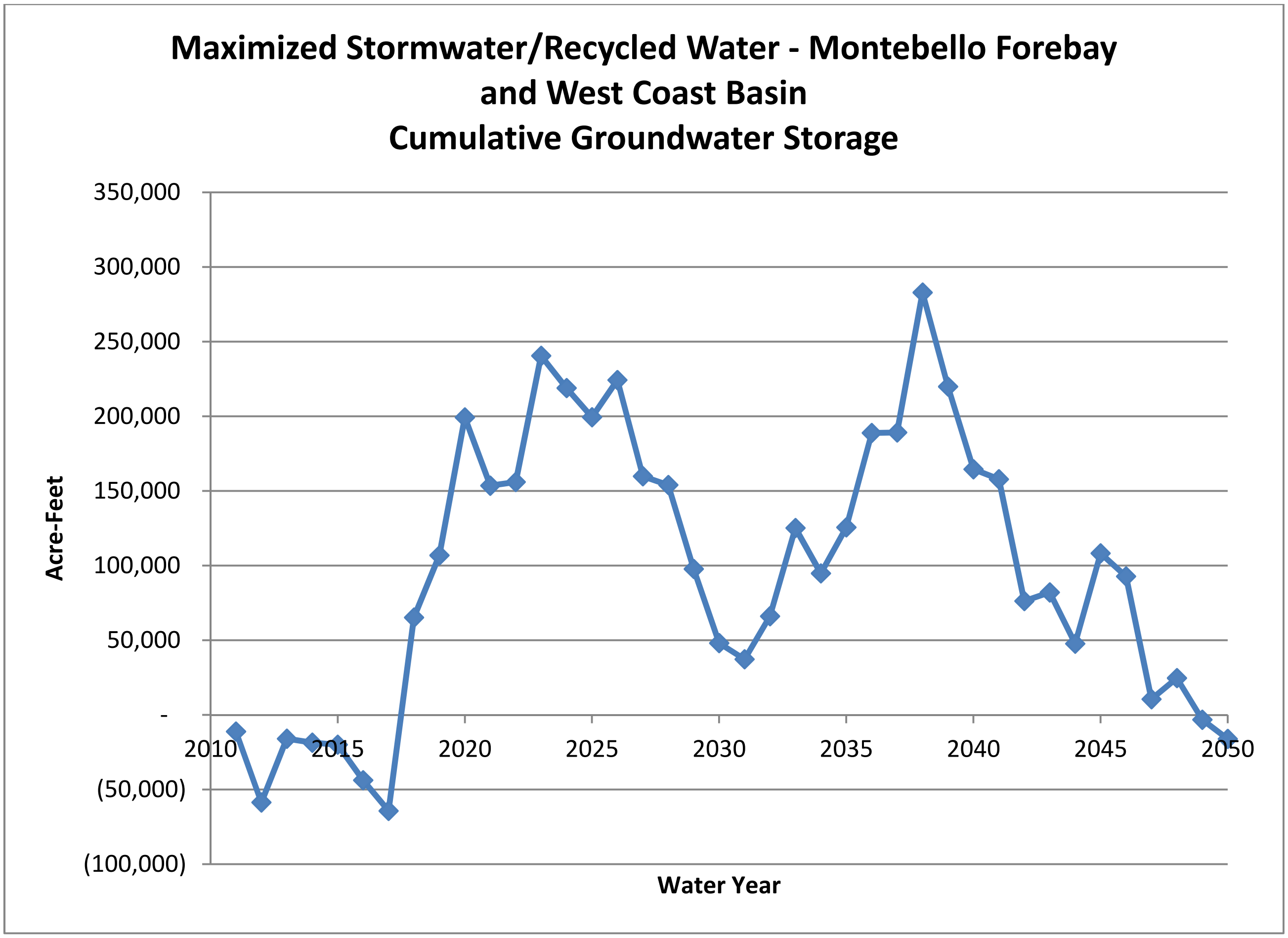
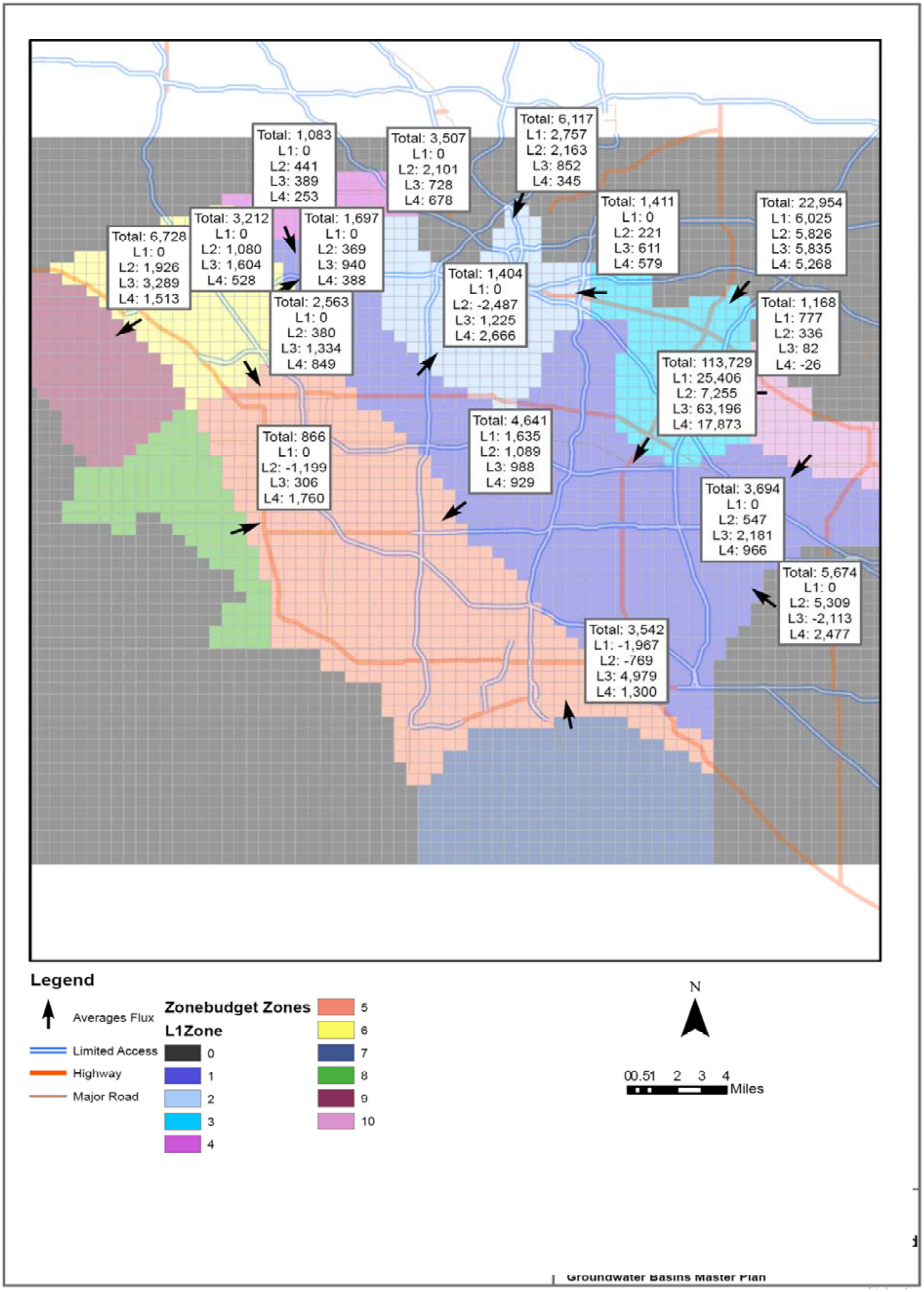


FIGURE 4-34
Zonebudget Summary of 10 Zones for Simulation Period (Water Years 2010 through 2050) Under Combination 7



SECTION 5.0

Formulation and Evaluation of Alternatives

5.1 Groundwater Basins Master Plan Components

GBMP alternatives were developed based on combining GBMP projects to provide sufficient replenishment to meet the water rights in the West Coast Basin and the APA in the Central Basin (Concept A) or exceed these adjudicated, consistent with the proposed Judgment amendments (Concept B). The projects are combined into GBMP alternatives, which are crafted to satisfy the target supply yields for the planning scenarios described in Section 3.0. Thus the alternatives with common supply yields can be directly compared against one another. Table 5-1 indicates the relationships between the GBMP Concepts, Scenarios and Alternatives.

Projects consist of facility components, such as treatment, conveyance (pump stations and pipelines), brine disposal, extraction wells and production wells. Each project includes a unique supply and recharge method and location. The recycled water and stormwater supplies considered, which were discussed in Section 3.0, include:

- SJCWRP
- LCWRP
- LBWRP
- TIWRP
- ECLWRF
- JWPCP
- San Gabriel River/Rio Hondo
- Los Angeles River

Recharge methods include surface spreading and injection. The potential locations, which were discussed in Section 3.0, include:

- MFSG
- ABP
- WCBBP
- DGBP
- New injection wells in both basins

TABLE 5-1
GBMP Concepts, Scenarios and Alternatives

Basin	Concept	Scenario	Alternative	Description (Pumping/Replenishment)
West Coast Basin	A (Meet Water Rights)	Scenario WCB-A1		Pump full water rights per 3 scenarios: WCB-A1a, WCB-A1b, WCB-A1c; Shift oil companies' non-potable demands from groundwater to recycled water, and shift this groundwater pumping to municipal purveyors; Assume 100% RWC at injection barriers (WCBBP and DGBP).
		Scenario WCB-A1a		Distribute to major water rights holders (Torrance, CWSC, Golden State Water Company, Manhattan Beach, El Segundo, Inglewood, and Lomita) and City of Los Angeles extracts their adjudicated rights.
		Scenario WCB-A1b		Distribute to major water rights holders and to the City of Los Angeles.
		Scenario WCB- A1c		Regional Partnership – Includes **containment/remediation of saline plume**.
			Alt. WCB-A1	Expansion of existing barrier recycled water supplies by 18,000 AFY (to a total of 40,000 AFY) to meet pumping at total water rights of 64,468 AFY. Additional replenishment includes injection of an additional 15,500 AFY beyond current supply capacity to WCBBP and replacement of imported blend water at DGBP.
		Scenario WCB-A2		Reduce or eliminate injection in Lower San Pedro aquifer by balancing pumping in Silverado aquifer.
		Scenario WCB-A3		Inject surplus imported water only when available (2 out of 10 years) and reduce or eliminate injection into Lower San Pedro aquifer during the remaining (8) years.
		Scenario WCB-A4		Pump and treat from Lower San Pedro aquifer.
	B (Above Water Rights)	Scenario WCB-B1		Pump additional **30,000 AFY above water rights** – Assume this pumping is distributed to CWSC, City of Torrance, and City of Los Angeles; otherwise all other pumping is the same as Scenario WCB-A1c; Increase injection at DGBP, WCBBP and using new inland injection wells (assuming 100% RWC); Includes containment/remediation of saline plume.
			Alt. WCB-B1	Expansion of up to 48,000 AFY of additional replenishment supply (18,000 AFY to meet existing water rights and 30,000 AFY for expanded pumping), including use of 22,500 AFY of JWPCP effluent to new inland injection wells and to DGBP.
			Alt. WCB-B2	Expansion of up to 48,000 AFY of additional replenishment supply (18,0000 AFY to meet existing water rights and 30,000 AFY for expanded pumping), including use of up to 16,000 AFY of JWPCP effluent to new inland injection wells only (TIWRP supply expanded for DGBP by expanding AWTF by an additional 6,500 AFY)
Central Basin	A (Meet APA)	Scenario CB-A1		Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with imported water usage; Assume 100% RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP** effluent for **spreading** at the MFSG.*
			Alt. CB-A1a	SJCWRP-100% tertiary

TABLE 5-1
GBMP Concepts, Scenarios and Alternatives

Basin	Concept	Scenario	Alternative	Description (Pumping/Replenishment)
			Alt. CB-A1b	SJCWRP-100% FAT
			Alt. CB-A1c	SJCWRP-50% FAT / 50% tertiary
			Alt. CB-A1d	SJCWRP-100% NF/UV/AOP
			Alt. CB-A1e	SJCWRP-50% NF/UV/AOP / 50% tertiary
			Alt. CB-A1f	SJCWRP-ozone/BAC/GAC/UV
		Scenario CB-A2		Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with imported water usage; Assume 100% RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP and LCWRP** effluent for **spreading** at MFSG.*
			CB-A2a	SJCWRP-100% tertiary / LCWRP-100% FAT
			CB-A2b	SJCWRP and LCWRP-100% FAT
		Scenario CB-A3		Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with imported water usage; Assume 100% RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP** effluent for **spreading** at MFSG and **LCWRP** FAT-treated effluent for **injection** in Montebello Forebay.*
			CB-A3a	SJCWRP-100% tertiary / LCWRP-100% FAT
			CB-A3b	SJCWRP & LCWRP-100% FAT
		Scenario CB-A4		Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with imported water usage; Assume 100% RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP** effluent for **spreading** at MFSG and **enhanced stormwater capture in Montebello Forebay.***
			CB-A4a	SJCWRP-100% tertiary, FIX-IT project
			CB-A4b	SJCWRP-100% FAT, FIX-IT project
		Scenario CB-A5		Pump full APA by distributing additional pumping similarly to recent 10 years of extraction and allocate unused water rights to pumpers with imported water usage; Assume 100% RWC at injection barrier (ABP); *Increase replenishment by 31,000 AFY using **SJCWRP** effluent for **spreading** at MFSG and **stormwater capture in Los Angeles Forebay using ARRF project.***

TABLE 5-1
GBMP Concepts, Scenarios and Alternatives

Basin	Concept	Scenario	Alternative	Description (Pumping/Replenishment)
			CB-A5a	SJCWRP-100% tertiary, ARRF project
			CB-A5b	SJCWRP-100% FAT, ARRF project
			CB-A5c	SJCWRP-50% FAT / 50% tertiary, ARRF project
	B (Above APA)	Scenario CB-B1		Maximizing use of stormwater capture from **San Gabriel and Los Angeles Rivers** (22,000 AFY) and available recycled water from **SJCWRP and LCWRP** (66,800 AFY) in the Montebello Forebay allows for increased pumping of **57,770 AFY above the APA.**
			CB-B1a	SJCWRP-100% tertiary / LCWRP-100% FAT, FIX-IT project, ARRF project
			CB-B1b	SJCWRP & LCWRP-100% FAT, FIX-IT project, ARRF project
			CB-B1c	SJCWRP-50% FAT / 50% tertiary / LCWRP-100% FAT, FIX-IT project, ARRF project
		Scenario CB-B2		Injection of 45,480 AFY of FAT-treated effluent from **new satellite AWTF** at new line of extraction wells in Los Angeles Forebay, in conjunction with maximizing stormwater capture and recycled water use (per Scenario CB-B1) allows for increased pumping in the Montebello and Los Angeles Forebays to a total of **103,270 AFY above the APA.**
			CB-B2a	New AWTF, SJCWRP-100% tertiary / LCWRP-100% FAT, FIX-IT project, ARRF project
			CB-B2b	New AWTF, SJCWRP and LCWRP-100% FAT, FIX-IT project, ARRF project

Notes:

% = percent
Gray-shaded scenarios are not carried forward into the formulation of GBMP alternatives.

The GBMP alternatives comprise the projects listed in Table 5-2. The projects identified for each basin are described below.

TABLE 5-2
List of GBMP Projects

ID	Replenishment Supply	Replenishment Location/Method	Annual Average Replenishment (AFY)
West Coast Basin			
WCB-P1	ECLWRF AWT	WCBBP	15,500 to 23,000
WCB-P2	TIWRP AWT	DGBP	2,500 to 9,000
WCB-P3	JWPCP AWT	DGBP	7,500
WCB-P4	JWPCP AWT	Mid-basin injection wells	15,000 to 16,000
Central Basin			
CB-P1	SJCWRP	MFSG	31,000
CB-P2	SJCWRP – 100% AWT	MFSG	31,000
CB-P3	SJCWRP – 50% AWT	MFSG	31,000
CB-P4	SJCWRP – 100% NF	MFSG	31,000
CB-P5	SJCWRP – 50% NF	MFSG	31,000
CB-P6	SJCWRP – Ozone/BAC/GAC/UV	MFSG	31,000
CB-P7	LCWRP AWT	MFSG	15,500
CB-P8	LCWRP FAT	Injection at Montebello Forebay	15,500
CB-P9	San Gabriel River/Rio Hondo	MFSG	17,000
CB-P10	Los Angeles River	ARRF at Los Angeles Forebay	5,000
CB-P11	New Satellite AWT (MBR/RO/AOP)	Los Angeles Forebay injection wells	45,480

Notes:

ID = Identification Number
MBR = membrane bioreactor

5.1.1 West Coast Basin

The West Coast Basin projects consist of injection of various recycled water supplies. Four projects are defined in this section:

- WCB-P1: ECLWRF to WCBBP
  - P1a: 15,500 AFY
  - P1b: Additional 7,500 AFY
- WCB-P2: TIWRP to DGBP
  - P2a: 2,500 AFY
  - P2b: Additional 6,500 AFY
- WCB-P3: JWPCP to DGBP, 7,500 AFY
- WCB-P4: JWPCP to Mid-basin
  - P4a: 15,000 AFY
  - P4b: 16,000 AFY

5.1.1.1 WCB-P1: ECLWRF to WCBB

Two project sizes are defined for this project. The initial project (**WCB-P1a**) would expand injection at WCBBP by 15,500 AFY from 17,000 AFY to 32,500 AFY with secondary effluent from HTP conveyed to an expanded AWTF at ECLWRF and new offsite AWTF. The AWTF product water would be conveyed to the existing WCBBP connection point. The initial project would be expanded for an additional 7,500 AFY (**WCB-P1b**) to 40,000 AFY and is based on the estimated maximum WCBBP injection capacity using existing injection wells (Appendix E). The initial project size to meet 32,500 AFY of injection is designed to meet projected geographical distribution of pumping in the basin within existing water rights. The expanded project size is based on the maximum potential sustainable injection of 40,000 AFY, again paired with the projected geographical distribution of pumping in the area, beyond existing water rights.

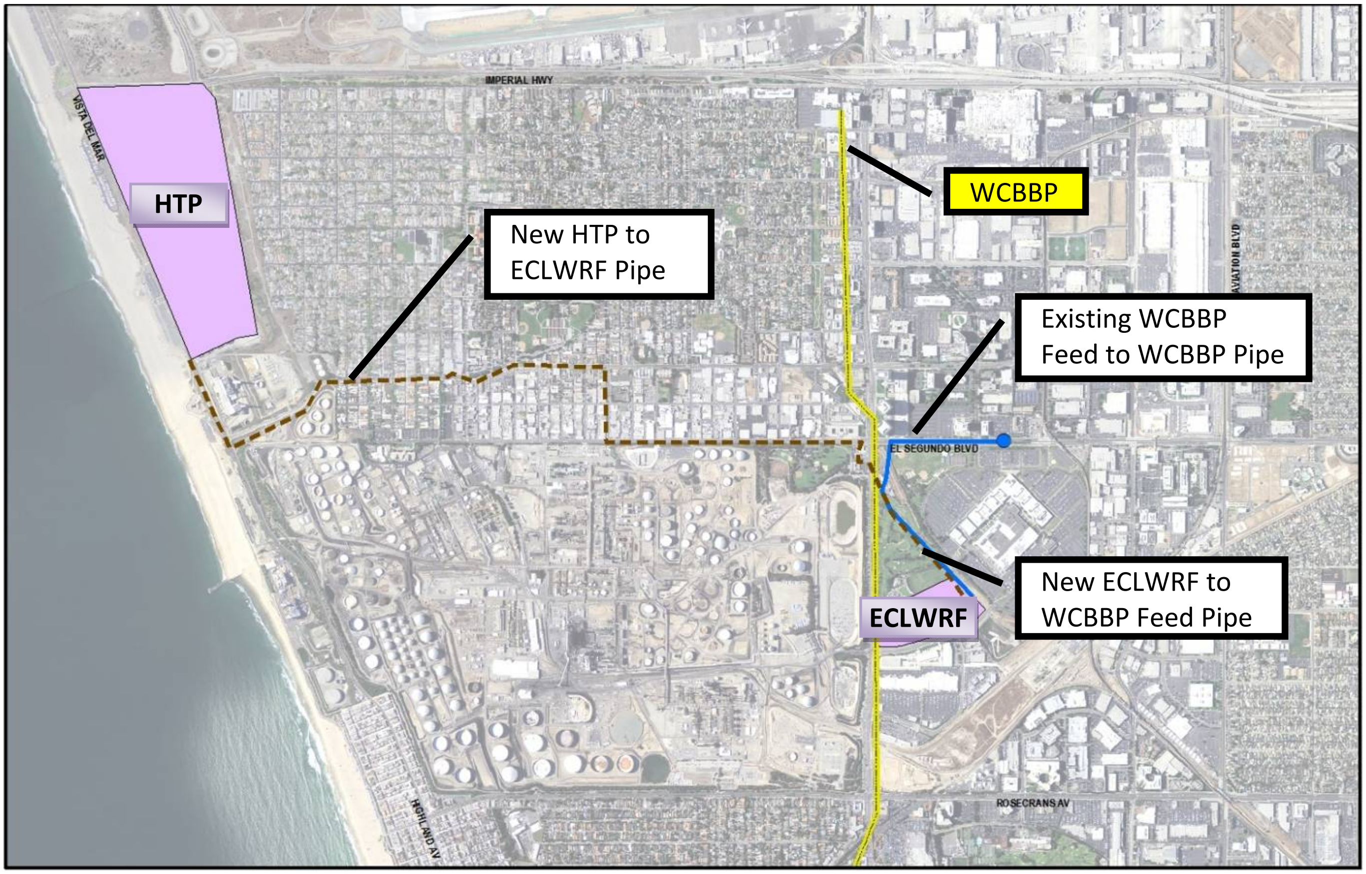
The initial project of 15,500 AFY includes the following facilities:

- **Supply:** 19,400 AFY of secondary effluent from HTP to produce 15,500 AFY of ECLWRF AWT product water
- **Treatment:** 10.0-mgd AWT expansion onsite at ECLWRF (estimated maximum site capacity) and new 3.8-mgd AWT offsite adjacent to the ECLWRF
- **Brine disposal:** 2.4-mgd flow increase to HTP outfall
- **Conveyance:**
  - HTP to ECLWRF: New pipeline (16,400 feet, 36-inch) and pump station (1,010 horsepower [hp])
  - ECLWRF to WCBBP: New pipeline (4,600 feet, 30-inch) and pump station (630 hp)
- **Recharge Method:** Injection at WCBBP within existing system capacity
- **Production Wells:** Pumpers will activate wells or install new wells, including treatment, as required to meet demands

The expanded project of 7,500 AFY includes the following facilities:

- **Supply:** 9,375 AFY of secondary effluent from HTP to produce 7,500 AFY of ECLWRF AWT product water
- **Treatment:** 6.7-mgd AWT offsite expansion near ECLWRF
- **Brine disposal:** 1.2-mgd flow increase to HTP outfall
- **Conveyance:**
  - HTP to ECLWRF: Upsize WCB-P1 pipeline (16,400 feet) from 36-inch to 42-inch diameter and expand pump station by 490 hp.
  - ECLWRF to WCBBP: Upsize WCB-P1 pipeline (4,600 feet) from 30-inch to 36-inch diameter and expand pump station by 175 hp.
- **Recharge Method:** Injection at WCBBP within existing system capacity
- **Production Wells**: Pumpers will activate wells or install new wells, including treatment, as required to meet demands

FIGURE 5-1
WCB-P1: ECLWRF to WCBBP (15,500 AFY)



5.1.1.2 WCB-P2: TIWRP to DGBP

Two project sizes are defined for this project. The initial project (**WCB-P2a**) would expand injection at the DGBP by 2,500 AFY from 5,000 AFY to 7,500 AFY by expanding the TIWRP AWTF from 5.0 mgd to 6.7 mgd. A new DGBP connection point may be needed for the DGBP to handle the increased recycled water flow. Currently, the DGBP has two supply sources: (1) imported water supplied from the north, which was the sole source of supply until recently, and (2) recycled water from the TIWRP, which is supplied from the south at a southerly connection point on the barrier pipeline. Given the original supply of imported water, the pipeline diameter decreases from north to south; it may not be feasible to supply the entire DGBP with recycled water from the southerly connection point due to potential capacity limitations. LACDPW is evaluating whether the existing pipeline can be used to convey this increased recycled water to the entire barrier or if a new pipeline is necessary to convey recycled water to a new connection point further to the north.

The expansion of the initial project (**WCB-P2b**) would expand injection by 6,500 AFY to 14,000 AFY. The initial project size is based on the injection needed to balance overall basin pumping beyond that provided at the WCBBP. The expanded project size is based on the maximum TIWRP yield of 12.5 mgd, which corresponds to the projected (year 2040) tertiary effluent flows of 16 mgd that could be available as feedwater to the TIWRP AWTF (per LA RWMP, see Appendix A, Section A1.3.2).

The initial project of 2,500 AFY includes the following facilities:

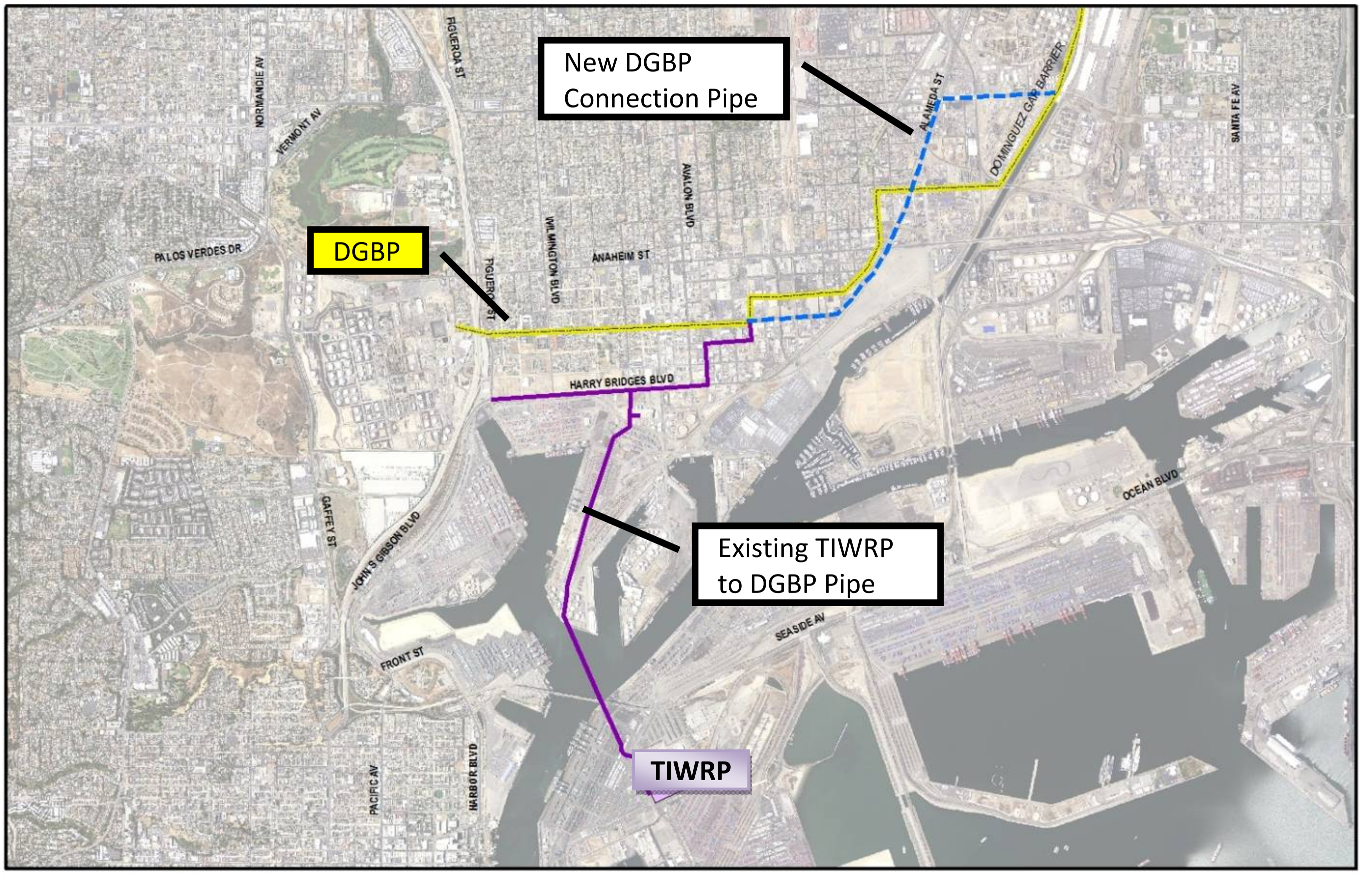
- **Supply:** 2,500 AFY of TIWRP AWTF product water
- **Treatment:** 1.7-mgd expansion at TIWRP from 5.0 mgd
- **Brine disposal:** No new brine disposal requirements

- **Conveyance:** A new 11,500-foot, 24-inch-diameter pipeline from the existing DGBP connection point to the northern end of the DGBP may be needed to provide a second, larger connection
- **Recharge Method:** Injection at DGBP within existing capacity
- **Production Wells:** Pumpers will activate wells or install new wells, including treatment, as required to meet demands

The expanded project of 6,500 AFY includes the following facilities:

- **Supply:** 6,500 AFY of TIWRP AWTF product water
- **Treatment:** 5.8-mgd expansion at TIWRP
- **Brine disposal:** No new brine disposal requirements
- **Conveyance:** Assumes new pipeline from the existing DGBP connection point to the northern end of the DGBP installed under WCB-P2
- **Recharge Method:** Injection at DGBP within existing capacity
- **Production Wells:** Pumpers will activate wells or install new wells, including treatment, as required to meet demands

FIGURE 5-2
WCB-P2: TIWRP to DGBP (2,500 AFY)

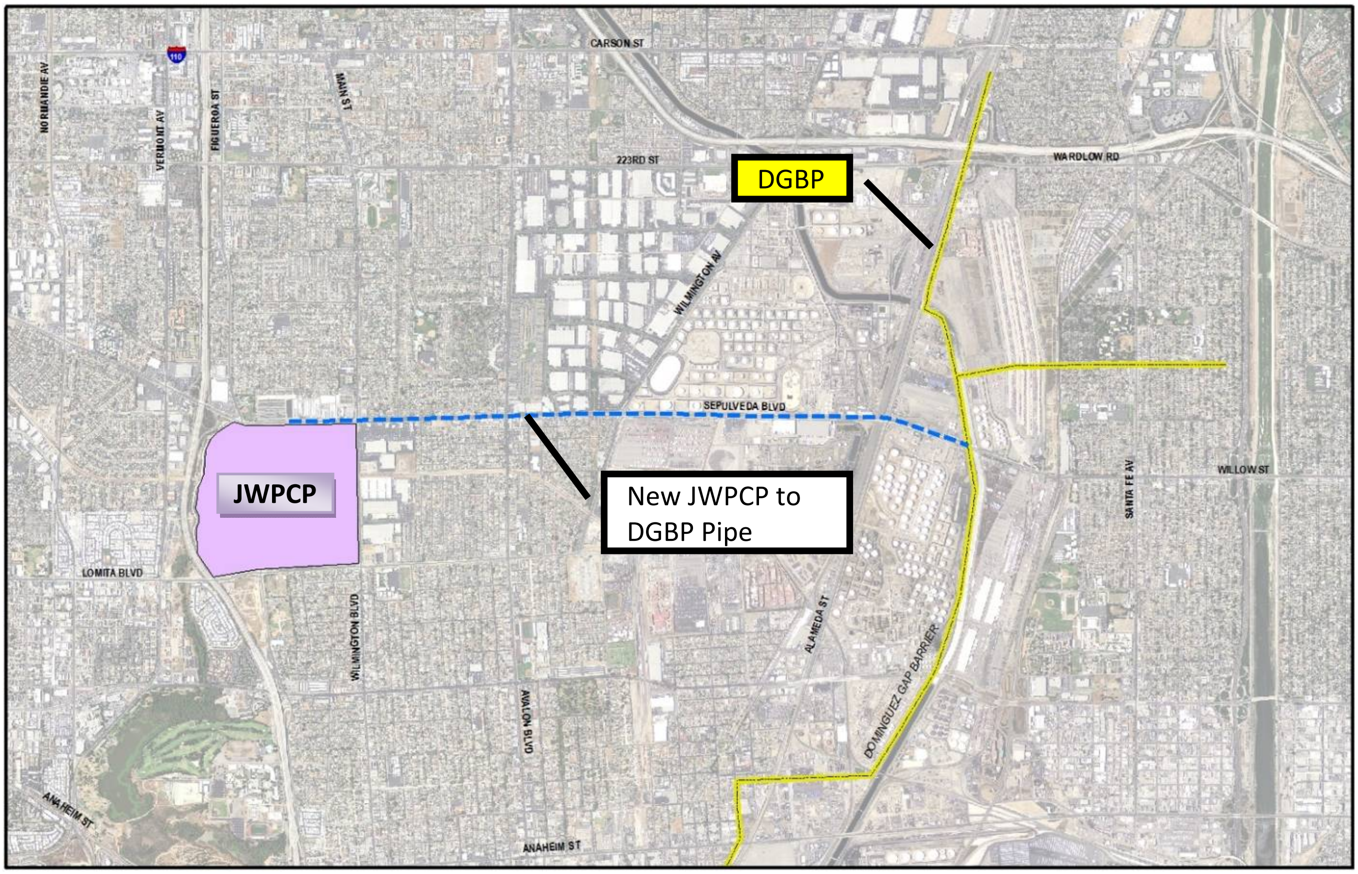


5.1.1.3 WCB-P3: JWPCP to DGBP (7,500 AFY)

This project would construct a new AWTF at JWPCP to treat secondary effluent from JWPCP and new conveyance facilities to the DGBP. The project size is based on the total replenishment needed to balance overall basin pumping beyond that provided at the WCBBP. This project includes the following facilities:

- **Supply:** 9,375 AFY of secondary effluent from JWPCP to produce 7,500 AFY of JWPCP AWT product water
- **Treatment:** New 6.7-mgd AWT at JWPCP
- **Brine disposal:** 1.2 mgd through existing JWPCP outfall
- **Conveyance:** JWPCP AWTF to DGBP: New pipeline (27,800 feet, 24-inch) and pump station (110 hp)
- **Recharge Method:** Injection at DGBP within existing capacity
- **Production Wells:** Pumpers will activate wells or install new wells, including treatment, as required to meet demands

FIGURE 5-3
WCB-P3: JWPCP to DGBP (7,500 AFY)

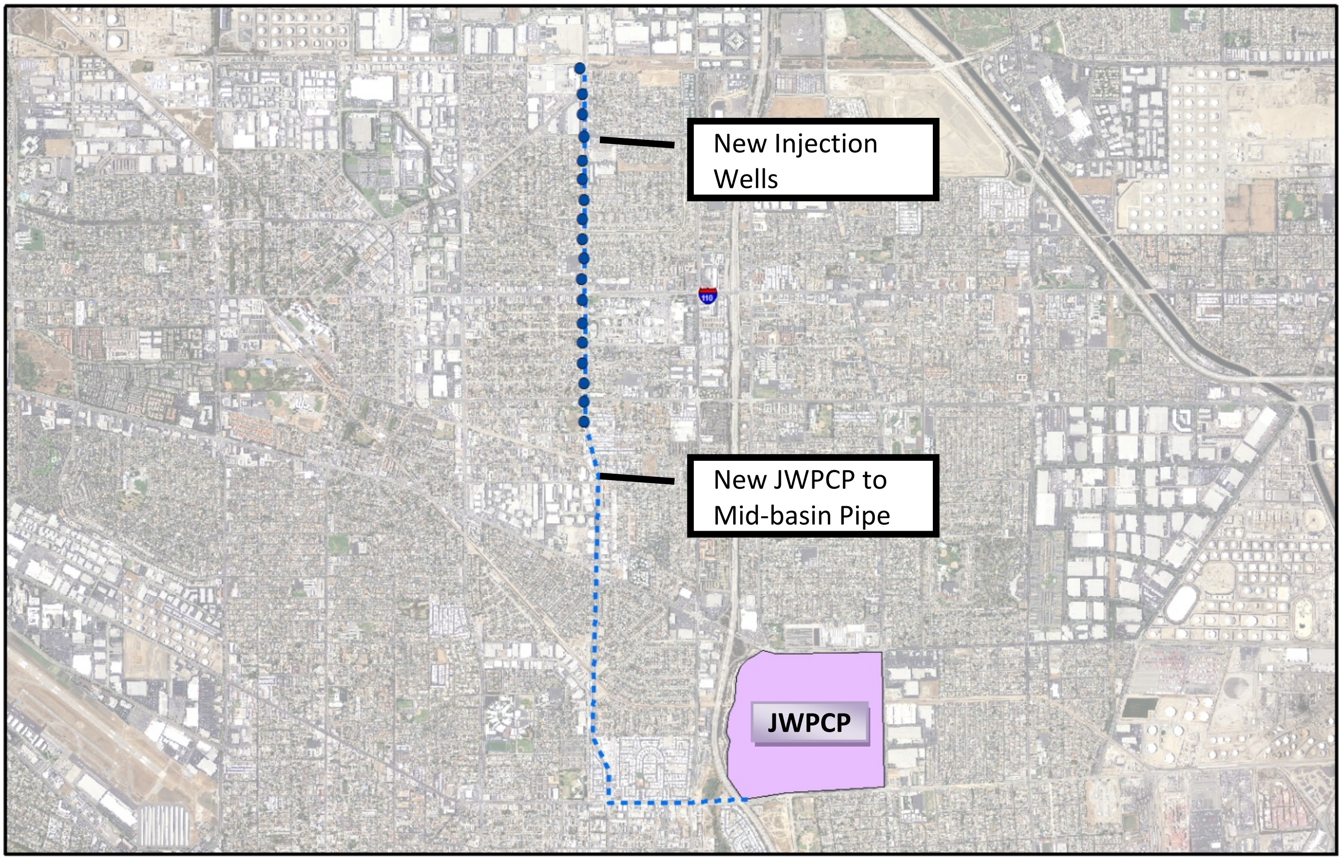


5.1.1.4 WCB-P4: JWPCP to Mid-basin (15,000 AFY or 16,000 AFY)

Two project sizes are defined for this project: 15,000 AFY **(CB-P4a)** and 16,000 AFY **(CB-P4b)**, depending on the companion projects that are used to make up an alternative. The project would consist of constructing a new AWTF at JWPCP to treat secondary effluent from the JWPCP and new conveyance facilities to new inland injection wells, centrally located within the West Coast Basin. This project includes the following facilities:

- **Supply:** 18,750 AFY of secondary effluent from JWPCP to produce 15,000 AFY of JWPCP AWT product water (or 20,000 AFY of secondary effluent to produce 16,000 AFY of AWT product water)
- **Treatment:** 13.4-mgd AWT at JWPCP (or 14.3-mgd AWT)
- **Brine disposal:** 2.4 mgd through existing JWPCP outfall (or 3.3 mgd)
- **Conveyance:** JWPCP AWTF to Mid-basin injection wells: New pipeline (25,600 feet, 30-inch) and pump station (220 hp)
- **Recharge Method:** Injection at 14 new Mid-basin wells
- **Production Wells:** 16 extraction wells, which may include activation of existing wells or installation of new wells, with treatment facilities as required

FIGURE 5-4
WCB-P4: JWPCP to Mid-basin (15,000 or 16,000 AFY)



5.1.2 Central Basin Projects

The Central Basin projects consist of surface spreading and/or injection of various recycled water and stormwater supplies. Eleven projects are defined in this section:

- CB-P1 to CB-P6: SJCWRP to MFSG (31,000 AFY), with varying levels of treatment
- CB-P7: LCWRP to MFSG – 100 percent AWT (15,500 AFY)
- CB-P8: LCWRP to Montebello Forebay Injection Wells – 100 percent FAT (15,500 AFY)
- CB-P9: FIX-IT (17,000 AFY)
- CB-P10: ARRF (5,000 AFY)
- CB-P11: Maximum SJCWRP to MFSG (+17,600 AFY), using tertiary effluent
- CB-P12: Maximum SJCWRP to MFSG (+17,600 AFY), 100 percent AWT
- CB-P13: Maximum SJCWRP to Montebello Forebay Injection Wells – 100 percent FAT (+8,690 AFY)
- CB-P14: Satellite AWT to Los Angeles Forebay Injection (45,480 AFY)

5.1.2.1 CB-P1 to P6: SJCWRP to MFSG (31,000 AFY)

Six projects are defined that would expand surface spreading at MFSG by 31,000 AFY with SJCWRP tertiary effluent plus varying levels of treatment:

- CB-P1: 100 percent tertiary
- CB-P2: 100 percent AWT
- CB-P3: 50 percent AWT, 50 percent tertiary
- CB-P4: 100 percent NF
- CB-P5: 50 percent NF, 50 percent tertiary
- CB-P6: 100 percent ozone/BAC/GAC

The addition of a treatment step beyond tertiary (CB-P2 to CB-P6) requires changes to the existing non-potable conveyance system so that non-potable customers from SJCWRP can continue to receive tertiary effluent. Three new pipelines required for these projects are:

- SJCWRP tertiary effluent diversion to new treatment step (1,235 feet, 48-inch diameter)
- SJCWRP to Puente Hills Pump Station (1,800 feet, 24-inch diameter)
- SJCWRP to Rio Hondo Pump Station (18,500 feet, 36-inch diameter)

Also, approximately 15,500 AFY of effluent is available for these projects, but some collection system diversions to SJCWRP are necessary to provide enough tertiary effluent to supply each of these projects. Each project would require implementation of one or more of the several diversion elements, the number of which varies for each project’s flow needs. The diversions, described in Section 3.3.2.1, can be divided into a set of relatively inexpensive diversions (“Diversion #1” - $1.6 million for 20,900 AFY) and a set of expensive diversions (“Diversion #2” - $76 million for 27,600 AFY). No new injection or extraction wells are included in these projects.

CB-P1: SJCWRP to MFSG – 100 Percent Tertiary (31,000 AFY)

This project includes the following facilities:

- **Supply:** 31,000 AFY of tertiary effluent from SJCWRP
- **SJCWRP Collection System Diversions:** 15,500 AFY (which is within “Diversion #1”)
- **Treatment:** No new treatment
- **Brine disposal:** No brine disposal
- **Conveyance:** No new conveyance pipelines

CB-P2: SJCWRP to MFSG – 100 Percent AWT (31,000 AFY)

This project includes the following facilities:

- **Supply:** 38,750 AFY of SJCWRP tertiary effluent to produce 31,000 AFY of AWT product water
- **SJCWRP Collection System Diversions:** 23,000 AFY (which requires “Diversion #2”)
- **Treatment:** 31.4-mgd AWT at SJCWRP
- **Brine disposal:** 4.9 mgd to LACSD’s JWPCP collection system
- **Conveyance:** Requires modifications to existing system (21,535 feet, 24-48 inch)

CB-P3: SJCWRP to MFSG – 50 Percent AWT (31,000 AFY)

This project includes the following facilities:

- **Supply:** 34,875 AFY of SJCWRP tertiary effluent to produce 15,500 AFY of AWT product water and 15,500 AFY of SJCWRP tertiary effluent
- **SJCWRP Collection System Diversions:** 19,400 AFY (which is within “Diversion #1”)
- **Treatment**: 15.5-mgd AWT at SJCWRP
- **Brine disposal:** 2.4 mgd to LACSD’s JWPCP collection system
- **Conveyance:** Requires modifications to existing system (21,535 feet, 24-48 inch)

CB-P4: SJCWRP to MFSG – 100 Percent NF (31,000 AFY)

This project includes the following facilities:

- **Supply:** 35,200 AFY from SJCWRP tertiary effluent to produce 31,000 AFY of NF product water
- **SJCWRP Collection System Diversions:** 23,000 AFY (which requires “Diversion #2”)
- **Treatment:** 31.4 mgd of NF at SJCWRP
- **Brine disposal:** 3.8 mgd to LACSD’s JWPCP collection system
- **Conveyance:** Requires modifications to existing system (21,535 feet, 24-48 inch)

CB-P5: SJCWRP to MFSG – 50 Percent NF (31,000 AFY)

This project includes the following facilities:

- **Supply:** 33,100 AFY of SJCWRP tertiary effluent to produce 15,500 AFY of AWT product water and 15,500 AFY of SJCWRP tertiary effluent
- **SJCWRP Collection System Diversions:** 19,400 AFY (which is within “Diversion #1”)
- **Treatment:** 15.5-mgd NF at SJCWRP
- **Brine disposal:** 1.9 mgd to LACSD’s JWPCP collection system
- **Conveyance:** Requires modifications to existing system (21,535 feet, 24-48 inch)

CB-P6: SJCWRP to MFSG – 100 Percent Ozone/BAC/GAC (31,000 AFY)

This project includes the following facilities:

- **Supply:** 31,000 AFY from SJCWRP with ozone-BAC treatment
- **SJCWRP Collection System Diversions:** 23,000 AFY (which requires “Diversion #2”)
- **Treatment:** 31.4 mgd of ozone/BAC/GAC treatment at SJCWRP
- **Brine disposal:** No brine disposal
- **Conveyance:** Requires modifications to existing system (21,535 feet, 24-48 inch)

FIGURE 5-5
CB-P1: SJCWRP to MFSG (31,000 AFY)

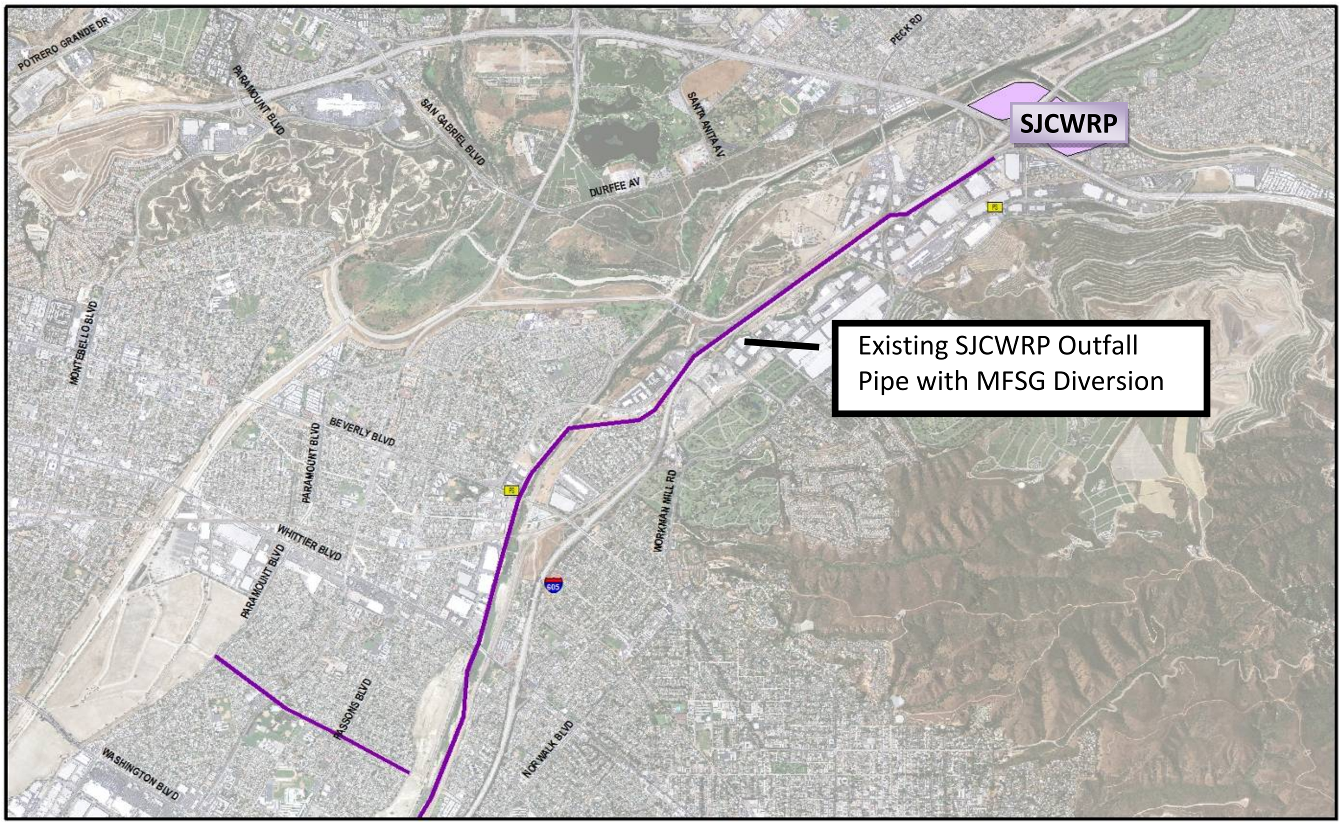
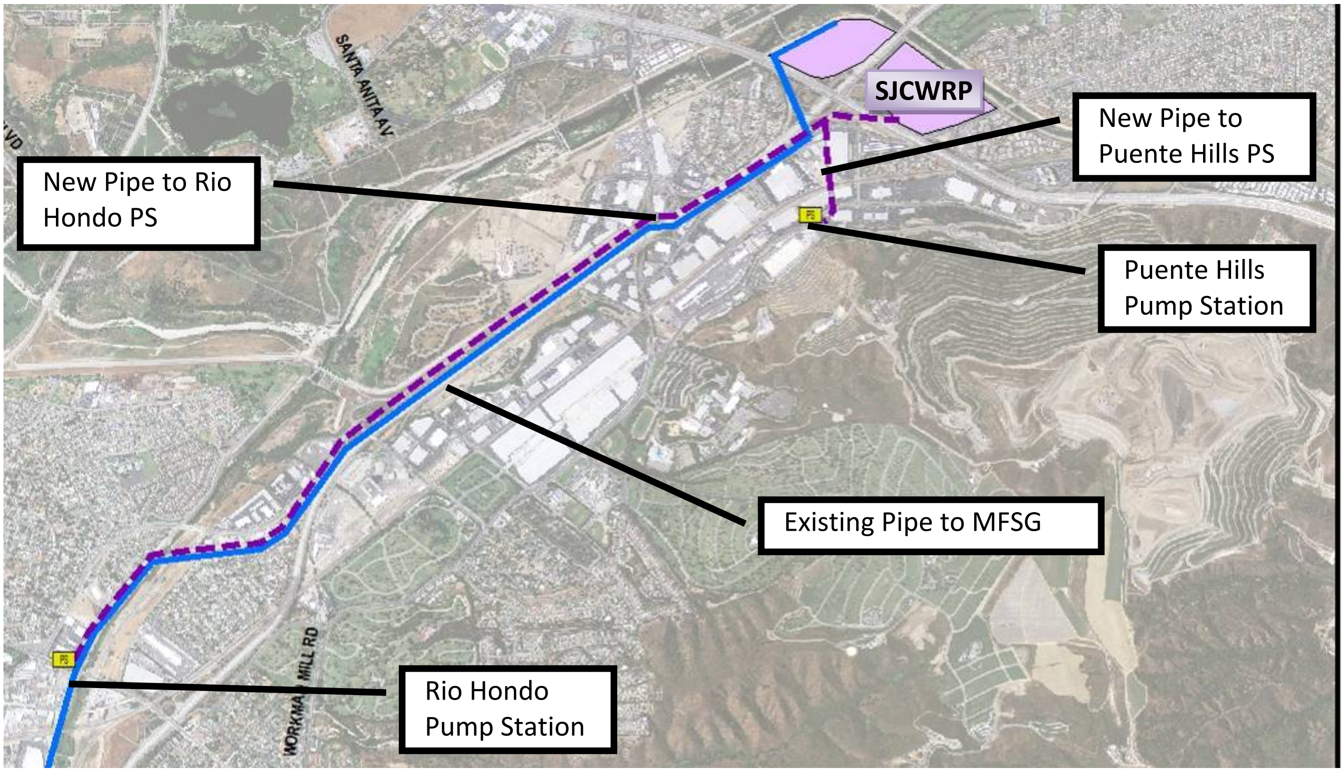


FIGURE 5-6
SJCWRP Tertiary Diversion Upgrades for CB-P2 to CB-P6 (SJCWRP to MFSG (31,000 AFY))

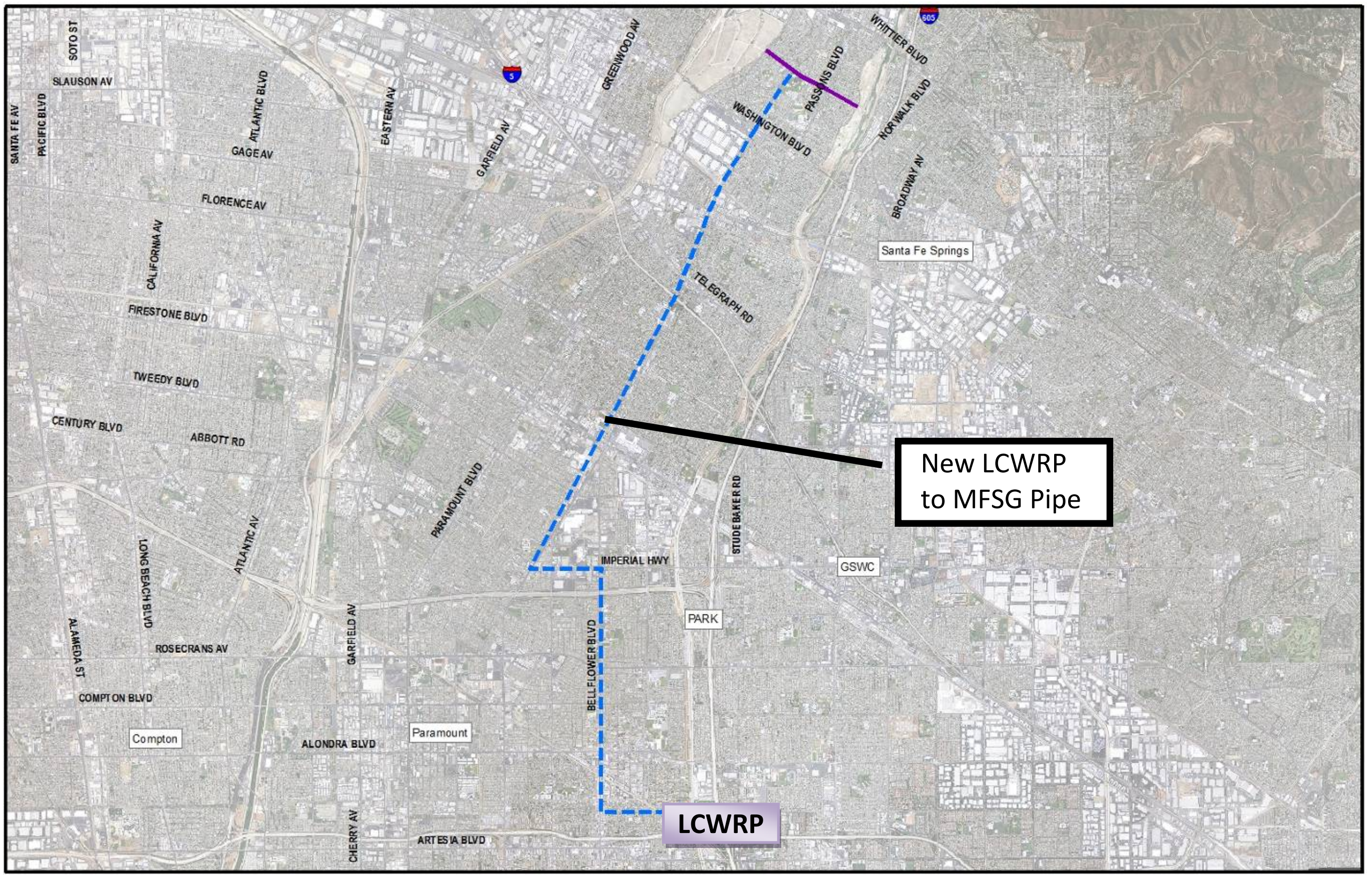


5.1.2.2 CB-P7: LCWRP to MFSG – 100 Percent AWT (15,500 AFY)

This project would expand surface spreading at MFSG by 15,500 AFY with AWT product water fed by LCWRP tertiary effluent. This project includes the following facilities:

- **Supply:** 19,375 AFY of LCWRP tertiary effluent to produce 15,500 AFY of AWT product water
- **Treatment:** 15.5-mgd AWT onsite at LCWRP
- **Brine disposal:** 2.4 mgd to LACSD's JWPCP collection system
- **Conveyance:** LCWRP to MFSG: New pipeline (47,000 feet, 30-inch) and pump station (645 hp)
- **Recharge Method:** Surface spreading at MFSG

FIGURE 5-7
CB-P7: LCWRP to MFSG – 100 Percent AWT (15,500 AFY)

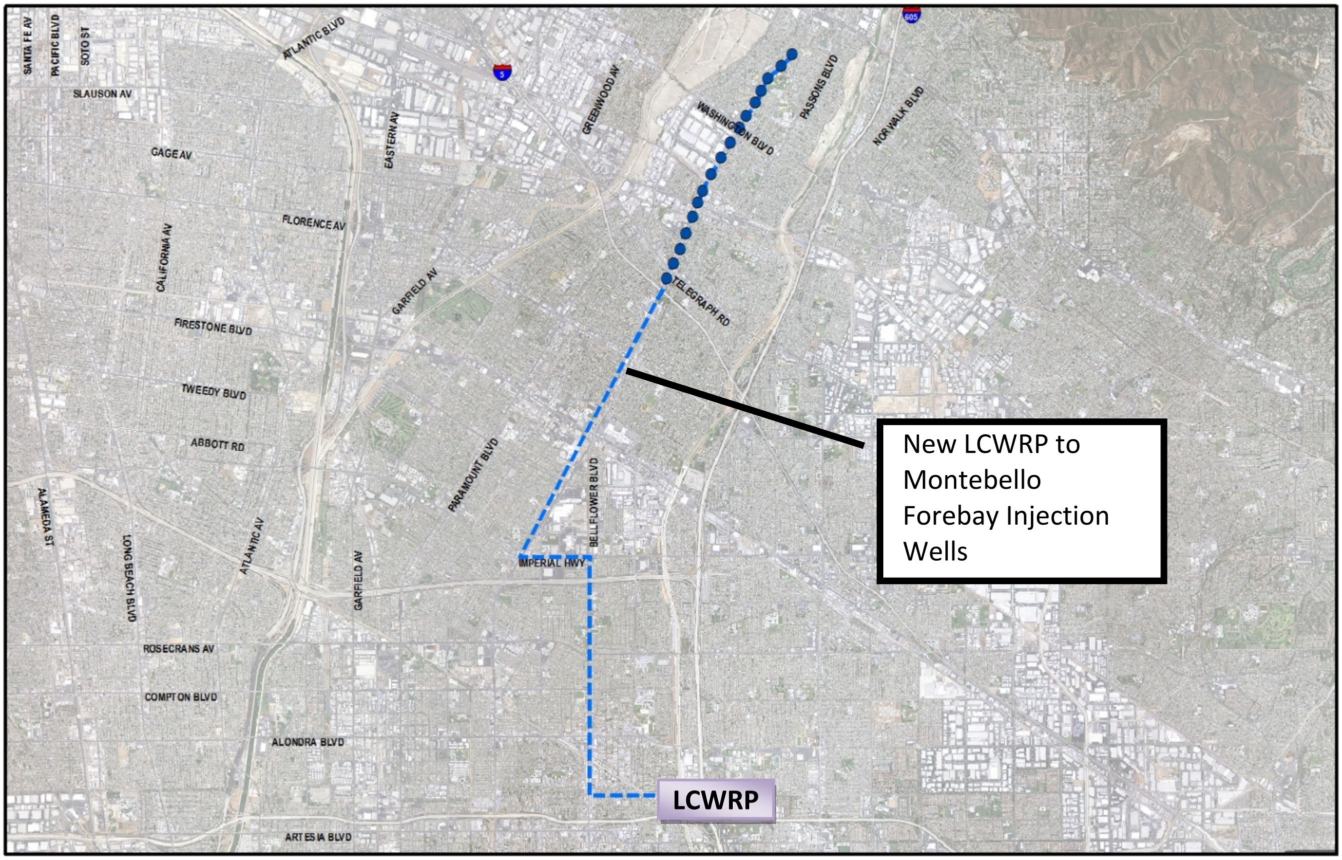


5.1.2.3 CB-P8: LCWRP to Montebello Forebay Injection Wells – 100 Percent FAT (15,500 AFY)

Similar to CB-P7, this project would recharge 15,500 AFY with FAT product water fed by LCWRP tertiary effluent; however, this project proposes to use injection wells instead of surface spreading at the MFSG. The AWTF size is reduced compared with CB-P7 because the injection wells do not have similar capacity constraints to MFSG. This project includes the following facilities:

- **Supply:** 19,375 AFY of LCWRP tertiary effluent to produce 15,500 AFY of FAT product water
- **Treatment:** 13.8-mgd AWTF onsite at LCWRP
- **Brine disposal:** 2.4 mgd to LACSD’s JWPCP collection system
- **Conveyance:** LCWRP to MFSG: New pipeline (66,500 feet, 30-inch) and pump station (575 hp)
- **Recharge Method:** Injection at 17 new injection wells in the Montebello Forebay

FIGURE 5-8
CB-P8: LCWRP to Montebello Forebay Injection Wells – 100 Percent AWT (15,500 AFY)

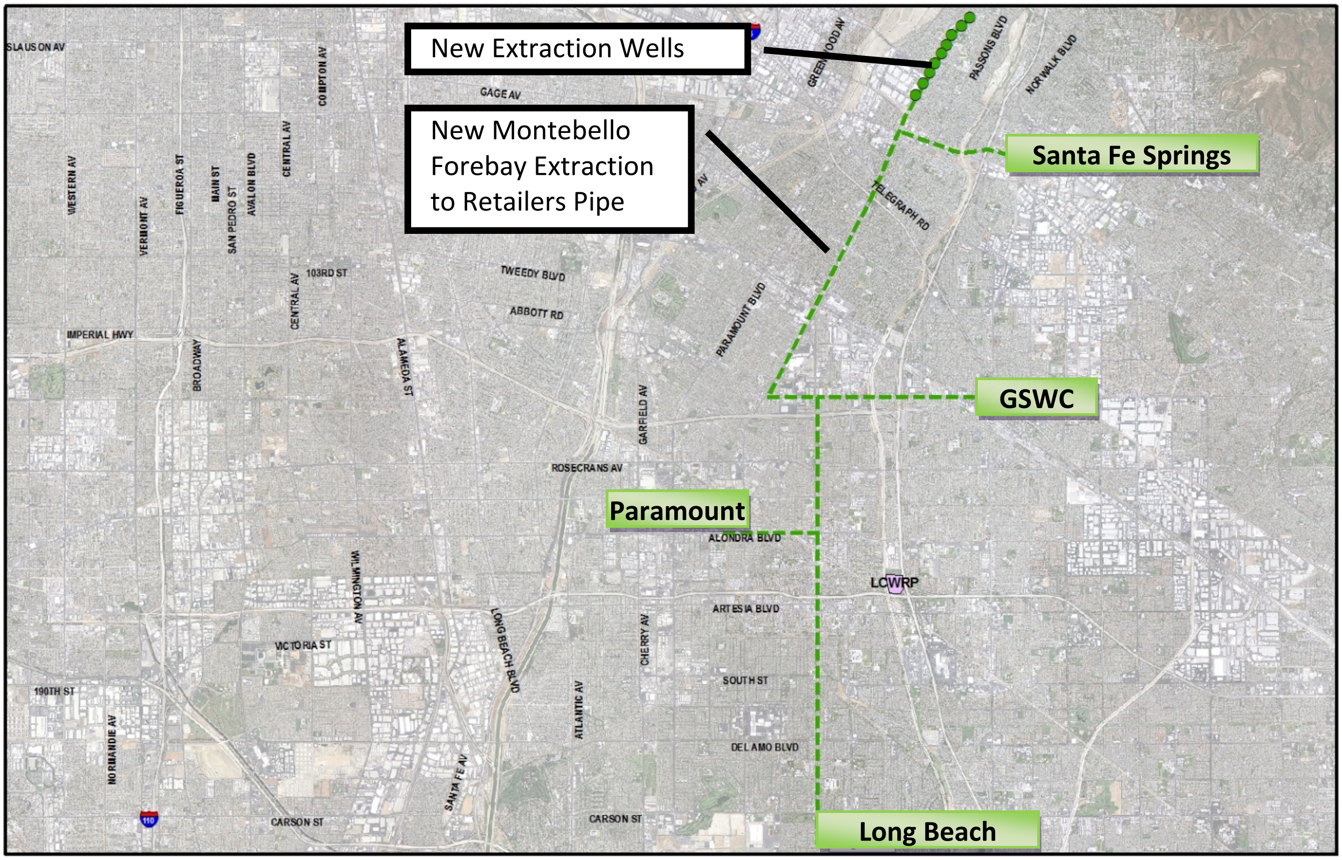


5.1.2.4 CB-P9: FIX-IT – San Gabriel River/Rio Hondo to MFSG (17,000 AFY)

This project would capture an additional 17,000 AFY of stormwater that is currently released to the ocean by increasing pumping in the Montebello Forebay area by 25,000 AFY to reduce elevated groundwater levels that prevent recharge following high recharge periods. The assumed distribution of the 25,000 AFY in shifted pumping was described in Section 3.3.3.4. This project includes the following facilities:

- **Supply:** 17,000 AFY of stormwater from San Gabriel River and Rio Hondo
- **Treatment:** No new treatment
- **Brine disposal:** No brine disposal
- **Conveyance:** Pipeline from new Montebello Forebay extraction wells to four retailers: MFSG to Junction 1 (12,300 feet, 36-inch), Junction 1 to Santa Fe Springs (11,000 feet, 14-inch), Junction 1 to Junction 2 (30,750 feet, 36-inch), Junction 2 to Golden State Water Company (15,000 feet, 16-inch), Junction 2 to Junction 3 (12,200 feet, 30-inch), Junction 3 to Paramount (8,500 feet, 16-inch), and Junction 3 to Long Beach (28,100 feet, 30-inch)
- **Recharge Method:** Surface spreading at MFSG
- **Production Wells**: Nine new extraction wells to provide 25,000 AFY of pumping shifted to the Montebello Forebay area from elsewhere in the Central Basin

FIGURE 5-9
CB-P9: FIX-IT – San Gabriel/Rio Hondo Rivers to MFSG (17,000 AFY)



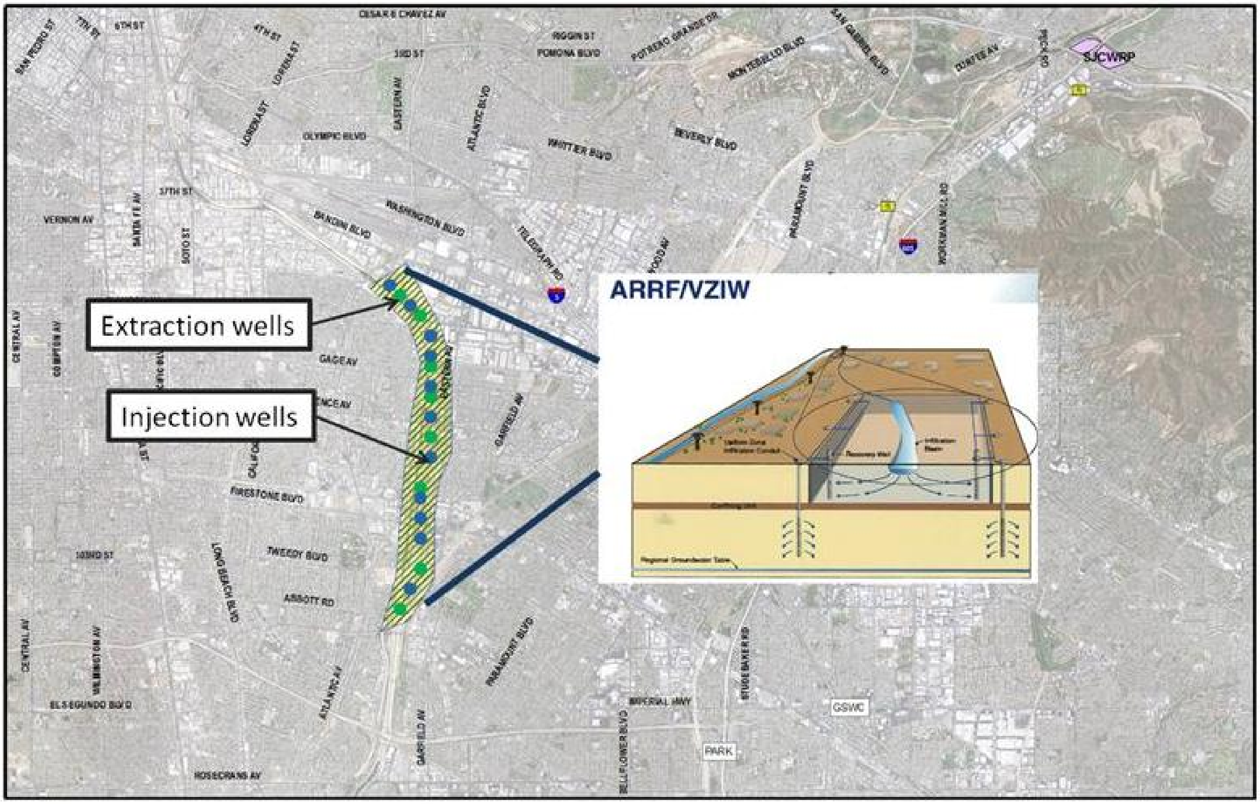
5.1.2.5 CB-P10: ARRF – Los Angeles River to Los Angeles Forebay (5,000 AFY)

The stormwater conveyed in the Los Angeles River between Atlantic Boulevard and Firestone Boulevard could be captured and diverted to the ARRF, described in Section 3.3.2.4.

This project includes the following facilities:

- **Supply:** 5,000 AFY of storm flows from the Los Angeles River
- **Treatment:** Soil aquifer treatment through ARRF facility as described in Section 3.3.2.4.
- **Brine disposal:** No brine disposal
- **Conveyance:** No new conveyance pipelines
- **Recharge Method:** Surface spreading and injection at Los Angeles Forebay

FIGURE 5-10
CB-P10: ARRF – Los Angeles River to Los Angeles Forebay (5,000 AFY)



5.1.2.6 CB-P11: Maximum SJCWRP to MFSG (+17,600 AFY), using tertiary effluent

This project is an expansion of project CB-P1 and includes the following facilities:

- **Supply:** 17,600 AFY of tertiary effluent from SJCWRP
- **SJCWRP Collection System Diversions:** 17,600 AFY (which requires “Diversion #2”)
- **Treatment:** No new treatment
- **Brine disposal:** No brine disposal
- **Conveyance:** No new conveyance pipelines

5.1.2.7 CB-P12: Maximum SJCWRP to MFSG (+17,600 AFY), 100 percent AWT

This project is an expansion of project CB-P2 and includes the following facilities:

- **Supply:** 20,710 AFY of SJCWRP tertiary effluent to produce 17,600 AFY of AWT product water
- **SJCWRP Collection System Diversions:** 17,600 AFY (which requires “Diversion #2”)

- **Treatment:** 19.6-mgd AWT at SJCWRP
- **Brine disposal:** 2.8 mgd to LACSD’s JWPCP collection system

5.1.2.8 CB-P13: Maximum SJCWRP to Montebello Forebay Injection Wells – 100 percent FAT (+8,690 AFY)

Similar to project CB-P8, this project would recharge AWT produce water via injection at the MFSG. The supply for this project comes from surplus SJCWRP tertiary effluent during periods that the effluent cannot be recharged at the spreading grounds due to stormwater capture and spreading ground capacity limitations. To capture and treat this flow when available, a treatment plant size of 23-mgd was identified. As this plant would not be operated year-round, it would produce only 8,690 AFY of product water for injection.

This project includes the following facilities:

- **Supply:** 10,224 AFY of LCWRP tertiary effluent to produce 8,690 AFY of FAT product water
- **Treatment:** 23.0-mgd AWTF onsite at SJCWRP
- **Brine disposal:** 2.4 mgd to LACSD’s JWPCP collection system
- **Conveyance:** LCWRP to MFSG: New pipeline (22,400 feet, 36-inch) and pump station (430 hp)
- **Recharge Method:** Injection at 17 new injection wells in the Montebello Forebay

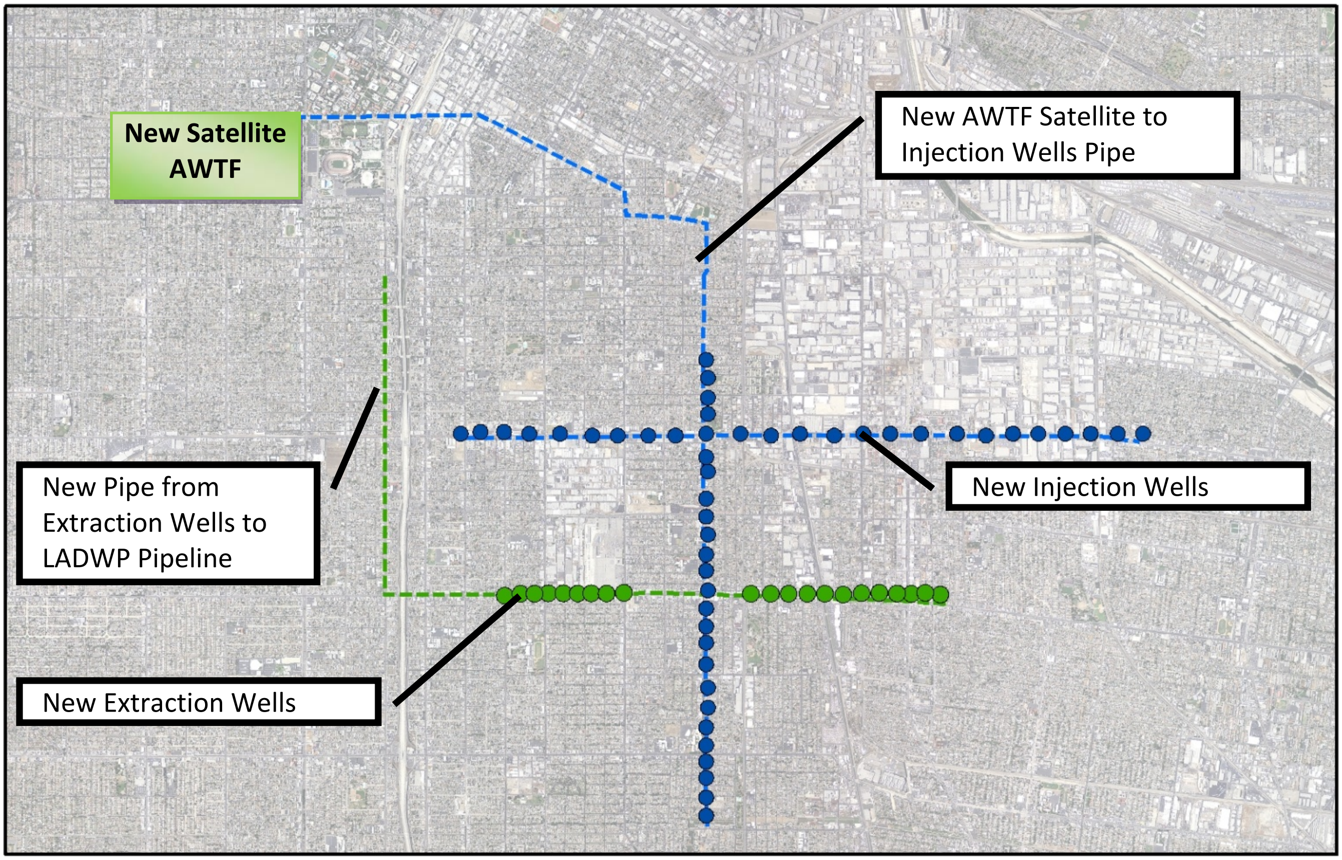
5.1.2.9 CB-P14: Satellite to Los Angeles Forebay Injection Wells – 100 Percent FAT (45,480 AFY)

This project would construct a new satellite water reclamation facility with AWT in eastern Los Angeles for injection into the Los Angeles Forebay. This project includes the following facilities:

- **Supply:** 45,480 AFY from new satellite AWTF (MBR/RO/AOP) supplied from raw wastewater from City of Los Angeles’ HTP collection system
- **Treatment**: 40.6 mgd new satellite AWTF
- **Brine disposal:** 7.2 mgd to City of Los Angeles’ HTP collection system
- **Conveyance:** Several new conveyance pipelines are needed:
    - AWTF to Los Angeles Forebay Injection Wells: Pipeline (26,900 feet, 48-inch), laterals (42,800 feet, 36-inch), and pump station (720 hp)
    - Extraction wells to LADWP (35,500 feet, 48-inch)
- **Recharge Method:** 50 new injection wells at Los Angeles Forebay
- **Production Wells:** 21 new extraction wells

FIGURE 5-11

CB-P14: Satellite to Los Angeles Forebay Injection Wells – 100 Percent FAT (45,480 AFY)



5.1.3 Groundwater Basins Master Plan Projects Summary

5.1.3.1 Facilities

Tables 5-3 and 5-4 summarize facilities for each project.

TABLE 5-3
West Coast Basin Projects – New Facilities

Project ID	Project Description	Annual Yield (AFY)	Treatment (mgd)	Brine (mgd)	Conveyance	Wells
WCB-P1	ECLWRF to WCBBP					
WCB-P1a		15,500	13.8	2.4	30” to 36”, 4.0 miles	--
WCB-P1b		+7,500	6.7	1.2	Upsize by 6”, 4.0 miles	--
WCB-P2	TIWRP to DGBP					
WCB-P2a		2,500	1.7	0.4	24”, 2.2 miles	--
WCB-P2b		6,500	5.5	1.0	--	--
WCB-P3	JWPCP to DGBP	7,500	6.7	1.2	24”, 5.3 miles	--
WCB-P4	JWPCP to Mid-basin	15,000-16,000	13.4	2.4	30”, 4.8 miles	14-15 injection

Note:

“ = inch(es)

TABLE 5-4
Central Basin Projects – New Facilities

Project ID	Project Description	Annual Yield (AFY)	SJCWRP Diversions (AFY)	Treatment (mgd)	Brine (mgd)	Conveyance	Wells
CB-P1	SJCWRP to MFSG (100% Tertiary)	31,000	--	--	--	--	--
CB-P2	SJCWRP to MFSG (100% AWT)	31,000	23,250	31.4	4.9	24” to 48”, 4.1 miles	--
CB-P3	SJCWRP to MFSG (50% AWT)	31,000	19,400	15.5	2.4	24” to 48”, 4.1 miles	--
CB-P4	SJCWRP to MFSG (100% NF)	31,000	21,000	31.4	3.8	24” to 48”, 4.1 miles	--
CB-P5	SJCWRP to MFSG (50% NF)	31,000	18,200	15.5	1.9	24” to 48”, 4.1 miles	--
CB-P6	SJCWRP to MFSG (Ozone/BAC/GAC)	31,000	15,500	31.4	--	24” to 48”, 4.1 miles	--
CB-P7	LCWRP to MFSG (100% AWT)	15,500	--	15.5	2.44	30”, 8.9 miles	--
CB-P8	LCWRP to Montebello Forebay Injection (100% FAT)	15,500	--	13.8	2.44	30”, 8.9 mi	17 injection
CB-P9	FIX-IT	17,000	--	--	--	14” to 36”, 22.3 mi	9 extraction
CB-P10	ARRF	5,000	--	--	--		64 injection 32 extraction
CB-P11	SJCWRP to MFSG (100% Tertiary)	17,600	17,600	--	--	--	--

TABLE 5-4
Central Basin Projects – New Facilities

Project ID	Project Description	Annual Yield (AFY)	SJCWRP Diversions (AFY)	Treatment (mgd)	Brine (mgd)	Conveyance	Wells
CB-P12	SJCWRP to MFSG (100% AWT)	17,600	20,500	19.6	2.8	24" to 48", 4.1 miles	--
CB-P13	SJCWRP to Montebello Forebay Injection (100% FAT)	8,690	--	23.0	1.4	24" to 48", 4.1 miles	17 injection
CB-P14	Satellite to Los Angeles Forebay Injection (100% FAT)	45,480	--	40.6	10.2	36" to 48", 19.9 mi	50 injection 21 extraction

5.1.3.2 Cost Estimates

Tables 5-5 and 5-6 summarize the capital, O&M, water purchase (as supply or as feed water to advanced treatment process), total present value and present value unit costs ($ per AF) for each GBMP project as defined above. These costs include supply treatment, conveyance and injection, where applicable and unique to the proposed project.Groundwater extraction costs are not included as they will vary by purveyor as some redundant pumping capacity may be available in existing systems and some pumpers may choose to reactivate or refurbish existing but currently unused wells. Additionally, some purveyors may opt to collaborate in the installation of larger extraction systems rather than install individual wells for each purveyor independently, potentially realizing cost savings.Thus the cost of installing additional wells to match additional proposed extraction under the GBMP alternatives is omitted from the GBMP project costs and left to the individual purveyor to consider.

Cost estimating details for the GMBP projects and alternatives are provided in Appendix J. Also provided in Appendix J are cost curves representating a range of wellhead treatment options that might need to be added for individual pumping projects associated with these alternatives as the projects may have site specific requirements for wellhead treatment of various water quality constituents (e.g., iron and manganese, iron, hydrogen sulfide, color/odor, and disinfection). Similarly, an estimate for the 7 assumed desalters for the West Coast Basin saline plume is provided in Appendix J, but not included in the GBMP cost estimates. If such mitigation of the saline plume is conducted as an element of any West Coast Basin alternative, the desalter costs would be added into the total cost of the alternative.

TABLE 5-5
West Coast Basin Projects – Preliminary Cost Estimates

Project ID	Project Description	Annual Yield (AFY)	Total Capital Cost ($M)	Total Annual O&M ($M)	Total Water Purchase ($M)	Total Present Value ($M)	Present Value Unit Cost ($/af)
WCB-P1a	ECLWRF to WCBBP	15,500	$141.9	$9.0	$0.018	$320	$1,040
WCB-P1b	ECLWRF to WCBBP	7,500	$64.1	$4.4	$0.009	$151	$1,020
WCB-P2a	TIWRP to DGBP	2,500	$23.7	$0.1	$2.250	$71	$1,430
WCB-P2b	TIWRP to DGBP	6,500	$45.7	$0.2	$5.850	$166	$1,290
WCB-P3	JWPCP to DGBP	7,500	$82.9	$3.0	$0.882	$160	$1,080
WCB-P4	JWPCP to Mid-basin	15,000	$230.5	$7.2	$1.765	$411	$1,380

Note:

$/af = dollar(s) per acre-foot
$M = million dollars
O&M = operations and maintenance

FIGURE 5-12
West Coast Basin Projects – Present Value Unit Costs

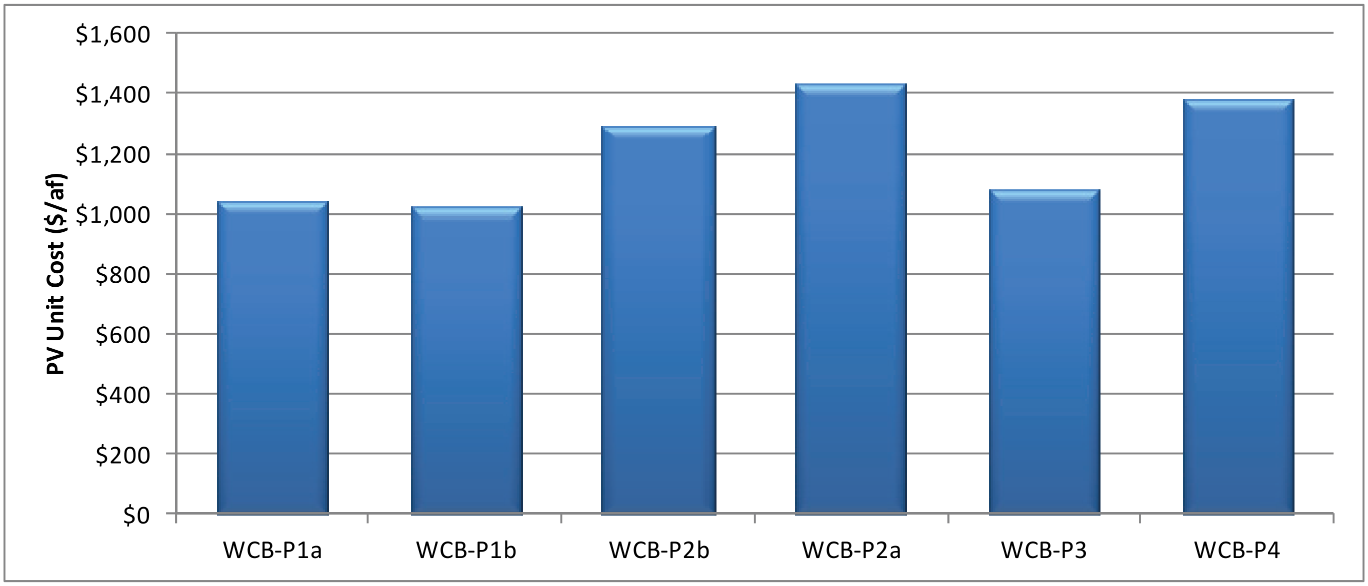
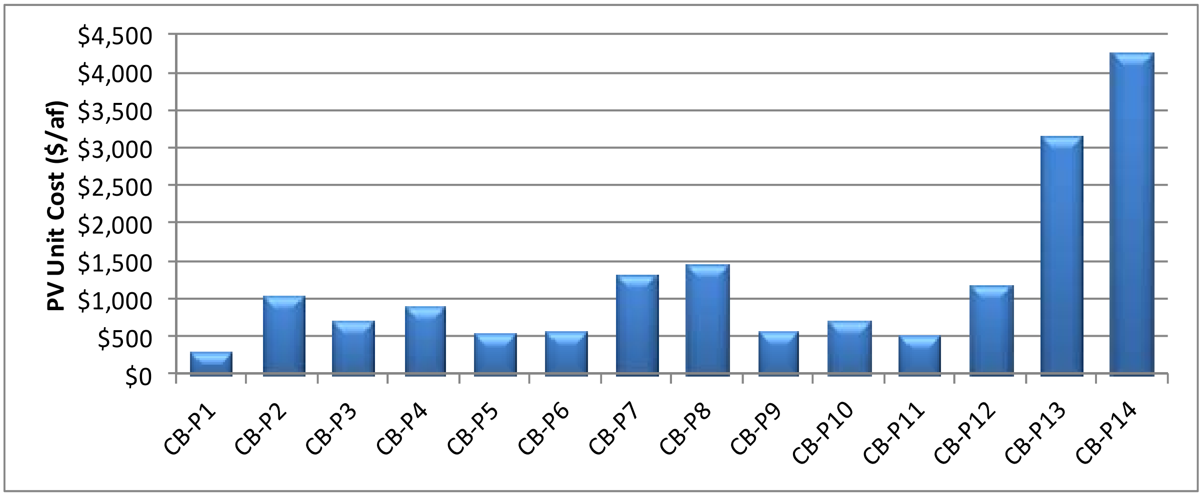


TABLE 5-6
Central Basin Projects – Preliminary Cost Estimates

Project ID	Project Description	Annual Yield (AFY)	Total Capital Cost ($M)	Total Annual O&M ($M)	Total Water Purchase ($M)	Total Present Value ($M)	Present Value Unit Cost ($/af)
CB-P1	SJCWRP to MFSG (100% Tertiary)	31,000	$0.1	$0.0	$9.300	$184	$300
CB-P2	SJCWRP to MFSG (100% AWT)	31,000	$267.0	$14.7	$3.647	$630	$1,030
CB-P3	SJCWRP to MFSG (50% AWT)	31,000	$161.0	$7.3	$6.474	$434	$710
CB-P4	SJCWRP to MFSG (100% NF)	31,000	$226.8	$12.5	$3.523	$544	$890
CB-P5	SJCWRP to MFSG (50% NF)	31,000	$137.4	$6.2	$3.585	$332	$540
CB-P6	SJCWRP to MFSG (Ozone/BAC/GAC)	31,000	$158.0	$5.9	$3.647	$346	$560
CB-P7	LCWRP to MFSG (100% AWT)	15,500	$179.6	$7.7	$1.824	$406	$1,320
CB-P8	LCWRP to Montebello Forebay Injection (100% AWT)	15,500	$231.2	$7.2	$1.824	$449	$1,460
CB-P9	FIX-IT	17,000	$147.6	$2.3	$0.000	$194	$580
CB-P10	ARRF	5,000	$55.9	$0.7	$0.000	$70	$710
CB-P11	SJCWRP to MFSG (100% Tertiary)	17,600	$77.5	$0.0	$5.280	$182	$520
CB-P12	SJCWRP to MFSG (100% AWT)	17,600	$195.6	$9.0	$2.071	$416	$1,190
CB-P13	SJCWRP to Montebello Forebay Injection (100% FAT)	8,690	$222.1	$15.0	$1.022	$539	$3,140
CB-P14	Satellite to Los Angeles Forebay Injection (100% FAT)	45,480	$1,226.3	$61.3	$0.000	$3,828	$4,250

FIGURE 5-13
Central Basin Projects – Present Value Unit Costs



5.2 Groundwater Basins Master Plan Alternatives

The section combines the projects defined in Section 5.1 into two sets of alternatives. The first set, the “Concept A” alternatives, are designed to meet either the projected pumping within existing rights/allotment, which is an increase of 18,000 AFY in the West Coast Basin and 31,000 AFY in the Central Basin. The second set, the “Concept B” alternatives, define conceptual programs to go beyond the Concept A replenishment goals in line with the proposed Judgment amendments for each basin.

5.2.1 West Coast Basin

West Coast Basin alternatives are summarized in the following tables and further described in the following sections. On average, existing recycled water replenishment supplies for the West Basin consist of 22,000 AFY of FAT recycled water (17,000 AFY at the WCBBP from WBMWD’s ECLWRF and 5,000 AFY at the DGBP from the City Los Angeles’ TIWRP).

5.2.1.1 Concept A Alternatives (18,000 AFY)

One Concept A alternative was defined in the West Coast Basin:

- **WCB-A1.** WCBBP and DGBP Expansions

The alternative is summarized in Table 5-7.

TABLE 5-7
List of West Coast Basin Concept A Alternatives

Alt ID	Project ID	Replenishment Supply	Replenishment Location/Method	Annual Average Replenishment (AFY)
WCB-A1: ECLWRF to WCBBP and TIWRP AWT to DGB				**18,000**
	WCB-P1a	ECLWRF AWT	WCBBP	15,500
	WCB-P2a	TIWRP AWT	DGBP	2,500

5.2.1.2 Concept B Alternatives (+30,000 AFY)

Two Concept B alternatives were defined in the West Coast Basin, and each alternative builds upon WCB-A1:

- **WCB-B1.** Further WCBBP Expansion; JWPCP to DGBP and Mid-basin Injection
- **WCB-B2.** Further DGBP and WCBBP Expansions; JWPCP to Mid-basin Injection

The alternatives are summarized in Table 5-8.

TABLE 5-8
List of West Coast Basin Concept B Alternatives

Alt ID	Project ID	Replenishment Supply	Replenishment Location/Method	Annual Average Replenishment (AFY)
WCB-B1: Alt WCB-A1 and ECLWRF to WCBB, JWPCP to WCB-Inland & DGBP				**+ 30,000**
	WCB-P1b	ECLWRF AWT	WCBBP	+ 7,500
	WCB-P3	JWPCP AWT	DGBP	7,500
	WCB-P4a	JWPCP AWT	Mid-basin	15,000
WCB-B2: Alt WCB-B1 and ECLWRF to WCBB, JWPCP to WCBBP & DGB, TIWRP to DGBP				**+ 30,000**
	WCB-P1b	ECLWRF AWT	WCBBP	+ 7,500
	WCB-P2b	TIWRP AWT	DGBP	+ 6,500
	WCB-P4b	JWPCP AWT	Mid-basin	16,000

5.2.2 Central Basin

Central Basin alternatives are summarized in the following tables and further described in the following sections. On average, existing replenishment supplies for the Central Basin consist of 57,000 AFY of stormwater and 50,000 AFY of tertiary recycled water.

5.2.2.1 Concept A Alternatives (31,000 AFY)

Five core Concept A alternatives were defined for the Central Basin, and each has multiple variations that adjust the level of treatment applied to recycled water prior to replenishment:

- CB-A1. SJCWRP to MFSG
- CB-A2. SJCWRP and LCWRP-Spreading
- CB-A3. SJCWRP-Spreading and LCWRP-Injection
- CB-A4. SJCWRP Spreading and Enhanced Montebello Forebay Stormwater Capture
- CB-A5. SJCWRP Spreading and Enhanced Los Angeles Forebay Stormwater Capture

The alternatives are summarized in Table 5-9.

TABLE 5-9
List of Central Basin Concept A Alternatives

Alt ID	Project ID	Replenishment Supply	Replenishment Location/Method	Annual Average Replenishment (AFY)
CB-A1a: SJCWRP (100% Tertiary) to MFSG				**31,000**
	CB-P1	SJCWRP	MFSG	31,000
CB-A1b: SJCWRP (100% AWT) to MFSG				**31,000**
	CB-P2	SJCWRP – 100% AWT	MFSG	31,000
CB-A1c: SJCWRP (50% AWT) to MFSG				**31,000**
	CB-P3	SJCWRP – 50% AWT	MFSG	31,000
CB-A1d: SJCWRP (100% NF) to MFSG				**31,000**
	CB-P4	SJCWRP – 100% NF	MFSG	31,000

TABLE 5-9
List of Central Basin Concept A Alternatives

Alt ID	Project ID	Replenishment Supply	Replenishment Location/Method	Annual Average Replenishment (AFY)
CB-A1e: SJCWRP (50% NF) to MFSG				**31,000**
	CB-P5	SJCWRP – 50% NF	MFSG	31,000
CB-A1f: SJCWRP (Ozone/BAC/GAC) to MFSG				**31,000**
	CB-P6	SJCWRP – Ozone/BAC/GAC	MFSG	31,000
CB-A2a: SJCWRP (100% Tertiary) to MFSG & LCWRP (100% AWT) to MFSG				**31,000**
	CB-P1	SJCWRP	MFSG	15,500*
	CB-P7	LCWRP AWT	MFSG	15,500
CB-A2b: SJCWRP (100% AWT) to MFSG & LCWRP (100% AWT) to MFSG				**31,000**
	CB-P2	SJCWRP – 100% AWT	MFSG	15,500*
	CB-P7	LCWRP AWT	MFSG	15,500
CB-A3a: SJCWRP (100% Tertiary) to MFSG & LCWRP (100% FAT) to Montebello Forebay Injection				**31,000**
	CB-P1	SJCWRP	MFSG	15,500*
	CB-P8	LCWRP AWT	Injection at Montebello Forebay	15,500
CB-A3b: SJCWRP (100% AWT) to MFSG & LCWRP (100% FAT) to Montebello Forebay Injection				**31,000**
	CB-P2	SJCWRP – 100% AWT	MFSG	15,500*
	CB-P8	LCWRP AWT	Injection at Montebello Forebay	15,500
CB-A4a: SJCWRP (100% Tertiary) to MFSG & Stormwater to MFSG				**31,000**
	CB-P1	SJCWRP	MFSG	14,000*
	CB-P9	San Gabriel/Rio Hondo Rivers	MFSG	17,000
CB-A4b: SJCWRP (100% AWT) to MFSG & Stormwater to MFSG				**31,000**
	CB-P2	SJCWRP – 100% AWT	MFSG	14,000*
	CB-P9	San Gabriel/Rio Hondo Rivers	MFSG	17,000
CB-A5a: SJCWRP (100% Tertiary) to MFSG & Los Angeles River to Los Angeles Forebay (via ARRF)				**31,000**
	CB-P1	SJCWRP	MFSG	26,000*
	CB-P10	Los Angeles River	ARRF at Los Angeles Forebay	5,000
CB-A5b: SJCWRP (100% AWT) to MFSG & Los Angeles River to Los Angeles Forebay (via ARRF)				**31,000**
	CB-P2	SJCWRP – 100% AWT	MFSG	26,000*
	CB-P10	Los Angeles River	ARRF at Los Angeles Forebay	5,000

* Project yield adjusted from description in Section 5.1 to meet yield total for alternative.

5.2.2.2 Concept B Alternatives

Two Concept B alternatives were defined, and each has two versions that adjust the level of treatment applied to recycled water prior to replenishment:

- **CB-B1.** Maximum Existing RW Sources with Enhanced Stormwater Capture (+ 57,770 AFY)
- **CB-B2.** Maximum Existing and Additional RW Sources with Enhanced Central Basin Stormwater Capture (Alternative CB-B1 + 45,480 AFY)

The alternatives are summarized in Table 5-10.

TABLE 5-10
List of Central Basin Concept B Alternatives

Alt ID	Project ID	Replenishment Supply	Replenishment Location/Method	Annual Average Replenishment (AFY)
CB-B1a: SJCWRP (100% Tertiary) to MFSG, SJCWRP to Montebello Forebay Injection, LCWRP to Montebello Forebay Injection, SW to MFSG (FIX-IT), Los Angeles River to Los Angeles Forebay (ARRF)				**88,770**
	CB-P8	LCWRP AWT	Injection at Montebello Forebay	9,500*
	CB-P9	San Gabriel River/Rio Hondo	MFSG	17,000
	CB-P10	Los Angeles River	ARRF at Los Angeles Forebay	5,000
	CB-P1+CB-P11	SJCWRP (100% Tertiary)	MFSG	48,580*
	CB-P13	SJCWRP (100% AWT)	Montebello Forebay Injection	8,690
CB-B1b: SJCWRP (100% AWT) to MFSG, SJCWRP to Montebello Forebay Injection, LCWRP to Montebello Forebay Injection, SW to MFSG, Los Angeles River to Los Angeles Forebay				**88,770**
	CB-P8	LCWRP AWT	Injection at Montebello Forebay	9,500
	CB-P9	San Gabriel River/Rio Hondo	MFSG	17,000
	CB-P10	Los Angeles River	ARRF at Los Angeles Forebay	5,000
	CB-P2+CB-P12	SJCWRP (100% AWT)	MFSG	48,580*
	CB-P13	SJCWRP (100% AWT)	Montebello Forebay Injection	8,690
CB-B2a: New Satellite AWT to Los Angeles Forebay w/ CB-B1a				**134,250**
	CB-B1a*			88,770
	CB-P14	New Satellite AWT (MBR/RO/AOP)	Los Angeles Forebay Injection Wells	45,480
CB-B2b: New Satellite AWT to Los Angeles Forebay w/ CB-B1b				**134,250**
	CB-B1b**			88,770
	CB-P14	New Satellite AWT (MBR/RO/AOP)	Los Angeles Forebay Injection Wells	45,480

* Indicates that this alternative includes all projects associated with Alternative CB-B1a, per above.
** Indicates that this alternative includes all projects associated with Alternative CB-B1b, per above.

5.2.3 Alternatives Evaluation

This section provides a qualitative and quantitative comparison of the alternatives defined in Section 5.2. The following criteria were defined for each alternative for comparison:

- Cost
- Water supply availability and reliability
- Energy/ GHG emissions
- Environmental impacts
- Total dissolved solids (TDS) loading

5.2.4 Cost Estimates

Tables 5-11 and 5-12 summarize the cost estimates for each West Coast Basin and Central Basin alternative, respectively, composed of the sum of the relevant project costs. The graphs in Figures 5-14 and 5-15 show the present value unit costs ($/af) for each alternative, relative to the total alternative yield.

TABLE 5-11
West Coast Basin Alternatives – Preliminary Cost Estimates

ID	Description	Annual Yield (AFY)	Total Capital Cost ($M)	Total Annual O&M ($M)	Total Water Purchase ($M)	Total Present Value ($M)	Present Value Unit Cost ($/af)
WB-A1	WCBB+DGBP	18,000	$170.4	$9.3	$2.268	$400	$1,120
WB-B1a	+30k-JWPCP	30,000	$332.0	$13.3	$2.656	$648	$1,090
WB-B1b	+30k-DGB	30,000	$308.9	$10.8	$7.741	$675	$1,140

TABLE 5-12
Central Basin Alternatives – Preliminary Cost Estimates

ID	Description	Annual Yield (AFY)	Total Capital Cost ($M)	Total Annual O&M ($M)	Total Water Purchase ($M)	Total Present Value ($M)	Present Value Unit Cost ($/af)
CB-A1a	SJCWRP (100% Tertiary) to MFSG	31,000	$0.1	$0.0	$9.300	$184	$300
CB-A1b	SJCWRP (100% AWT) to MFSG	31,000	$267.0	$14.7	$3.647	$630	$1,030
CB-A1c	SJCWRP (50% AWT) to MFSG	31,000	$161.0	$7.3	$6.474	$434	$710
CB-A1d	SJCWRP (100% NF) to MFSG	31,000	$226.8	$12.5	$3.523	$544	$890
CB-A1e	SJCWRP (50% NF) to MFSG	31,000	$137.4	$6.2	$3.585	$332	$540
CB-A1f	SJCWRP (Ozone/BAC/GAC) to MFSG	31,000	$158.0	$5.9	$3.647	$346	$560
CB-A2a	A1a & LCWRP (100% AWT) to MFSG	31,000	$190.5	$8.3	$6.474	$482	$790
CB-A2b	A1b & LCWRP (100% AWT) to MFSG	31,000	$347.1	$15.8	$3.648	$731	$1,190
CB-A3a	A1a & LCWRP (100% FAT) to Montebello Forebay Injection	31,000	$242.0	$7.8	$6.474	$524	$850

TABLE 5-12
Central Basin Alternatives – Preliminary Cost Estimates

ID	Description	Annual Yield (AFY)	Total Capital Cost ($M)	Total Annual O&M ($M)	Total Water Purchase ($M)	Total Present Value ($M)	Present Value Unit Cost ($/af)
CB-A3B	A1b & LCWRP (100% FAT) to Montebello Forebay Injection	31,000	$402.0	$7.8	$3.648	$773	$1,260
CB-A4a	A1a & Stormwater to MFSG	31,000	$151.3	$2.4	$4.200	$281	$460
CB-A4b	A1b & Stormwater to MFSG	31,000	$302.3	$15.1	$1.647	$634	$1,030
CB-A5a	A1a & Los Angeles River to Los Angeles Forebay (ARRF)	31,000	$55.9	$0.7	$7.800	$224	$370
CB-A5b	A1b & Los Angeles River to Los Angeles Forebay (ARRF)	31,000	$265.8	$13.2	$3.059	$587	$960
CB-B1a	Max SJCWRP (100% Tertiary) to MFSG, SJCWRP & LCWRP to Inject, FIX-IT, ARRF	88,770	$768.9	$24.5	$16.720	$1,584	$900
CB-B1b	Max SJCWRP (100% AWT) to MFSG, SJCWRP & LCWRP to Inject, FIX-IT, ARRF	88,770	$1,166.0	$10.8	$7.856	$2,215	$1,260
CB-B2a	CB-B1a plus Satellite AWTF to Los Angeles Forebay Injection	134,250	$2,063.8	$84.8	$16.714	$4,072	$1,530
CB-B2b	CB-B1b plus Satellite AWTF to Los Angeles Forebay Injection	134,250	$2,809.1	$109.8	$7.856	$5,137	$1,930

FIGURE 5-14
West Coast Basin Alternatives – Present Value Unit Costs

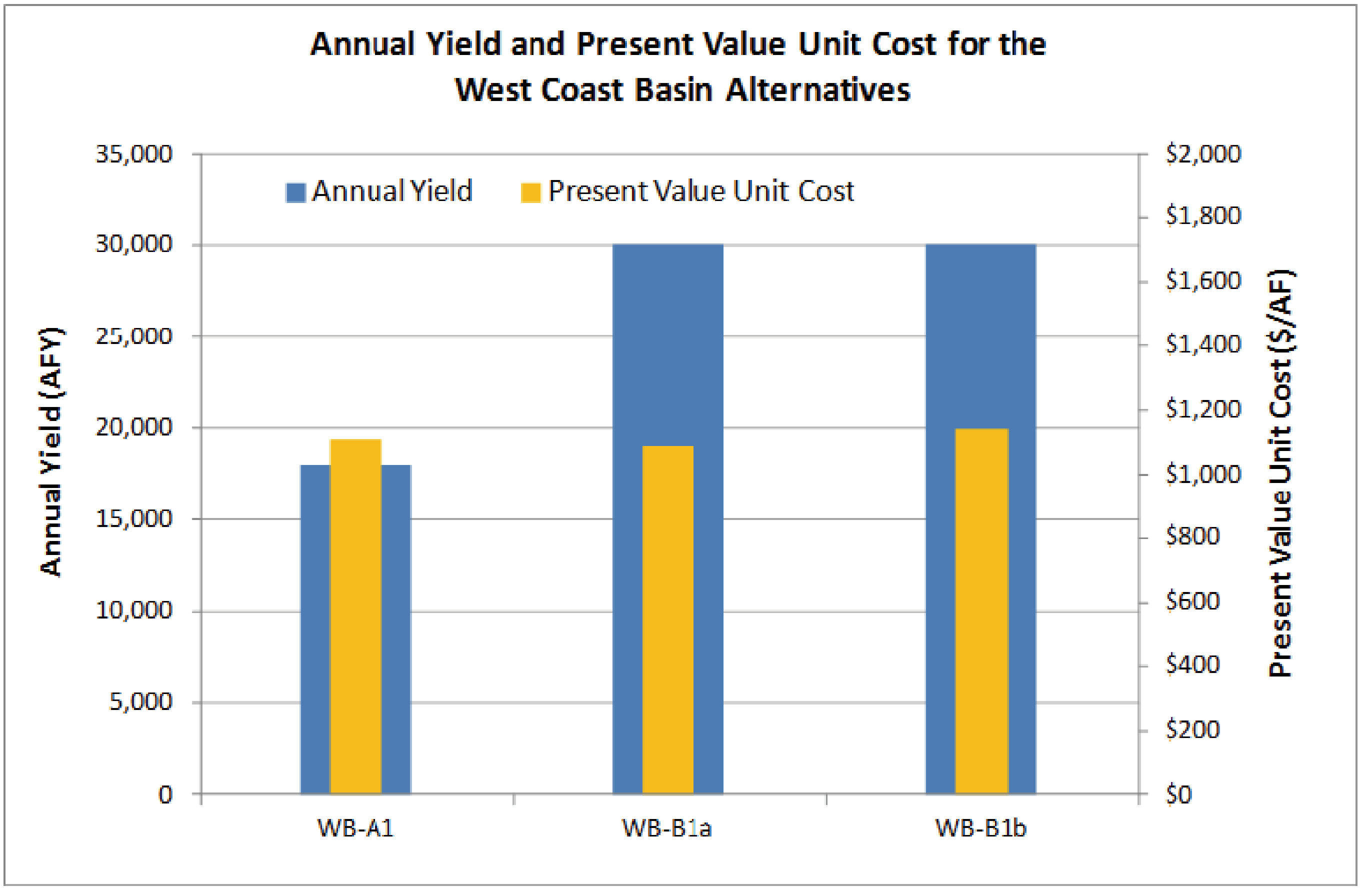
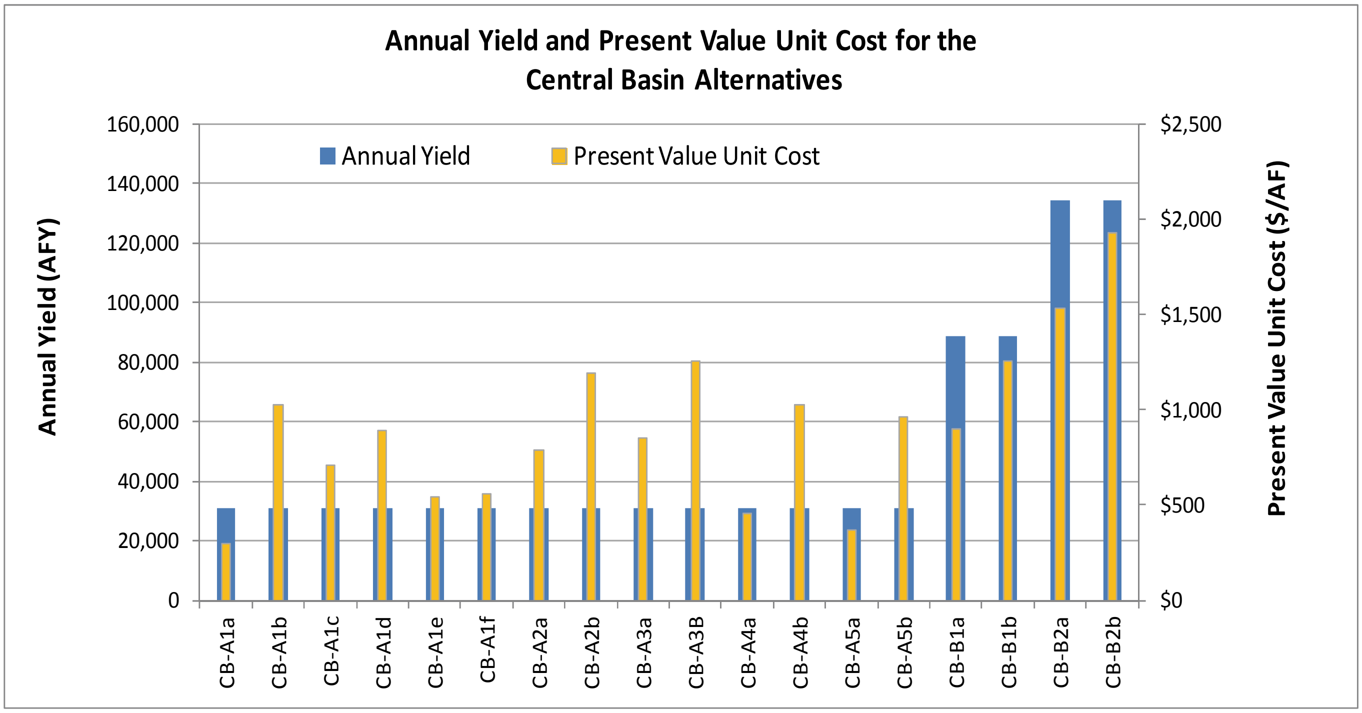


FIGURE 5-15
Central Basin Alternatives – Present Value Unit Costs



5.2.5 Water Supply Availability and Reliability

The replenishment supplies considered in the Draft GBMP include:

- SJCWRP
- LCWRP
- JWPCP
- TIWRP
- ECLWRF from HTP
- Satellite AWTF from Los Angeles raw wastewater
- San Gabriel River/Rio Hondo
- Los Angeles River

Of these, JWPCP and HTP have significant surplus effluent such that its availability for a GBMP project is the most likely. Los Angeles raw wastewater should also be available, but its use would reduce flows to HTP. The volumes of remaining recycled water supplies included in the GBMP—SJCWRP, LCWRP, and TIWRP—are currently not being reused, but there may be alternate plans for these supplies that could supersede GBMP project needs. All of the recycled water supplies are reliable if they are available.

The San Gabriel River/Rio Hondo flows in the GBMP are captured wet-weather conditions when the existing MFSG are at capacity. They would require the same conditions in the future, so availability and reliability is dependent on future flow conditions. The Los Angeles River flows in the GBMP are also wet weather, but none of these flows are currently captured. Therefore, there is a higher availability and reliability.

5.2.6 Energy/Greenhouse Gas Emissions

Energy demand is expressed as total annual kilowatt-hours (kWh) for an alternative. It is calculated from combining the energy requirements for treatment and pumping. The calculations include the energy required for typical operation only and do not include raw material or construction activities. The basis for treatment and conveyance energy calculations is summarized in Table 5-13. The calculations for energy demand are included in Appendix J.

TABLE 5-13
Treatment and Conveyance Energy Values for GBMP Replenishment Supplies

Supply	kWh/AF	Reference
Recycled Water – Tertiary	0	
Recycled Water – FAT	980	CPES
Recycled Water – NF Alternative	770	CPES
Recycled Water – Ozone/BAC/GAC	390	CPES
Stormwater	0	
Imported Water - MWD Treated	2,500	WBMWD, 2007

Notes:

Conveyance energy intensity for MWD imported water is calculated using the average values for State Project Water and Colorado River Authority water (WBMWD, 2007).

Energy calculations for conveyance are based on the Hazen-Williams formula, using inputs for flow rate, total dynamic head, a pumping efficiency of 0.75, and a motor efficiency of 0.95. The calculations for conveyance energy are included with the cost estimates in Appendix J.

CPES = CH2M HILL Parametric Estimating System
kWh/AF = kilowatt-hour per acre-foot

Using these assumptions, annual values for energy demands (in kWh) were calculated for each project/ alternative. In addition to lifecycle energy demands, lifecycle carbon dioxide (CO_2) emissions were also calculated to indicate potential contributions with respect to climate change. The emissions calculated were carbon dioxide, methane, and nitrous oxide, which each converted to metric tons of carbon dioxide equivalents. The metric tons CO_2 equivalents were then divided by the total potable water use offset by recycled water use. The Global Warming Potential Factors were based on the *General Reporting Protocol* (California Climate Action Registry, 2008).

FIGURE 5-16
West Coast Basin Alternatives – Energy Use/Greenhouse Gas Emissions

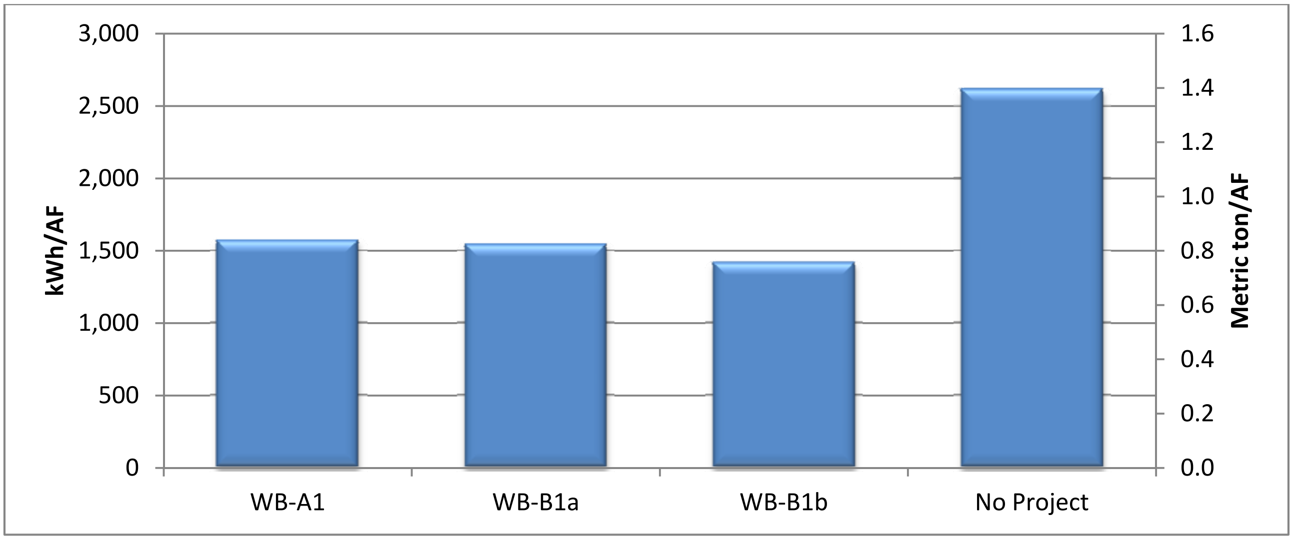
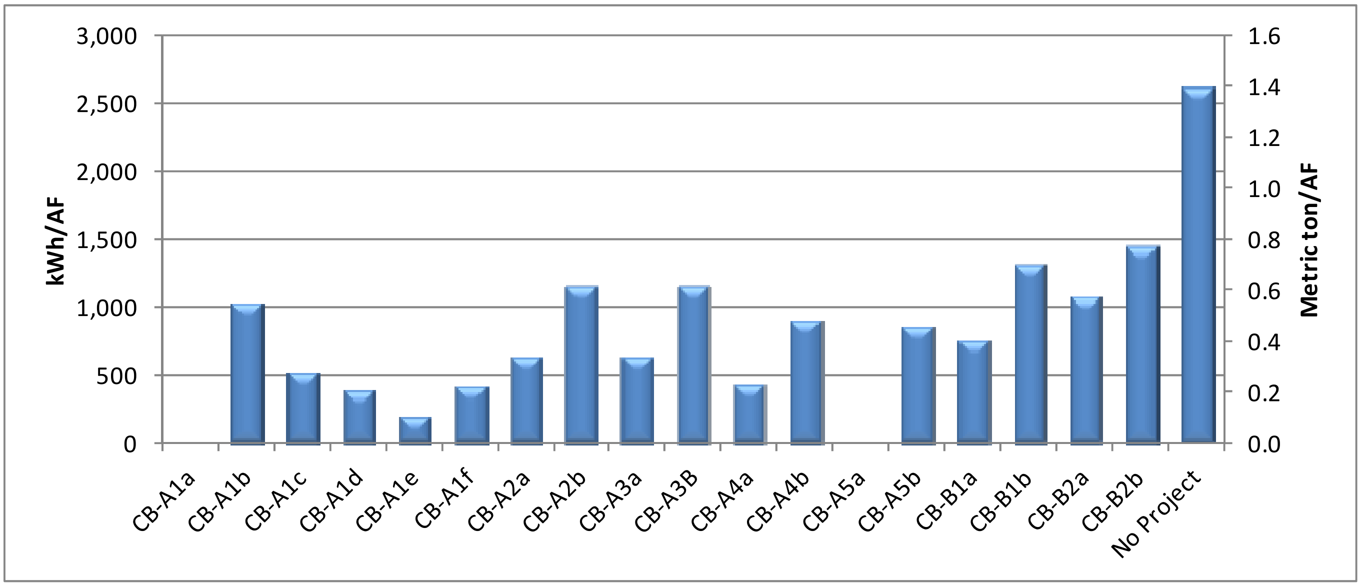


FIGURE 5-17
Central Basin Alternatives – Energy Use/Greenhouse Gas Emissions



5.2.7 Environmental Impacts and Total Dissolved Solids Loading

The GBMP alternatives vary with respect to the environmental impacts they may have. Generally, the greater the number of new facilities included in an alternative, the greater the potential environmental impact. Evaluations of these alternatives will be conducted at a programmatic level with the preparation of a Programmatic Environmental Impact Report (PEIR). These evaluations will indicate the nature and extent to which each alternative may have operational impacts to the groundwater basins, as well as potential operational impacts associated with infrastructure projects, such as noise, air pollution and energy use/GHG emissions. In addition, the nature and extent of construction impacts related to the installation of facilities included in the alternatives will be identified. Such potential impacts may include traffic, air pollutants, noise, and disruptions to biological or cultural resources. Ultimately, mitigations for these potential impacts will also be identified.

A critical operational consideration is the potential impacts, which can be potentially beneficial as well as detrimental, to the groundwater quality. Such issues are being explored more fully under the WRD/LACSD GRIP program with regard to recycled water impacts on the Central Basin. Also, a Salt and Nutrient Plan (SNMP) is currently under development for the Central and West Coast Basins. The potential changes in TDS due to varying proposed levels of treatment are identified in Table 5-14. For broad planning purposes, TDS can be used as an indicator to compare alternatives on the basis of water quality impacts.

The TDS concentration values used for various types of supply sources are summarized in Table 5-14.

Using these assumptions and the supply graphs, the annual tons of TDS added to the basins were calculated for each alternative, based on the volumes and estimated TDS concentrations of the various supply sources. These are shown on Figures 5-18 and 5-19 for the West Coast Basin and Central Basin alternatives, respectively.

TABLE 5-14
Total Dissolved Solid Concentration Values for GBMP Replenishment Supplies

Supply	TDS Concentration (mg/L)	Reference
Recycled Water – Tertiary (SJCWRP)	567	CH2M HILL, 2012b
Recycled Water – 100% FAT	100	MWH, 2009
Recycled Water – 100% NF	340	CH2M HILL
Recycled Water – Ozone/BAC/GAC	567	CH2M HILL
Stormwater[a]	271	LACDPW, 2010
Imported Water (No Project) [b]	439	Metropolitan, 2010b

[a] Average value for wet weather months

[b] Average of Colorado River Aqueduct (628 mg/L) and State Water Project (250 mg/L)

FIGURE 5-18
West Coast Basin Alternatives – Total Dissolved Solid Loading Rates

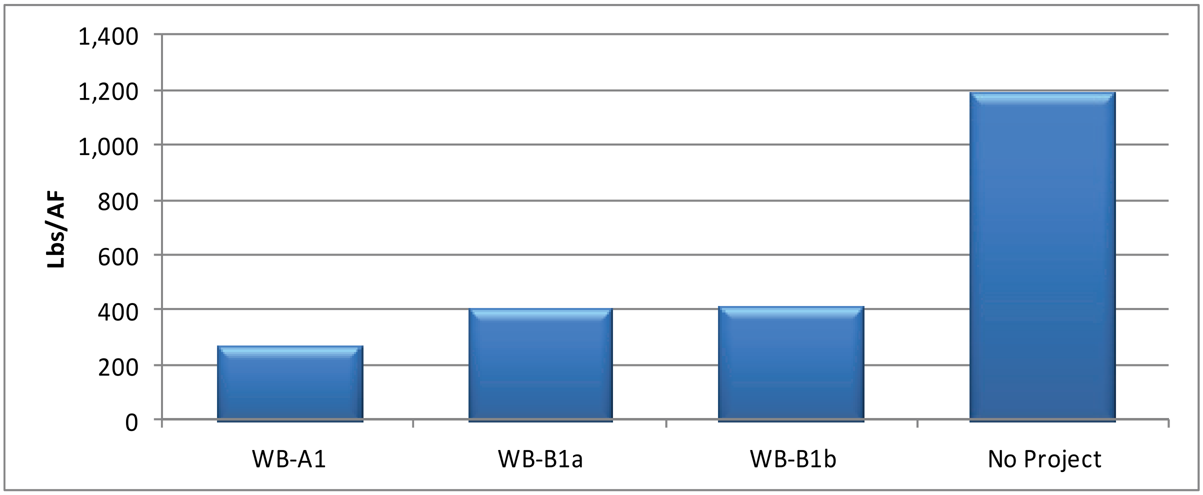
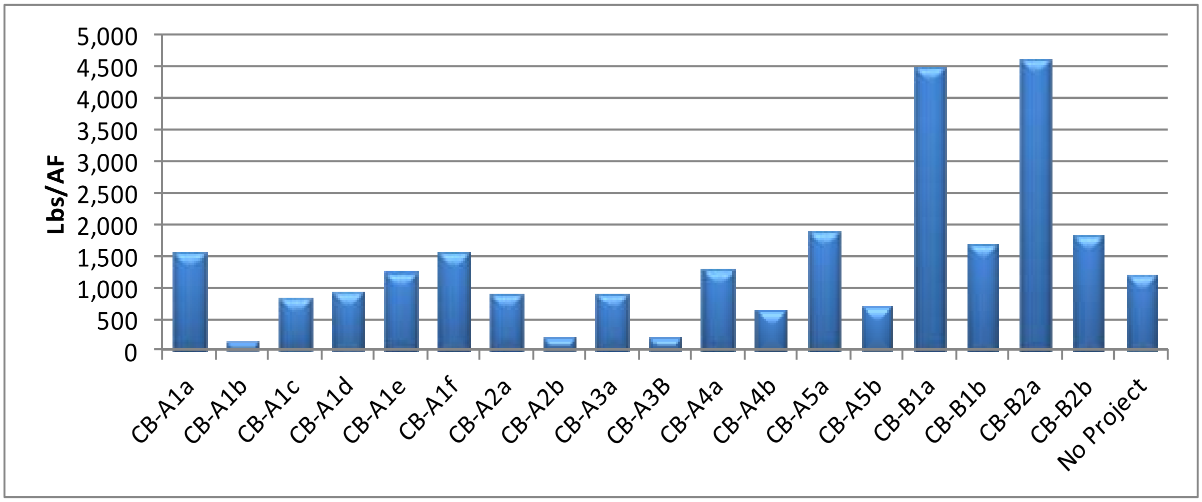


FIGURE 5-19
Central Basin Alternatives – Total Dissolved Solid Loading Rates



The SNMP will establish guidelines for projects within the Central and West Coast Basin. These will need to be considered as elements of the GBMP alternatives move forward toward implementation.

5.2.7.1 Summary of Alternatives Evaluation

Key findings of a comparison of the GBMP alternatives against the evaluation criteria described above include:

- AWT alternatives lifecycle costs are more than twice the costs for tertiary alternatives.
- The lifecycle costs for tertiary alternatives could be even lower if the purchase price for tertiary effluent is reduced. These estimates assume a price of $300 per AF for tertiary projects and a price of $100 per AF for AWT projects.
- Energy demands and CO_2 emissions are significantly higher for the No Project Alternative due to pumping required for the conveyance of imported water.
- CO_2 emissions for AWT alternatives are approximately 60 percent less than the No Project Alternative.
- CO_2 emissions for tertiary alternatives are significantly lower than the No Project Alternative.
- AWT alternatives result in a TDS loading that is significantly lower than the No Project Alternative.
- Tertiary alternatives result in a TDS loading that is approximately 40 percent higher than the No Project Alternative.

As the GBMP alternatives move forward through the environmental review process, there are numerous challenges to implementation of any part of these alternatives. Such considerations are discussed in the next section.

SECTION 6.0

Implementation Plan

WRD initiated the preparation of this Draft GBMP to facilitate long-term planning with basin stakeholders and to identify sustainable, reliable sources of replenishment water to meet projected groundwater production demands cost-effectively.

As an element of WRD's WIN program, the GBMP establishes a framework in which projects recommended for further evaluation can be examined and considered within an open, transparent process. By considering regional, basin-wide needs and opportunities, the GBMP offers stakeholders options that can satisfy individual water systems' interests and priorities while also providing broader basin benefits. Under the WIN program, WRD has been implementing projects and programs that enhance basin replenishment, increase the reliability of groundwater resources, improve and protect groundwater quality, and ensure that the groundwater supplies are suitable for beneficial uses. Offering a wide range of alternatives for the basin stakeholders to consider in advancing the WIN program goals is the primary objective of the GBMP.

WRD is responsible for ensuring that replenishment goals are met with respect to quantity and quality of replenishment water to meet the pumping demands in the West Coast and Central Basins, up to the adjudicated water rights and APA, respectively. Toward that end, WRD would lead the development of such projects that would provide reliable, cost-effective replenishment sources.

The implementation of any projects or programs that would exceed the replenishment obligations of WRD would result solely from the impetus of the basin stakeholders to invest in the development of additional replenishment water to more fully utilize the basins, and "WIN BIGGR."

This section summarizes potential implementation issues associated with the projects that make up the GBMP alternatives and identifies next steps for implementation of the GBMP program. Some of the implementation issues described below vary with respect to whether the project is considered to meet replenishment needs for pumping within the adjudicated rights, or extend beyond these limits to further utilize basin storage, and are discussed in that context.

6.1 Implementation Considerations

Advancement of the GBMP projects or alternatives described above will require consideration of the following:

- New recycled water regulations
- Ongoing GRIP implementation
- Recycled water flow availability
- River storm flow availability
- MFSG capacity
- SNMP development
- West Coast Basin Flow and Transport Model revisions
- Public and stakeholder participation process
- Replenishment assessment
- Potential Judgment amendments

6.1.1 Recycled Water Regulations

There are two significant regulatory activities underway in California that will impact recycled water project implementation: the 2011 Draft Recharge Regulation and The Water Recycling Act of 2012, a proposed statutory rewrite of state-wide water recycling regulations intended to consolidate the regulations and streamline the permitting process.

The 2011 Draft Recharge Regulation was released in November 2011 and will evolve over the year or so as CDPH revises it based on stakeholder input prior to initiating formal rulemaking in 2013. This new regulation, and how it is revised and implemented, will have significant implications for planning, design, and implementation of GBMP projects in the Montebello Forebay. Potential changes include:

- Reducing the required 6-month retention time as part of the pathogen control provisions
- Increasing RWC averaging period from 60 to 120 months
- Eliminating obstacles and speeding up the timeline for increasing the RWC
- Facilitating higher maximum RWCs for surface spreading projects using tertiary recycled water or some combination of tertiary/advanced treatment
- Facilitating higher initial RWC for injection projects using FAT
- Allowing for alternatives to all sections of the Draft Recharge Regulation if the alternative provides an equivalent level of health protection and, as required by CDPH, review by an expert panel

Recognizing the recycled water permitting scheme has not been updated in over 20 years, and that the existing scheme is disjointed and not well grounded in the current state of scientific knowledge, The Water Recycling Act of 2012 was introduced to the Legislature in February 2012 as Assembly Bill (AB) No. 2398. This bill proposes a new statutory scheme that recognizes recycled water as a resource, separate and distinct from potable water and from sewage and wastewater. It establishes a system for regulating and permitting recycled water that is grounded in objective scientific review. It preserves most of the current functions of the water boards and funds the CDPH's currently unfunded workload related to recycled water. Finally, it specifies that most highly treated recycled water, the advanced treated purified water that is blended with drinking water, is to be permitted by CDPH in accordance with criteria specifically developed to protect public health. (WateReuse, 2012.)

Passage of AB 2398, as currently drafted, would accomplish the following:

- Revise and consolidate provisions relating to recycled water, including the law requiring the adoption of uniform water recycling criteria for groundwater recharge (discussed above) and surface water augmentation.
- Establish a statewide goal to recycle 1.5 million AFY of water by 2020 and 2.5 million AFY of water by 2030.
- Prescribe the types and contents of permits for recycled water to be issued by the State Water Resources Control Board (SWRCB) or a Regional Board, as appropriate.
- Establish a Water Recycling Research Fund for the SWRCB to conduct or fund research necessary to support the continued and safe use of recycled water in the state.
- Authorize CDPH to issue permits in accordance with prescribed procedures for raw water or treated water augmentation projects.

Passage of this, or a similar, bill into law would further encourage and expedite the implementation of recycled water projects, such as those reflected in the GBMP alternatives.

6.1.2 Groundwater Reliability Improvement Project

The GRIP Recycled Water Project will define how 21,000 AFY of the 31,000 AFY of the additional replenishment water needed to pump the full APA in the Central Basin will be provided. The project target of 21,000 AFY is intended to replace historical imported water used for spreading at the MFSG. The determination of the level of treatment needed for the GRIP project will depend largely on the other implementation issues discussed in this section. Preliminary design of this project is currently underway with consideration of various treatment schemes, ranging from tertiary to conventional advanced treatment using MF/RO/UV-AOP to alternative advanced treatment options including NF and ozone/BAC/GAC/UV-AOP. While the conventional AWT treatment train may be the most viable option for near-term full-scale implementation based on current regulatory requirements, a number of "AWT – Alternative" options may merit consideration for further investigation in light of the potential for significant O&M cost savings. Preliminary design will be completed in the fall of 2012, followed by a project-specific EIR/Environmental Impact Statement (EIS) process that will be conducted through late 2013. The outcome of this process will largely define future operations of the MFSG.

6.1.3 Recycled Water Flow Availability

Implementing all of the identified GBMP alternatives requires a large supply of recycled water for replenishment. Of the wastewater treatment plants, the JWPCP and HTP have significant surplus effluent such that its availability for a GBMP project is the most likely. Los Angeles raw wastewater should also be available, but its use would reduce flows to HTP. The volumes of remaining recycled water supplies included in the GBMP—SJCWRP, LCWRP, and TIWRP—are currently not being reused, but there may be alternate plans for these supplies that could impact their availability for GBMP project needs. GBMP projects represent very high beneficial use of these supplies (that is, groundwater replenishment), so firming up these supplies for GBMP projects should be a high priority. All of the recycled water supplies are reliable if they are secured by a long-term commitment.

6.1.4 Storm Flow Availability

The San Gabriel River/Rio Hondo flows considered in the GBMP are based on historical wet-weather conditions. Thus future hydrological patterns would need to be relatively similar to historical patterns to provide sufficient storm flow for the assumed capture volumes for the enhanced stormwater capture scenarios described in this draft GBMP. The Los Angeles River flows estimated for capture and use in the GBMP alternatives are also based on historical patterns, but none of these flows are currently captured and used. Therefore, there is a higher chance of availability of these flows. However, countywide programs targeting reduction of storm flows to mitigate downstream water quality impacts along with climate change impacts can affect these patterns in the long term, resulting in potentially less available storm flows than identified for the GBMP alternatives. Further study of storm flow availability is recommended if enhanced stormwater capture is chosen to be advanced forward. Given that enhanced stormwater capture from the San Gabriel River/Rio Hondo could be one of the more economical replenishment projects, with potential additional benefits to pumpers, this project should be considered for early implementation.

6.1.5 Montebello Forebay Spreading Grounds Capacity

Replenishment of the groundwater basins with stormwater provides both water supply as well as dilution credit to meet RWC requirements. The most cost-effective method for capturing and infiltrating large volumes of stormwater from the San Gabriel River and Rio Hondo is limited by the available capacity of the existing MFSG. Recharge is typically highest during the wet season when large volumes of stormwater are available from storm events and from subsequent releases from upstream dams. An analysis of historical, monthly recharge at the MFSG was conducted for the GBMP modeling and is described in Section 4.1.2. Historical records of recharge at the MFSG were used as the basis of assumptions for potential future recharge capacities during short-term high recharge events and for “normal” operations. Further detailed study of the recharge capacity, especially short-term high-rate recharge capacity to capture storm flows, is recommended to confirm that the assumed quantities of short-term high recharge rates are possible, as reductions in these rates will reduce the long-term average stormwater volumes that can be conserved. This study should be conducted as a part of the study of storm flow availability, as the two considerations are linked and critical to the overall supply volume that can be created from enhanced stormwater capture.

6.1.6 Salt and Nutrient Management Plan

The Central and West Coast Basins SNMP is currently being prepared in a partnership led by WRD. The plan may identify the need to reduce salt and/or nutrient loading to either basin in the future. As shown in Section 5.3.4, the salt loading for each alternative varies based on the replenishment supply mix and the level of treatment applied to recycled water. The alternatives with AWT and/or stormwater have lower salt and nutrient loadings than projects that rely more on tertiary effluent. Therefore, recommendations from the SNMP should be considered as GBMP projects are advanced for potential implementation.

6.1.7 West Coast Basin Flow and Transport Model

WBMWD and WRD are in the process of further calibrating the West Coast Basin groundwater flow and solute transport model for simulations of the saline plume. As described in Section 3.2.3.6, preliminary simulations of saline plume containment/remediation were conducted with the current West Coast Basin groundwater flow and solute transport model. These preliminary simulations indicated significant improvement in basin water quality. Once the groundwater flow and solute transport model is recalibrated for the saline plume, these simulations should be repeated to refine this operating condition. It is recommended that the West Coast Basin groundwater flow and solute transport model maintained by WBMWD be used to simulate this condition.

6.1.8 Public and Stakeholder Participation

As described in Section 2.1.2, many West Coast and Central Basin stakeholders have been engaged in the development of the GBMP. Several key opportunities for public and stakeholder participation are converging in the next year or so and can serve to advance the planning reflected in the Draft GBMP to replace imported water use and more fully utilize the groundwater basins. These include the following processes led by WRD:

- GBMP PEIR process
- GRIP Recycled Water Project EIR/EIS process
- SNMP stakeholder process

In addition, the Los Angeles RWQCB is considering the development of a Groundwater Quality Protection Strategy to “guide comprehensive, consistent, and coordinated groundwater protection within the Los Angeles Region.” This strategy would provide an overarching framework for the implementation and coordination of RWQCB groundwater programs. In addition to examining regulatory processes and procedures conducted by RWQCB, this program would include identification of plans and/or policies that would directly impact implementation of projects identified in the GBMP alternatives, such as promoting recycled water and stormwater use, as well as potential future actions to improve and protect groundwater quality.

The Los Angeles RWQCB has indicated that this Groundwater Quality Protection Strategy would be developed through an active stakeholder process (CH2M HILL, 2012).

Coordination among these various public/stakeholder outreach and involvement processes is critical to moving forward with implementation of a long-term, basin-wide plan that achieves the fundamental goals of the GBMP.

6.1.9 Replenishment Assessment

Each year, WRD establishes a replenishment assessment (RA) for the ensuing fiscal year (July 1 through June 30) based on the planned purchase of replenishment water as well as projects and programs related to groundwater replenishment and groundwater quality over the next water year (October 1 through September 30). The cost of replenishment water is the most significant component of the RA.

Although the costs for projects and alternatives developed in this GBMP are not projected as elements of future RAs, any water supply that can minimize the costs of replenishment water will be beneficial to minimizing future RAs. As the GBMP alternatives are intended to replace imported water use, their costs can be measured relative to projected imported water purchase costs, and thus their relative impact on the RA inferred.

Ultimately, specific agreements will be developed for each potential project, and the costs and benefits of implementation will be weighed by the affected parties. The RA impact of a particular project will necessarily become a part of that project’s implementation evaluation process.

6.1.10 Potential Judgment Amendments

The proposed Judgment amendments for the West Coast and Central Basins remain in a state of flux (see Appendix B for descriptions). Should they, or some alternative version, ultimately be approved by the courts in a manner that supports the proposed use of storage space in the basins, the Concept B alternatives and associated projects will warrant further investigation. Until that time, such projects should be considered in light of broader basin planning activities so that they may be implemented in conjunction with other water supply projects.

In addition, phasing of projects should be considered that can be implemented initially to meet more near-term pumping needs—that is, to satisfy potential extractions up to the current adjudicated limits (Concept A), and potentially be expanded to meet pumping demands that could materialize if Judgment amendments are approved (such that Concept B alternatives may move forward). For example, SJCWRP can in large part meet near-term replenishment demands in the Central Basin with the GRIP Recycled Water Project, which may or may not require implementation of the diversion projects that would provide additional influent flow to the plant (described in Section 3.3.2.2). However, an augmentation project that would be allowable under the Judgment amendments might justify the implementation of some of the even more expensive diversion projects to maximize the use of the SJCWRP as a producer of replenishment water for the Central Basin.

6.2 Next Steps

This Draft GBMP is intended to be a starting point for basin-wide planning that will serve as the basis for a programmatic environmental review process. Complementing stakeholder outreach conducted during the preparation of the Draft GBMP, WRD intends to use the EIR process to formally vet the Draft GBMP alternatives and further open dialogue about these potential opportunities. The determination of the relative value of these opportunities will stem from such dialogue. WRD's intent is to facilitate these discussions with the preparation of this Draft GBMP. The Draft GBMP is not intended to be a capital improvement program, nor does it address any of the institutional, financial, regulatory, or legal issues that might be associated with implementation of any of the identified projects or alternatives. Rather, the Draft GBMP provides technical analysis of what might be possible to enhance utilization of the West Coast and Central groundwater basins for local and regional benefits.

Next steps for moving forward with the findings of this GBMP include:

- New recycled water regulations: Track and continue active participation in the ongoing review and approval process for the CDPH Groundwater Recharge Regulation and AB 2398.
  - Pursue alternative treatment under draft GRRP regulations – Alternative AWT technologies could provide significant cost savings and lessen environmental impacts associated with energy use/GHG emissions.
  - Pursue increased RWC for recycled water – Prove efficacy of SAT at spreading grounds:
    - Determine the basis for RWC requirements (such as TOC, biodegradable dissolved organic carbon)
    - Determine allowable flows that can be counted as blend water (such as underflow, infiltration, runoff)
    - Determine the methodology for computing RWC
- Ongoing GRIP Recycled Water Project implementation: utilize GRIP project-specific analysis and EIR process to explore near-term and long-term project options, including phasing considerations.
- Recycled Water Flow Availability: Coordinate with LACSD for SJCWRP and LCWRP, with LADWP for TIWRP, and with WBMWD for ECLWRF. Define available flows with and without any improvements considering flow and use projections, seasonal and diurnal flow variations, and improvements necessary to maximize effluent, such as equalization or collection system diversions.
- River Flow Availability: Continue to update the WRD/USGS Groundwater Flow Model with stormwater data to maximize its benefit as a predictive tool using historical data. Explore potential long-term climate change impact predictions on future storm flows in the Los Angeles region. Consider a collaborative study with LACDPW and San Gabriel River/Rio Hondo stakeholders to assess stormwater availability and enhanced stormwater capture.
- MFSG Capacity: Coordinate with LACDPW to define the constraints and timing available for recharge via surface spreading of recycled water in the MFSG, as well as facilities necessary to convey the supply considering historic and projected stormwater recharge, historic and projected recycled water recharge, historic and projected spreading basins (including unlined river stretches), capacity/infiltration rates, LACDPW O&M, groundwater mounding, potential spreading grounds improvements, and existing and necessary

conveyance facilities. Consider development of an operational model/planning tool of the spreading basins, such as the Orange County Recharge Facilities Model, to conduct scenario analysis of basin operations in order to optimize the operation of the recharge facilities.

- SNMP: Coordinate advancement of GBMP alternatives with plan development.
- West Coast Basin Flow and Transport Model: Once the West Coast Basin flow and transport model is refined by WBMWD and WRD, reassess and refine desalter alternatives for saline plume containment/remediation, as appropriate.
- Public and Stakeholder Outreach: Coordinate among public/stakeholder participation efforts associated with the GBMP, GRIP, SNMP and other key stakeholder forums such as the West Basin Water Association and Central Basin Water Association

The Draft GBMP is intended to be a tool or resource to be used by all of the basin stakeholders to aid in decision making for future development of groundwater resources in the West Coast and Central Basins. The components of the various Draft GBMP alternatives can be used as building blocks to provide comparative cost estimates of future basin management scenarios. By considering a long-term planning horizon, WRD can work with the basin stakeholders to cultivate those programs and projects that will ultimately provide cost-effective replenishment for adjudicated pumping rights in the basins and ultimately a reliable supply alternative to a portion or all of the imported water use in the basins.

SANITATION DISTRICTS OF LOS ANGELES COUNTY

GRACE ROBINSON CHAN
Chief Engineer and General Manager

Memorandum

Date: October 29, 2012

To: Bryan Langpap

Through: Mark McDannel

From: Andre Schmidt

Subject: **Update to San Jose Creek East WRP Process Air Compressor Efficiency Study**

Summary

A study was performed in 2010 to evaluate the energy usage of the process air compressors (PACs) at San Jose Creek East WRP (SJCE) and to determine how much energy could be saved by replacing the PACs with new high efficiency units. It was determined that replacing all Stage One and Stage Two PACs at SJCE would annually save the plant 4.67 million kilowatt hours (kWh) and $570,000 in electricity costs (see DOC#1586534 for the study summary memo).

The Planning Section has requested that the energy savings calculations be updated for current conditions at SJCE as part of a grant funding application for a project that would include replacement of the PACs at SJCE. New data was collected for September 13, 2012 through October 17, 2012. Based on current air usage and PAC performance at SJCE, it is calculated that the plant would annually save 4.14 million kWh by replacing the PACs. Based on the 10-year historical average power price at SJCE of $0.109, this represents an annual electricity cost savings of $450,000. As with the 2010 study, these savings assume that there would be no changes to the air distribution or dissolved oxygen control systems. Optimizing these systems would result in additional savings.

Discussion

Several items contributed to the change in energy savings associated with replacing the PACs. The most significant items are as follows:

- The average power price used in the 2010 study was $0.122 per kWh. Since then the price of power has dropped significantly due to record low natural gas prices. It is expected that power prices will rebound in coming years due to compliance costs associated with California's Renewables Portfolio Standard and due to likely increases in natural gas prices. Rather than use the current power price, which is at a temporary ten year low, the average power price over the past ten years ($0.109/kWh) was used for this study.

- Average PAC air flow at SJCE increased from 66,900 scfm during the 2010 study period to 70,300 scfm for the current study period.

- The average efficiency of the PACs was 66% during the 2010 study period. The average efficiency of the PACs was 70% during the current study period. This increase in efficiency is partially due to the fact that during the previous study, one of the Stage Two PACs was being idled during the nighttime to avoid premature coupling failures that had occurred in the past from frequent starts. The second Stage Two PAC was not being operated during the current study period, eliminating the need for idling during the 2010 study period.

- The 2010 study assumed that the Stage One and Stage Two PACs would each be replaced in-kind, and that the two systems would continue to operate independently. The current study assumes that the two stages would be combined into one air distribution system since this is the current plan for the project.

- The 2010 study interpreted the PAC air flow data to be in units of "inlet cubic feet per minute" (icfm) based on information that was available at the time. Accordingly, corrections for temperature were made in the energy savings calculations. Since the 2010 study, it has been determined that the PAC air flow data is in units of "standard cubic feet per minute" (scfm). Therefore, the current study uses scfm and makes no temperature correction. The temperature correction in the 2010 study affected the results by only one or two percent.

The data differences between the two studies are summarized in the table below.

Table 1: Summary of Data Differences between 2010 Study and Current Study

Item	Units	2010 Study	2012 Study
Power Price	$/kWh	$0.122	$0.109
Average SJCE PAC Airflow	scfm	66,900	74,300
Average PAC Efficiency	percent	66.1%	70.3%
Average SJCE Total PAC Power	kW	2,119	2,249
Average SJCE Total PAC Power with New PACs	kW	1,586	1,776
Power Reduction of New PACs	kW	533	472
Annual Electricity Cost Savings	$	$570,000	$451,000

Compiled performance data for the existing PACs and the calculated energy consumption of new PACs is presented in Attachment 1. The energy consumption of new PACs is based upon Turblex model KA66 (the same as for the 2010 study). Performance data for the KA66 is presented in Attachment 2.

Attachment 1: San Jose Creek East WRP PAC Data and Energy Savings Calculations

Time[1]	Total PAC Airflow (kscfm)	Total PAC Power (kW)[2]	PAC 2 Discharge Pressure (psi)[3]	Average PAC Efficiency[4]	Number of Turblex KA66 Units[5]	Percent Airflow Capacity per KA66 Unit	KA66 Efficiency[6]	Total KA66 Power (kW)
0:00	79.6	2387	6.68	72%	4	83%	89.7%	1926
0:15	79.1	2359	6.65	72%	4	83%	89.7%	1907
0:30	78.5	2337	6.64	72%	4	82%	89.7%	1887
0:45	77.2	2328	6.62	71%	4	81%	89.6%	1854
1:00	76.8	2314	6.63	71%	4	80%	89.6%	1846
1:15	75.0	2254	6.60	71%	4	79%	89.4%	1800
1:30	73.2	2203	6.57	71%	4	77%	89.2%	1754
1:45	71.7	2159	6.54	71%	4	75%	89.0%	1712
2:00	70.0	2106	6.50	70%	3	98%	89.3%	1655
2:15	68.1	2054	6.46	69%	3	95%	89.5%	1595
2:30	66.7	2016	6.42	69%	3	93%	89.6%	1552
2:45	64.7	1964	6.38	68%	3	90%	89.7%	1493
3:00	64.0	1939	6.34	68%	3	89%	89.8%	1469
3:15	62.5	1893	6.30	68%	3	87%	89.8%	1425
3:30	62.0	1865	6.27	68%	3	87%	89.8%	1407
3:45	60.3	1828	6.23	67%	3	84%	89.8%	1360
4:00	58.6	1788	6.20	66%	3	82%	89.7%	1317
4:15	57.8	1767	6.16	65%	3	81%	89.6%	1291
4:30	57.4	1766	6.12	65%	3	80%	89.5%	1276
4:45	57.0	1751	6.09	64%	3	80%	89.5%	1261
5:00	56.5	1741	6.07	64%	3	79%	89.4%	1246
5:15	56.1	1729	6.05	64%	3	78%	89.4%	1233
5:30	55.8	1720	6.04	64%	3	78%	89.3%	1225
5:45	55.5	1732	6.03	63%	3	78%	89.3%	1219
6:00	55.5	1727	6.03	63%	3	77%	89.3%	1216
6:15	55.4	1735	6.03	62%	3	77%	89.3%	1215
6:30	54.6	1709	6.03	63%	3	76%	89.1%	1200
6:45	54.0	1686	6.03	63%	3	75%	89.0%	1188
7:00	53.9	1693	6.04	62%	3	75%	89.0%	1187
7:15	54.2	1702	6.05	63%	3	76%	89.1%	1197
7:30	55.2	1720	6.06	63%	3	77%	89.2%	1218
7:45	56.3	1736	6.08	64%	3	79%	89.4%	1243
8:00	57.3	1768	6.10	64%	3	80%	89.5%	1269
8:15	57.7	1778	6.13	65%	3	81%	89.6%	1283
8:30	58.6	1802	6.16	65%	3	82%	89.7%	1309
8:45	61.3	1858	6.19	66%	3	86%	89.8%	1374
9:00	64.2	1945	6.26	67%	3	90%	89.8%	1454
9:15	66.3	2007	6.30	68%	3	93%	89.7%	1513
9:30	67.6	2022	6.34	69%	3	94%	89.6%	1555
9:45	70.8	2127	6.35	69%	3	99%	89.3%	1637
10:00	73.6	2201	6.40	69%	4	77%	89.2%	1715
10:15	75.6	2280	6.44	69%	4	79%	89.5%	1769
10:30	77.3	2332	6.48	70%	4	81%	89.6%	1816
10:45	78.1	2317	6.51	71%	4	82%	89.6%	1843
11:00	79.9	2374	6.56	72%	4	84%	89.7%	1897
11:15	80.7	2398	6.60	72%	4	85%	89.8%	1927
11:30	82.4	2442	6.63	73%	4	86%	89.8%	1976
11:45	83.6	2483	6.65	73%	4	88%	89.8%	2011
12:00	84.2	2502	6.67	73%	4	88%	89.8%	2031
12:15	85.2	2517	6.68	73%	4	89%	89.8%	2061
12:30	85.8	2535	6.69	74%	4	90%	89.8%	2080
12:45	86.5	2549	6.71	74%	4	91%	89.7%	2101

13:00	86.9	2561	6.72	74%	4	91%	89.7%	2114
13:15	86.7	2561	6.73	74%	4	91%	89.7%	2114
13:30	87.1	2569	6.74	74%	4	91%	89.7%	2126
13:45	87.3	2574	6.75	74%	4	91%	89.7%	2134
14:00	87.2	2572	6.76	74%	4	91%	89.7%	2136
14:15	86.8	2570	6.77	74%	4	91%	89.7%	2127
14:30	86.3	2556	6.77	74%	4	90%	89.7%	2117
14:45	85.7	2539	6.74	74%	4	90%	89.8%	2091
15:00	84.7	2519	6.78	74%	4	89%	89.8%	2079
15:15	85.7	2543	6.79	74%	4	90%	89.8%	2105
15:30	85.1	2534	6.80	74%	4	89%	89.8%	2093
15:45	84.4	2525	6.80	74%	4	88%	89.8%	2078
16:00	82.9	2528	6.81	73%	4	87%	89.8%	2042
16:15	82.8	2515	6.82	73%	4	87%	89.8%	2043
16:30	82.6	2516	6.83	73%	4	86%	89.8%	2040
16:45	82.5	2513	6.83	73%	4	86%	89.8%	2040
17:00	82.0	2499	6.84	73%	4	86%	89.8%	2030
17:15	81.6	2492	6.84	73%	4	85%	89.8%	2021
17:30	81.2	2489	6.85	73%	4	85%	89.8%	2012
17:45	80.9	2491	6.85	72%	4	85%	89.8%	2007
18:00	80.8	2486	6.85	72%	4	85%	89.8%	2004
18:15	80.7	2479	6.86	73%	4	85%	89.8%	2003
18:30	80.8	2485	6.86	72%	4	85%	89.8%	2005
18:45	81.0	2489	6.86	72%	4	85%	89.8%	2010
19:00	80.5	2470	6.84	72%	4	84%	89.8%	1993
19:15	80.4	2469	6.84	72%	4	84%	89.8%	1992
19:30	80.4	2463	6.85	73%	4	84%	89.8%	1993
19:45	80.4	2452	6.85	73%	4	84%	89.8%	1992
20:00	80.8	2461	6.85	73%	4	85%	89.8%	2003
20:15	80.9	2466	6.84	73%	4	85%	89.8%	2005
20:30	81.1	2470	6.84	73%	4	85%	89.8%	2009
20:45	81.2	2471	6.84	73%	4	85%	89.8%	2010
21:00	81.1	2469	6.84	73%	4	85%	89.8%	2007
21:15	81.0	2455	6.82	73%	4	85%	89.8%	1998
21:30	81.0	2462	6.80	73%	4	85%	89.8%	1995
21:45	81.5	2478	6.80	73%	4	85%	89.8%	2007
22:00	81.6	2482	6.79	73%	4	86%	89.8%	2008
22:15	81.8	2482	6.78	73%	4	86%	89.8%	2008
22:30	81.8	2481	6.77	73%	4	86%	89.8%	2004
22:45	81.8	2478	6.76	73%	4	86%	89.8%	2003
23:00	81.8	2471	6.75	73%	4	86%	89.8%	1998
23:15	81.6	2461	6.74	73%	4	85%	89.8%	1991
23:30	81.3	2449	6.73	72%	4	85%	89.8%	1978
23:45	80.5	2423	6.71	72%	4	84%	89.8%	1954
Average	**74.3**	**2249**	**6.55**	**70%**	**3.67**	**85%**	**89.6%**	**1776**

Notes:

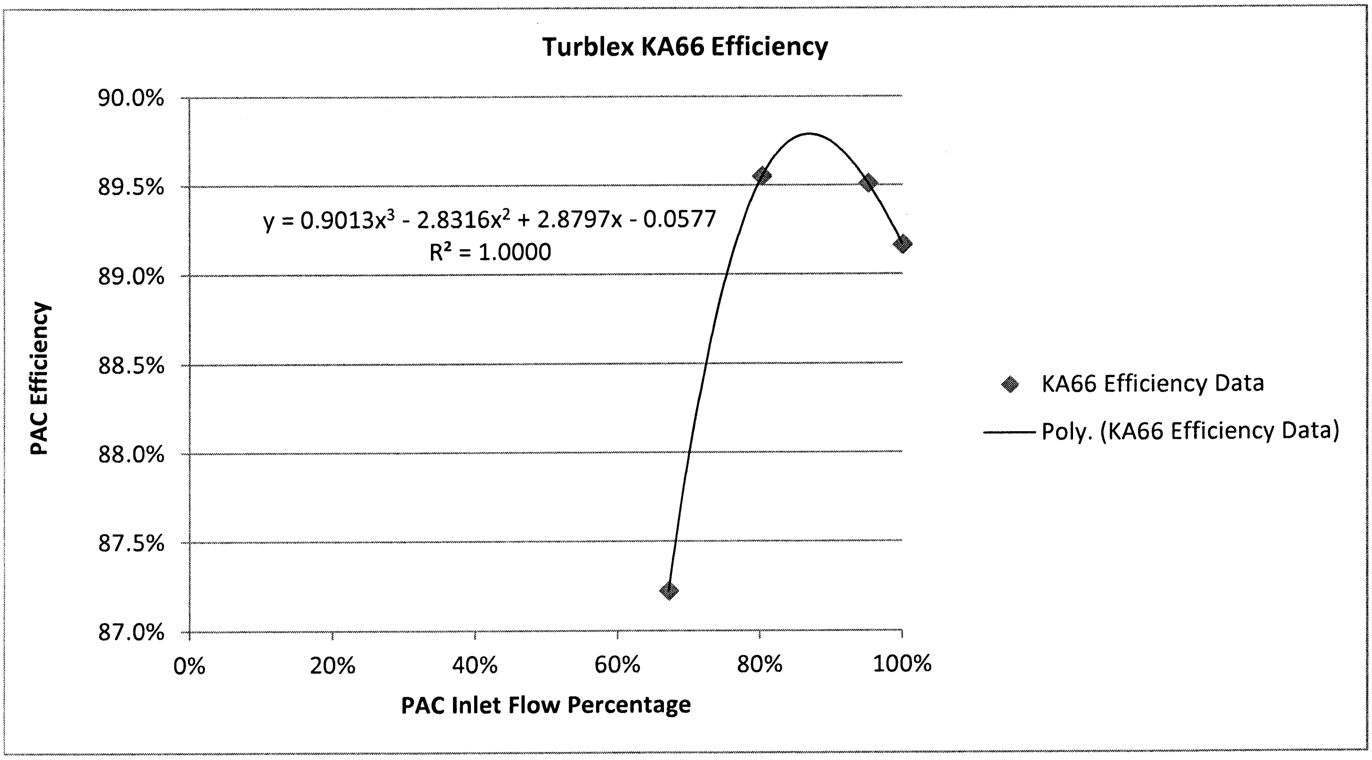
1. 15-minute interval data for time period 9/13/12 to 10/12/12 was collected. Data for each 15-minue period was averaged to create this composite profile.
2. Power data for Stage One PACs #1 and #3 was not available. Total Stage One PAC power was estimated based on PAC #2 power. This estimate is based on the assumption that the total Stage One PAC airflow per kW is the same as the PAC #2 airflow per kW.
3. For the PAC efficiency calcualtion it is assumed that the overall average discharge pressure is the same as the PAC #2 discharge pressure.
4. Efficiency is based on the formula: HP = [Flow (cfm) x Pressure (in w.c.)] / [6356 x Efficiency]
5. Energy of new system is based on Turblex KA66 single stage centrifugal PACs. Capacity of KA66 is 23,872 scfm each.
6. KA66 efficiency for the current data was not collected due to time constraints. The efficiency is derived from the best fit curve equation for data provided during 2010 study. See Attachement 2.

Attachment 2: Turblex KA66 Performance Data[1]

P0 psia	P2 psia	Gauge Pressure (psi)	Guage Pressure (in WC)	Inlet Flow %	acfm at 67 ºF 60% rh	hp at 67 ºF 60% rh	Efficiency[2]
14.7	21.72	7.02	194.3	100%	23872	818.6	89.2%
14.7	21.69	6.99	193.5	95.2%	22726	773	89.5%
14.7	21.47	6.77	187.4	80.3%	19169	631.2	89.6%
14.7	21.27	6.57	181.9	67.2%	16042	526.3	87.2%
14.7	21.27	6.57	181.9	45.0%	10742	374.3	82.1%

Notes:

1. Data per 5/12/10 Performance Data from Siemens (attached). Data for 67 degrees is used since this is the closest to standard conditions.
2. Efficiency = [Flow (cfm) x Pressure (in w.c.)] / [6356 x hp]



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                        ID: 2010-05-12_005004-640
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Attachment 2: Turblex KA66 Performance Data

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DOC-H
     Siemens               Performance Data Sheet                       12-05-10 : 00:50:04

                  Project: San Jose Creek WRP East Stage Two/One

                  Compressor Type: STC-GO(45-1-KA3LV) (Former name: KA66 SV GL400)
                  Power Supply: E-motor, Rpm = 1800
                  with Variable Diffuser Vanes: for Flow Regulation
                  and with Variable Inlet Guide Vanes: for Minimizing Power Consumption.

                  Inlet Conditions:
                  Pressure: see Table, Temperature: see Table, Relative Humidity: see Table.
                  Flow:  23790. scfm (@14.7 psia,36 % rh, 68 °F)
---------------------------------------------------------------------------------------------------
|             |       |   Compressor Performance and Power Consumption                            |
|             |       |   on the Motor Shaft at Inlet Conditions:                                 |
|press. press.|       |---------------------------------------------------------------------------|
|             | Inlet-|  100.00 °F      |   67.00 °F      |   47.00 °F      |         °F      |         °F      |
| P0    P2    | flow  |    60. % rh     |    60. % rh     |    60. % rh     |       % rh      |       % rh      |
|psia   psia  |  %    | acfm        hp  | acfm        hp  | acfm        hp  | acfm        hp  | acfm        hp  |
|-------------|-------|-----------------|-----------------|-----------------|-----------------|-----------------|
|14.700 21.720| 100.0 | 26038.    874.3| 23872.    818.6| 22806.    787.2|                 |                 |
|14.700 21.690|  95.2 | 24788.    824.8| 22726.    773.0| 21711.    743.9|                 |                 |
|14.700 21.470|  80.3 | 20908.    677.8| 19169.    631.2| 18313.    613.5|                 |                 |
|14.700 21.270|  67.2 | 17497.    552.9| 16042.    526.3| 15326.    512.9|                 |                 |
|14.700 21.270|  45.0 | 11717.    400.8| 10742.    374.3| 10263.    365.4|                 |                 |
|-------------|-------|-----------------|-----------------|-----------------|-----------------|-----------------|

+-----------------------------------------------------+
|WARNING -- WARNING -- WARNING -- WARNING -- WARNING|
|                                                     |
|THIS PDS IS CREATED USING EXTENDED PERFORMANCE DATA|
|IT IS  N O T  VALID WITHOUT APPROVAL FROM SIEMENS   |
|TURBOMACHINERY EQUIPMENT A/S, HELSINGOER, DENMARK   |
|                                                     |
|WARNING -- WARNING -- WARNING -- WARNING -- WARNING|
+-----------------------------------------------------+
                         - Inlet pressure drop 0.00 psid
                         - All losses incl. mech. oil pump are included.
                         - For ASME PTC-10 TORQUE METER TEST
                           with power tolerance of + 0% /- 4%.
```

WRD
WATER REPLENISHMENT DISTRICT
OF SOUTHERN CALIFORNIA

DIRECTORS
ALBERT ROBLES, PRESIDENT
LILLIAN KAWASAKI, VICE PRESIDENT
WILLARD H. MURRAY, JR., SECRETARY
SERGIO CALDERON, TREASURER
ROBERT KATHERMAN, DIRECTOR

ROBB WHITAKER, P.E., GENERAL MANAGER

October 15, 2012

Grace Robinson Chan
Chief Engineer and General Manager
County Sanitation Districts of Los Angeles County
1955 Workman Mill Road
Whittier CA 90607

Dear Ms. Chan;

Support for the San Jose Creek WRP East Process Optimization Project

On behalf of the Water Replenishment District of Southern California (WRD), I am pleased to support the San Jose Creek WRP East Process Optimization Project, which, among other benefits, will increase the volume of recycled water available for reuse, and will improve water quality due to improved treatment processes.

The WRD continues to pursue projects that develop local, sustainable sources of water to offset imported water used for groundwater replenishment in the Montebello Forebay. This program is referred to as the Groundwater Reliability Improvement Program (GRIP). The overall goal of the GRIP is to offset the current use of imported water by providing recycled water as a reliable supply source for groundwater basin replenishment via the Montebello Forebay. In addition to the subject project having merit on its own, the San Jose Creek WRP East Process Optimization project is one of the elements necessary to prepare the way for the GRIP. As such, I am pleased to support the project.

Very truly yours,

Robb Whitaker
General Manager
Water Replenishment District of Southern California

Upper District
WHERE SOLUTIONS flow
UPPER SAN GABRIEL VALLEY MUNICIPAL WATER DISTRICT

October 16, 2012

Grace Robinson Chan
Chief Engineer and General Manager
County Sanitation Districts of Los Angeles County
1955 Workman Mill Road
Whittier, CA 90607

Subject: Support for the San Jose Creek WRP East Process Optimization Project

Dear Ms. Chan:

On behalf of the Upper San Gabriel Valley Municipal Water District (Upper District), I am pleased to support the San Jose Creek WRP East Process Optimization Project, which, among other benefits, will increase the volume of recycled water available for reuse, and will improve water quality due to improved treatment processes.

The Upper District mission is focused on providing a reliable supply of water for drinking, residential, commercial, irrigation and industrial purposes. Our service area requires innovative water supply solutions that address water quality and development of new sources of water. The San Jose Creek WRP East Process Optimization project helps us accomplish our mission. As such, I am pleased to support the project on behalf of the Upper District.

Very truly yours,

Shane Chapman
Shane Chapman
General Manager

SJC WRP East Process Optimization - O&M Costs and Power Savings

Component	Incremental O&M Cost[1]	Power kWh/yr	Greenhouse Gases[2] MT CO$_2$e/yr	Greenhouse Gases equivalent homes[3]
Flow Equalization				
Pump Stations				
Power	$15,000	136,364	45	21
Maintenance	$27,000	-	-	-
Odor Control				
Power				
Blowers	$100,000	909,091	299	140
Recirculation Pumps	$22,000	200,000	66	31
Chemicals	$37,000	-	-	-
Carbon	$378,000	-	-	-
Maintenance	$55,000	-	-	-
Aeration System Controls	nominal decrease[4]	-	-	-
Process Air Compressor Replacement				
Power	-$451,000	-4,100,000	-1,346	-632
Maintenance	nominal decrease[5]	-	-	-
Sub-Total	**$183,000**	**-2,854,545**	**-937**	**-440**
Water Supply				
Replacing Imported State Water Project Water with Increased Groundwater Recharge[6,7,8]				
Up to 8,400 afy	-$6,837,600	-25,200,000	-8,276	-3,887
Grand Total	**-$6,654,600**	**-28,054,545**	**-9,213**	**-4,328**

[1] Incremental relative to existing operations/conditions. Assume 5% of all O&M costs cover administrative costs. ($0.11/kWh) assumed for average power cost for past 10 years (see DOC# 2393956).

[2] Based on 0.724 lb CO$_2$e/kWh (California Action Registry, General Reporting Protocol).

[3] Based on 0.74 kW per single family home.

[4] Improvements will reduce the amount of process air required and consequently, the electricity required by the PACs. However, the degree of improvement is unknown at this point.

[5] Newer PACs expected to require less frequent maintenance.

[6] Volume based on flow bypassing the WRP due to treatment limitations.

[7] Costs based on $814/acre-ft, which is the cost of imported water (http://www.centralbasin.org/budget2012.html).

[8] Power based on 3,000 kWh/AF (Analysis of the Energy Intensity of Water Supplies for West Basin Municipal Water District Report, March 2007, pg 4.)

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SEQUENTIAL CHLORINATION: A NEW APPROACH FOR DISINFECTION OF RECYCLED WATER

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SEQUENTIAL CHLORINATION: A NEW APPROACH FOR DISINFECTION OF RECYCLED WATER

Stephen R. Maguin, P.E., BCEE, Philip L. Friess, P.E., BCEE, Shiaw-Jy Huitric, P.E.,
Chi-Chung Tang, Ph.D., P.E., BCEE, Jeff Kuo, Ph.D., P.E., and Naoko Munakata, Ph.D.[1]

ABSTRACT

Recycled water must be properly disinfected to protect public health. The most widely practiced recycled water disinfection technology is chloramination. However, chloramines are precursors to the carcinogen N-nitrosodimethylamine (NDMA). To address this concern, engineers at the Sanitation Districts of Los Angeles County (Districts) developed the two-step "sequential chlorination" process. In the first step, free chlorine is added to fully nitrified secondary effluent to inactivate pathogens and to react with NDMA precursors, thus reducing subsequent NDMA formation. Chloramines are then added to media filtered effluent to stop formation of trihalomethanes (THMs) and haloacetic acids and to provide further disinfection.

The sequential chlorination process was extensively tested for disinfection efficacy and disinfection byproduct (DBP) formation in the laboratory, at the pilot scale, and at several water reclamation plants operated by the Districts. Results indicate that the process (1) provides effective disinfection against total coliform bacteria and viruses at chlorine contact times well below those required by California regulations for disinfected tertiary recycled paper; (2) reduces NDMA formation by 50 to 85% in comparison to chloramination; (3) produces effluent consistently meeting the total THM limit for recycled water; (4) generates insignificant amounts of cyanide (a DBP of concern); and (5) causes no aquatic toxicity.

INTRODUCTION

The Sanitation Districts of Los Angeles County (Districts) operate 11 wastewater treatment plants serving over five million residents in the Los Angeles County, California. The 11 plants treat a combined average daily flow of approximately 500 million gallons per day (MGD). Seven of the 11 plants are tertiary water reclamation plants (WRPs) that produce over 150 MGD of recycled water. Typical treatment processes at these tertiary WRPs include primary sedimentation, activated sludge with biological nitrogen removal, media filtration, chlorine disinfection, and dechlorination. Approximately one-third of the recycled water is currently reused for groundwater replenishment, landscape and agricultural irrigation, wildlife habitat maintenance, and industrial process water supply; the remainder is discharged to surface water.

Recycled water must be properly disinfected. The disinfection method must be effective for pathogen inactivation, and should minimize the generation of potentially harmful disinfection byproducts (DBPs). In California, disinfection requirements are specified in California Title 22 water recycling criteria. For groundwater replenishment, the recycled water must meet drinking water standards.

Historically, chlorination is the most widely practiced wastewater disinfection technology. Depending on the ammonia level in the water, chlorine may be present as either free chlorine or chloramines. At the Districts' tertiary WRPs, either free chlorine or chloramines may be used for disinfection because these plants are designed to remove nitrogen. Secondary effluents of these plants are considered fully nitrified and usually contain <1 mg NH_3-N/L. Until recently, chloramination was practiced at these WRPs because chloramines produce lower levels of trihalomethanes (THMs) than free chlorine (Kuo *et al.*, 2003). Low levels of ammonia nitrogen (typically 1.0 to 1.5 mg NH_3-N/L) were added to fully nitrified secondary effluent, followed by chlorine addition (8 to 10 mg Cl_2/L) upstream of the media filters. Additional chlorine could be added downstream of the filters, if necessary, to maintain sufficient chlorine residual in the chlorine contact tank effluent.

Chloramination has provided effective disinfection. However, researchers recently found that chloramines generate N-nitrosodimethylamine (NDMA), a chemical with high carcinogenic potency (Mitch *et al.*, 2003; Choi and Valentine, 2004; Mitch and Sedlak, 2004; Sedlak *et al.*, 2005). NDMA precursors are chloramines and dimethylamine, a component in the cationic polymer commonly added to the return activated sludge or to the mixed liquor entering the secondary clarifiers to enhance settling and for foam control. In previous work, the Districts attempted to reduce NDMA formation by replacing the cationic polymer with emulsion polymers that do not contain dimethylamine; although this change reduced NDMA formation, the alternative polymers were less effective than the cationic polymer as a settling aid, caused operational issues with the media filters, and were not considered a practical solution for reducing NDMA formation (Huitric *et al.*, 2006). Free chlorine and chloramines may also produce other DBPs such as cyanide (Kavanaugh *et al.*, 2003; Zheng *et al.*, 2004a & 2004b).

Due to these concerns, the Districts decided to replace chloramination with a new disinfection method that would continue to protect public health with its high disinfection efficacy, minimize DBP (specifically THM, NDMA, and cyanide) formation, and have no adverse impact to

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[1] Stephen R. Maguin, P.E., BCEE, is the Chief Engineer and General Manager of the Sanitation Districts of Los Angeles County. Philip L. Friess, P.E., BCEE, is a Departmental Engineer, Shiaw-Jy Huitric, P.E., is a Senior Engineer, Chi-Chung Tang, Ph.D., P.E., BCEE, is a Division Engineer, Naoko Munakata, Ph.D., is a project engineer of the Districts. Jeff Kuo, Ph.D., P.E., is a Professor in the Department of Civil and Environmental Engineering, California State University at Fullerton. Correspondence should be addressed to Chi-Chung Tang, Wastewater Research Section, Sanitation Districts of Los Angeles County, 1955 Workman Mill Road, Whittier, CA 90601; email: cctang@lacsd.org.

the environment (i.e., no aquatic toxicity). The new disinfection method should be easily and cost-effectively implemented by using existing infrastructure and practice. To meet these objectives, the Districts' staff conceived the idea of "sequential chlorination" in which chlorine is applied in two steps, as shown in Figure 1.

In the first step of sequential chlorination, free chlorine is added to fully nitrified secondary effluent. Free chlorine rapidly inactivates bacteria and viruses because it is a strong oxidant (Tchobanoglous *et al.*, 2003). It also reacts with NDMA precursors to make them less available for subsequent NDMA formation (Schreiber and Mitch, 2005). Furthermore, free chlorine residual helps to control biofouling on the filter media. In the second step of the process, ammonia and additional chlorine are added to filtered effluent to form chloramines. Chloramines minimize THM formation and provide additional bacterial and viral disinfection. The only change in system configuration from chloramination to sequential chlorination was to relocate the ammonia addition line from upstream to downstream of the media filters.

OBJECTIVES AND SCOPE

The main objective of the study was to evaluate the disinfection performance and DBP formation of the sequential chlorination process. The evaluation was conducted in four phases (Huitric *et al.*, 2007, Huitric *et al.*, 2008). Because DBP formation prompted this investigation, the first two phases focused on DBP formation, first at the laboratory scale (Phase I), then at the plant scale (Phase II). Phase II also examined regulatory compliance with respect to microbial inactivation and aquatic toxicity. The last two phases continued to study disinfection efficacy at the laboratory scale (Phase III) and pilot scale (Phase IV) with the specific goal of meeting California Title 22 virus inactivation requirements for "disinfected tertiary recycled water." Table 1 summarizes the specific objectives and scope of each phase of the study.

FIGURE 1
Sequential Chlorination at the Districts' Tertiary Water Reclamation Plants

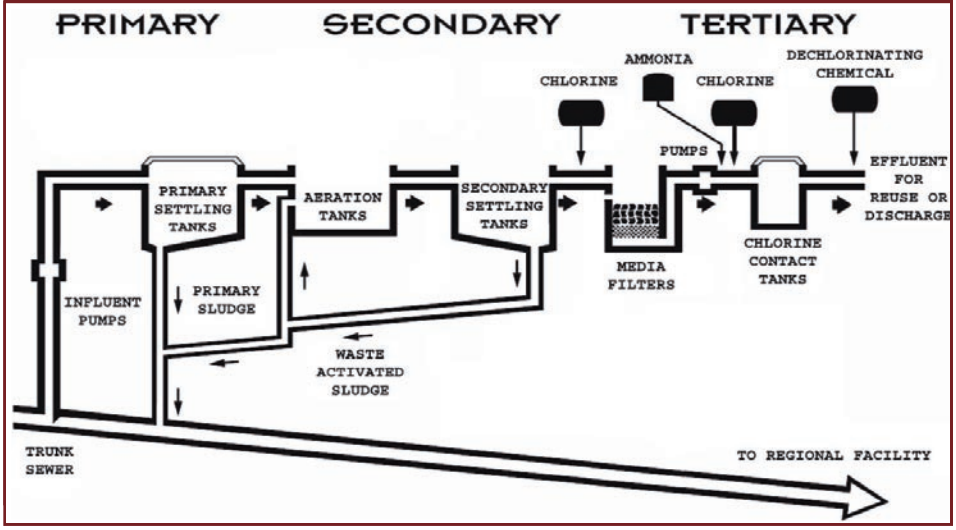


TABLE 1
Sequential Chlorination Research Objectives and Scope

Phase	Objectives	Scope
I	Evaluate DBP formation by sequential chlorination	Laboratory experiments using secondary effluent samples from Long Beach WRP
II	• Verify DBP formation results from laboratory study • Evaluate microbial (coliform and enteric virus) inactivation and aquatic toxicity • Determine operating conditions (i.e., chlorine dose and residual) for full-scale operation	Plant-scale testing at Long Beach WRP, San Jose Creek WRP*, and Whittier Narrows WRP
III	Determine chlorine doses and contact times needed to meet California Title 22 requirements for "disinfected tertiary recycled water" (5-log inactivation of poliovirus or MS2 coliphage and total coliform <2.2/0.1 L)	Laboratory experiments using secondary effluent samples from San Jose Creek WRP* seeded with surrogate viruses (poliovirus and MS2 coliphage)
IV	Verify virus inactivation results from laboratory experiments	Pilot-scale testing using secondary effluent from San Jose Creek West WRP seeded with MS2 coliphage

*San Jose Creek WRP includes two separate treatment systems, San Jose Creek East WRP and San Jose Creek West WRP.

MATERIALS AND METHODS

Phase I – Laboratory Experiments on DBP Formation

The focus of the Phase I experiments was to determine DBP formation from sequential chlorination and compare that with DBP formation from chloramination. Specific DBPs evaluated included THMs, NDMA, and cyanide. Microbial analyses were not conducted in these bench-scale experiments. Fully nitrified secondary effluent samples from the Districts' Long Beach WRP were used for the experiments. The samples were disinfected by chloramination and sequential chlorination. Figure 2 shows the test plan, including the ammonia and chlorine doses, contact times, and the water quality parameters analyzed. This procedure was repeated five times to evaluate the consistency of the results.

Phase II – Plant-scale Testing on DBP Formation and Disinfection Efficacy

Plant-scale studies were conducted at several WRPs operated by the Districts. Table 2 summarizes the average flow treated and the type of nitrification/denitrification (NDN) processes employed at these WRPs.

Each plant was tested for several weeks during which extensive sample collection and analysis was conducted. Samples were analyzed for chemical parameters (ammonia, THMs, NDMA, and cyanide), microbial indicators (total coliform and enteric virus), and aquatic toxicity. For NDMA analysis, 24-hour composite samples were collected. All other samples were grab samples. Typically, two sets of samples were collected on a daily basis; secondary effluent samples were collected around 7:30 a.m. and 9:30 a.m., and chlorinated final effluent samples at 10:30 a.m. and 12:30 p.m. The time difference was to account for the hydraulic retention time in the filters and in the chlorine contact tanks. Samples were also collected immediately downstream of the media filters (filtered effluent samples) to evaluate disinfection efficacy of free chlorine added upstream of the filters.

Phase III – Laboratory Experiments on Disinfection Efficacy

It was not feasible to demonstrate high levels of virus inactivation (5 logs required by California regulations for “disinfected tertiary recycled water”) by sequential chlorination at plant-scale because indigenous virus concentrations are usually lower than 10^5/0.1L in Districts’ tertiary WRP secondary effluent, and it was not practical to seed the amount of virus needed for the demonstration. Consequently virus inactivation by the sequential chlorination process was studied initially at the laboratory scale. The experiments were conducted with fully nitrified secondary effluent samples collected from the San Jose Creek WRP. Two indicator viruses, MS2 coliphage and poliovirus, were seeded to the samples, and three disinfection schemes were tested:

1. Chlorination: to simulate the first step of sequential chlorination;
2. Chloramination: to simulate the second step of sequential chlorination; and
3. Sequential chlorination: to simulate overall sequential chlorination process with free chlorine addition followed by chloramines (ammonia then chlorine) addition.

FIGURE 2
Schematic Diagram for Sequential Chlorination Bench-Scale Experiments

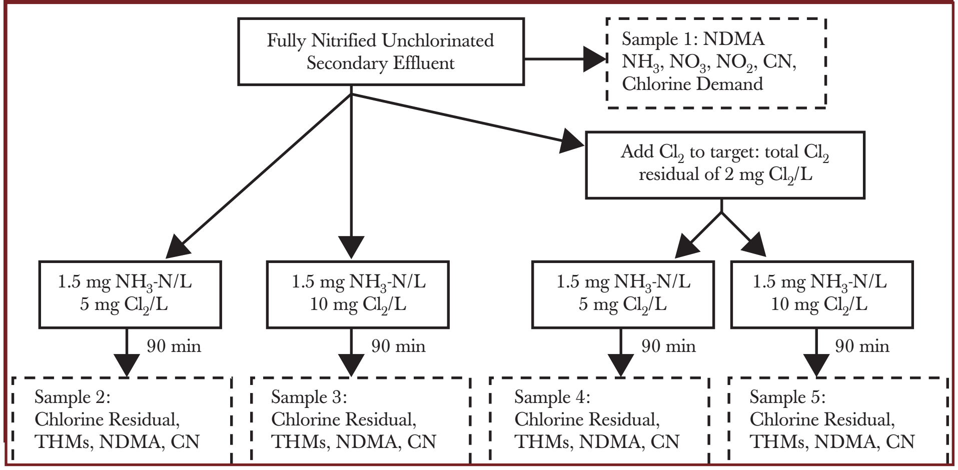


TABLE 2
Full-Scale Sequential Chlorination Testing: Facility Information

Test Facility	Test Period	Average Flow (MGD)	NDN Process
San Jose Creek East WRP	01/23/07 - 02/16/07	55	Step Feed
San Jose Creek West WRP	10/02/06 - 10/30/06	30	Step Feed
Whittier Narrows WRP	11/01/06 - 12/01/06	8	Modified Ludzack-Ettinger
Long Beach WRP	05/22/06 - 06/27/06	20	Step Feed

In each experiment, a portion of the effluent sample was first analyzed to obtain the baseline water quality parameters as well as total coliform concentrations. The rest of the sample was seeded with poliovirus and MS2 coliphage, and thoroughly mixed for at least 20 minutes. After mixing, initial virus concentrations were determined by collecting an aliquot of the sample before any chlorine treatment. For the free chlorine experiments, chlorine was added to the sample. Chloramine experiments added ammonia followed by chlorine. The sequential chlorination experiments added chlorine first, followed by ammonia then more chlorine. At pre-determined contact times, total and/or free chlorine residuals were measured. Samples were then dechlorinated using sodium thiosulfate, and analyzed for viruses as well as total coliform.

Phase IV – Pilot-scale Testing of Virus Inactivation

To verify the results from the Phase III study, the Districts conducted pilot-scale testing on virus inactivation at the San Jose Creek WRP. Figure 3 is a schematic diagram of the pilot-scale chlorine contact system constructed for the study. The system included two channels with 1-foot by 1-foot cross-sections. The length of the channels varied by experiment, as described below. Baffles were installed near the inlet of each channel to provide uniform flow distribution. Tracer tests were performed prior to any virus testing to determine modal contact times corresponding to several test flow rates. During virus testing, the channels were covered, as are the full-scale chlorine contact tanks at the plant, to avoid any effects from sunlight, wind, or dust.

Two types of tests were conducted with nitrified secondary effluent. One tested virus inactivation by free chlorine alone and used a single 24-foot long channel with an effluent flow rate of 8 gallons per minute (gpm). The other tested sequential chlorination and used two channels; the first channel was 12 feet long, used a flow rate of 22 gpm, and was dosed with free chlorine, while the second channel was 36 feet long, used a flow rate of 6 gpm, and was dosed with chloramines. In both types of experiments, virus (M2 coliphage) was mixed into the effluent with a static inline mixer. Following mixing, a sample was collected for analysis of initial virus concentration.

For the free chlorine experiments, chlorine was added upstream of the channel, and mixed into the flow using static inline mixers. Free chlorine residuals were measured at all sampling points within the channel. Samples were collected at four points along the length of the channel (corresponding to four different contact times), dechlorinated, and delivered to the laboratory for virus analysis. For the sequential chlorination experiments, chlorine was also added upstream of the first channel. Ammonia was then added to the end of the first channel, followed by more chlorine addition upstream of the second channel to form chloramines (Figure 3). Free and/or total chlorine residuals were measured at selected locations in each channel. Samples were collected at the end of each channel, dechlorinated, and delivered to the laboratory for virus analysis.

Water Quality

Table 3 provides water quality data for the secondary effluents used in this study. During Phase II at the full-scale plants, water quality samples were not taken specifically for this project; data in Table 3 were taken from routine monitoring samples for process control. During Phase III, some samples were taken in the morning when the effluent flow through the WRP was low and some samples were taken at noon (high flow); no performance differences were observed, so the data were combined for this paper. For Phases III and IV, pH values were also measured, with values of 7.2 ± 0.2 in both phases.

Mixing and Sampling

The rate at which chlorine is mixed into the effluent may affect disinfection efficacy and DBP formation. Consequently, mixing in the laboratory, pilot, and full-scale systems was evaluated through the calculation of the product Gt, where G is the velocity gradient and t is the mixing time. The Gt values for the three systems were of the same order of magnitude

FIGURE 3
Schematic Diagram of Pilot-Scale Chlorine Contact System

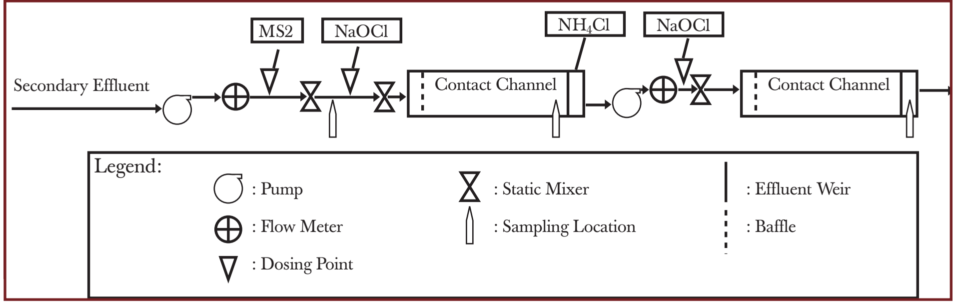


TABLE 3
Water Quality Data

	WRP[a]	Turbidity (NTU)	Ammonia Nitrogen (mg N/L)	Nitrate Nitrogen (mg N/L)	Nitrite Nitrogen (mg N/L)	Chlorine Demand (mg/L)
Phase I: Laboratory	LB	—	0.4 ± 0.3	5.2 ± 2.7	0.22 ± 0.20	—
Phase II: Full-Scale	LB	1.1 ± 0.1	<1[b]	5.6 ± 0.7	0.02 ± 0.01	—
	SJCE	2.0 ± 0.8	1.2 ± 0.6	2.2 ± 0.9	1.30 ± 0.40	—
	SJCW	1.4 ± 0.4	<1[b]	6.1 ± 1.1	0.09 ± 0.03	—
	WN	1.6 ± 0.6	<1[b]	7.2 ± 1.0	0.02 ± 0.00	—
Phase III: Laboratory	SJCE & SJCW	1.0 ± 0.3	0.2 ± 0.1	2.0 ± 1.2	0.06 ± 0.03	3.9 ± 0.5
Phase IV: Pilot-Scale	SJCW	0.8 ± 0.2	<0.10[c]	4.0 ± 1.2	0.05 ± 0.01	3.4 ± 0.4

—: Not measured.

[a] Abbreviations: LB: Long Beach. SJCE: San Jose Creek East. SJCW: San Jose Creek West. WN: Whittier Narrows.

[b] All ammonia samples from LB, SJCW, and WN during Phase II had concentrations below the reporting limit of 1 mg N/L; ammonia analysis in Phases III and IV had a lower reporting limit (0.10 mg N/L).

[c] 14 samples were below the reporting limit of 0.10 mg N/L; one sample had an ammonia concentration of 0.13 mg N/L.

TABLE 4
Results of Bench-scale Study to Evaluate DBP Formation

Sample Number	Sample Description	Chlorine Residual (mg/L)	Cyanide (µg/L)	Total THMs (µg/L)	NDMA (ng/L)
1	Unchlorinated Secondary Effluent	—	<5	—	100 - 140
2	Chloramination	2.8 - 3.3	<5	3 - 5	300 - 1,300
3	Chloramination	4.6 - 5.8	<5	7 - 11	1,100 - 5,400
4	Sequential Chlorination	3.4 - 7.0	<5	56 - 65	110 - 230
5	Sequential Chlorination	0.5 - 3.0	<5	63 - 72	100 - 200

TABLE 5
Comparison of NDMA Concentrations in Chlorinated Effluents

Test Facility	Chloramination			Sequential Chlorination		
	No. of samples	NDMA (ng/L)		No. of Samples	NDMA (ng/L)	
		Range	Median		Range	Median
San Jose Creek East WRP	34	1,000 - 5,000	2,050	18	200 - 590	310
San Jose Creek West WRP	28	400 - 3,700	985	21	260 - 650	440
Whittier Narrows WRP	28	52 - 850	320	17	37 - 590	160
Long Beach WRP	21	500 - 3,200	1,400	30	93 - 880	425

(calculations not shown), indicating that the mixing should be similar across the systems; the full-scale system had slightly better mixing, with Gt values 1-3 times higher than at laboratory or pilot-scale.

Samples for NDMA, THMs, and microbial analyses were collected in amber glass jugs, amber glass vials, and sterilized plastic containers, respectively. Plastic containers were used for other samples. Samples for microbial and NDMA analyses were dechlorinated by adding sodium thiosulfate in the sample containers. Samples for THM analysis were first quantitatively dechlorinated and then poured into the sample vials. The quantitative dechlorination procedure avoided over-dechlorination, which may damage the analytical instrument.

Chemicals and Microorganisms

Chlorine was applied as sodium hypochlorite. Sodium hypochlorite, 4-6% by weight (Fisher Scientific, Pittsburgh, PA), was diluted to different strengths and standardized in the laboratory for each bench and pilot scale experiment. For bench scale experiments, ammonia standard (1,000 mg NH_3-N/L) obtained from Environmental Resource Associates (Arvada, CO) was used as received. Ammonia solutions used for pilot-scale experiments were made in the laboratory using ammonium chloride powder (99.5% purity) from EMD Chemicals (Gibbstown, NJ). MS2 coliphage (American Type Culture Collection #15597B1) was purchased from GAP EnviroMicrobial Laboratory in Canada. Poliovirus was cultured in the Districts' Microbiology Laboratory, using CHAT type-1 poliovirus (American Type Culture Collection #VR192, a predecessor to the currently available #VR1562).

Laboratory Analyses

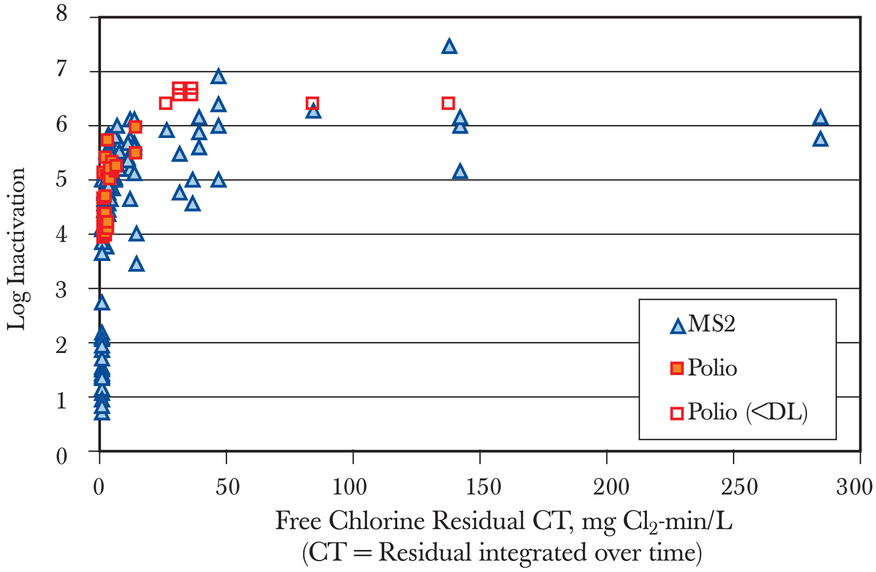
The Districts' laboratories conducted all chemical analyses for this project, and are certified by the California Department of Public Health for these analyses. NDMA analysis used EPA Method 1625, which employs liquid-liquid extraction followed by chemical ionization isotope dilution gas chromatography/mass spectrophotometry; the reporting limit is 2 nanograms per liter (ng/L) in secondary and final effluent

TABLE 6
Total Coliform Results from Full-Scale Chlorination Testing

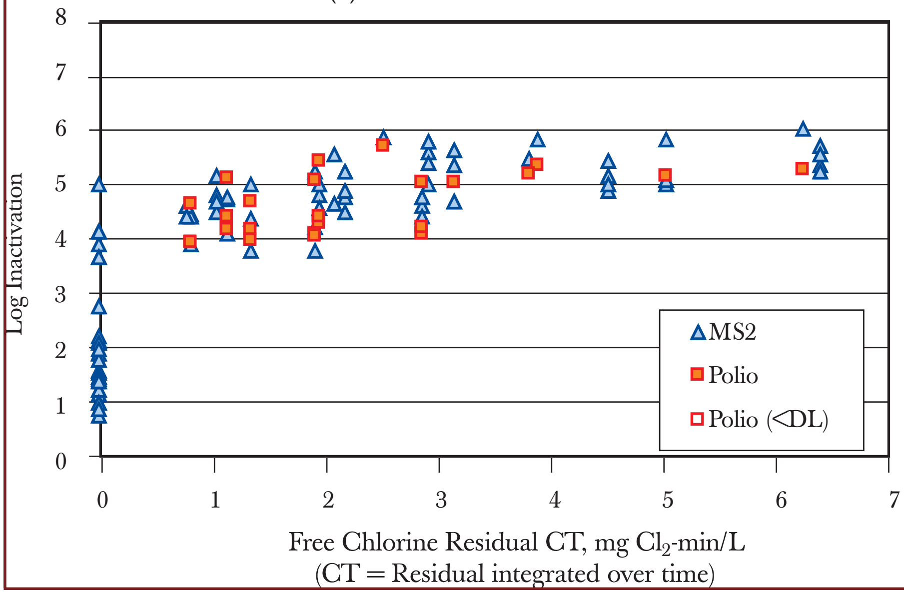
Test Facility	Filtered Effluent (After Free Chlorine)		(Sequential Chlorination)	
	No. of Samples	Total Coliform (CFU/0.1 L)	No. of Samples	Total Coliform (CFU/0.1 L)
San Jose Creek East WRP	19	1 - >200	19	<1 - 2
San Jose Creek West WRP	28	<1 - 115	21	<1 - 1
Whittier Narrows WRP	13	1 - 400	15	<1 - 2
Long Beach WRP	22	<1 - 2	26	<1 - 1

FIGURE 4
Laboratory Experiment Results of Virus Inactivation by Free Chlorine

(a) Over All CT Values



(b) Over Low CT Values



samples. THM analysis used EPA Method 8260 and the reporting limit for each THM species is 2 microgram per liter (µg/L). Free and total chlorine residuals were measured using a colorimeter test kit manufactured by Hach Company (Loveland, Colorado). Free chlorine analysis used EPA-approved Alternative Method 8021, with a factory-reported detection limit of 0.02 mg Cl_2/L. Chloramine analysis used EPA approved Alternative Method 8167, with a factory-reported detection limit of 0.1 mg Cl_2/L. Total cyanide measurements were conducted using the Midi Distillation System followed by manual colorimetric analysis [EPA 335.4, Standard Method 4500-CN-C (American Public Health Association, 1998)]. The method detection limit is 1 µg/L, and laboratory reporting limit is 5 µg/L.

For enteric virus, the laboratories adapted the procedure described in EPA's *Manual of Methods for Virology* for sample collection and concentration; Standard Methods 9510 C and 9510 G were used for poliovirus quantification. The reporting limit of enteric viruses is typically 0.001 IU (infectious unit) per liter. The detection limit for poliovirus analysis depends on the sample volume. EPA Method 1601 was used to measure the concentration of MS2 coliphage. The typical detection limit is 2 MPN/0.1L. Total coliform analysis used Standard Method 9222B, a membrane filter (MF) procedure. The MF method was chosen because the membrane filter technique is highly reproducible and usually yields numerical results more rapidly than the multiple-tube fermentation procedure (American Public Health Association, 1998). The detection limit for the MF method is 1 colony forming unit (CFU)/0.1 L.

Chronic toxicity testing was conducted using concurrently collected secondary effluent (prior to chlorine addition) and final effluent (disinfected) samples. Tests were conducted on *Pimephales promelas* and *Ceriodaphnia dubia* and followed procedures described in *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms* (EPA, 2002). Potential chronic toxicity as a result of sequential chlorination was determined by comparing survival and sub-lethal effects on the two test organisms in secondary effluent samples versus those in disinfected final effluent samples.

FIGURE 5
Laboratory Experiment Results of Total Coliform Inactivation by Free Chlorine

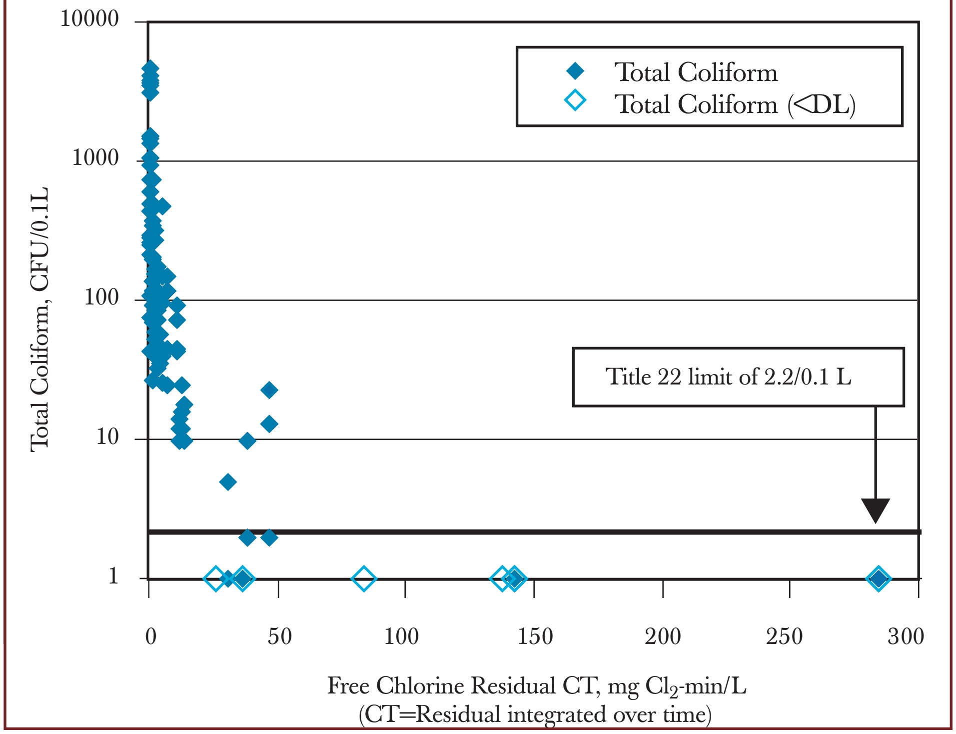
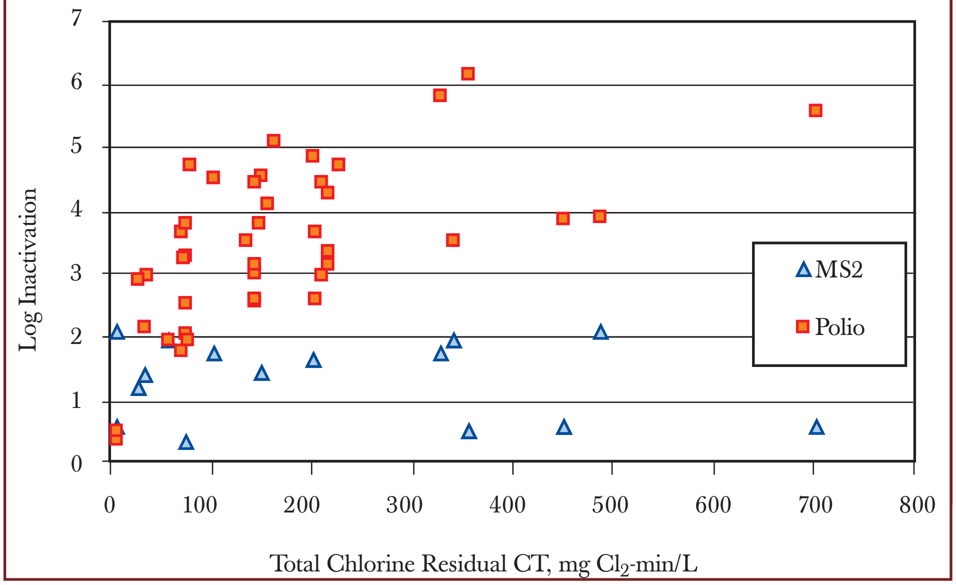


FIGURE 6
Laboratory Experiment Results of Virus Inactivation by Chloramines



RESULTS AND DISCUSSION

Phase I

As indicated in Table 4, sequential chlorination resulted in significantly reduced NDMA levels (100 – 230 ng/L), as compared to the levels from chloramination (300 – 5,400 ng/L). Sequential chlorination resulted in higher total THM concentrations; however, these concentrations were below the drinking water standard for total THMs, 80 µg/L. Neither chloramination nor sequential chlorination generated cyanide concentrations above the laboratory reporting limit.

Phase II

Because the laboratory DBP results were promising, the Districts tested the sequential chlorination process at several of their WRPs. Operating conditions were as follows: chlorine dose added to nitrified secondary effluent was typically 5 mg Cl_2/L. This chlorine dosage exceeded chlorine demand of the secondary effluent and resulted in approximately 1 mg Cl_2/L of total chlorine residual. Following filtration, ammonia was dosed at approximately 1 mg N/L. Chlorine was then added at a chlorine to ammonia nitrogen mass ratio of approximately 5:1 to form chloramines, which resulted in approximately 4.5 mg Cl_2/L of total chlorine residual immediately after chlorine addition.

Table 5 compares the NDMA concentrations in the final effluent under chloramination (historical data, 2004 – 2006) and sequential chlorination. The table shows that sequential chlorination yielded much lower NDMA concentrations at all four WRPs. Reduction of median NDMA concentrations ranged from 160 ng/L (~50%) at Whittier Narrows WRP to 1,740 ng/L (~85%) at San Jose Creek East WRP. The extent of NDMA reduction appeared to be related to the polymer doses. Among the WRPs tested, the Whittier Narrows WRP used the least amount of polymer, had the lowest NDMA concentrations under chloramination, and experienced the smallest reduction in NDMA concentrations with sequential chlorination.

As expected, total THM concentrations were higher under sequential chlorination. Out of 161 samples analyzed during the sequential chlorination testing, the total THM concentrations ranged from 7.0 to 75 µg/L; median concentration was 35 µg/L. These levels were well within the drinking water standard, 80 µg/L. Out of 162 samples collected for cyanide analysis, all but two samples (from the same WRP; the highest value was 9 µg/L) had concentrations below the laboratory reporting limit of 5 µg/L.

FIGURE 7
Laboratory Experiment Results of Total Coliform Inactivation by Chloramines

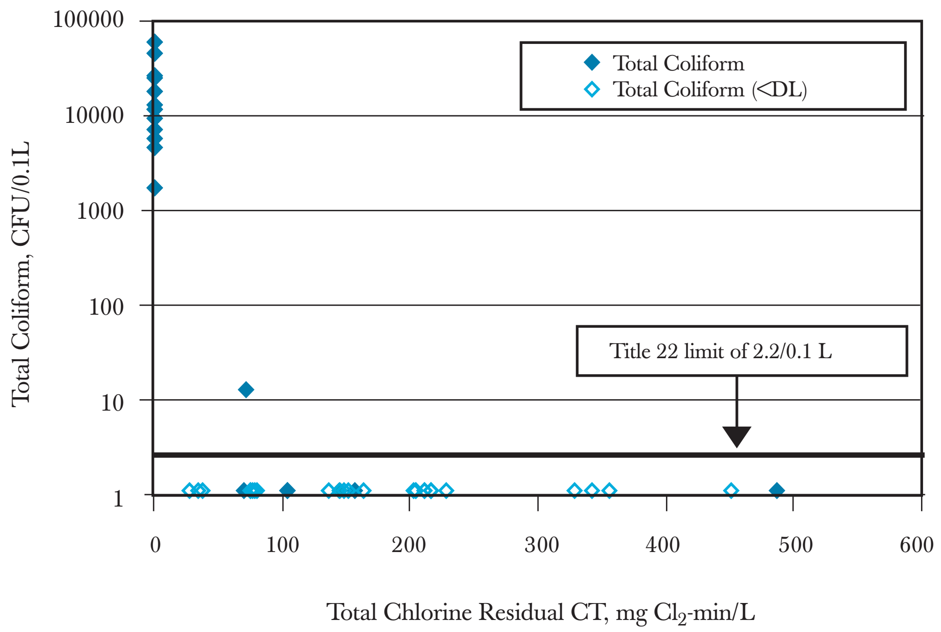


FIGURE 8
Laboratory Experiment Results of Virus Inactivation by Sequential Chlorination

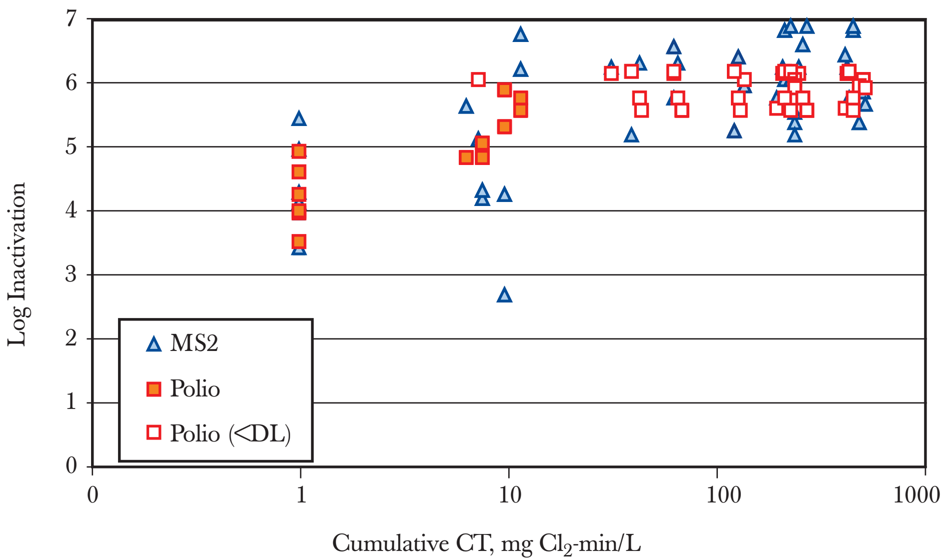


Table 6 summarizes the total coliform results from the Phase II study. Typical total coliform concentration in unchlorinated secondary effluents is approximately 10^4/0.1 L. Free chlorine and filtration reduced total coliform concentrations by at least two to three orders of magnitude. However, the filtered effluent total coliform levels could still exceed the California Title 22 standard of 2.2/0.1 L for unrestricted reuse (except at the Long Beach WRP). The total coliform concentrations after subsequent chloramination, however, were consistently in compliance with the standard. At the Long Beach WRP, three filtered effluent samples were collected and analyzed for indigenous enteric virus. None of the samples detected enteric virus (detection limit = 0.001 IU/L).

A total of 14 sets of secondary and chlorinated final effluent samples (final effluent samples were dechlorinated in the laboratory) were collected for chronic toxicity testing. The results indicated no aquatic toxicity resulting from sequential chlorination.

In summary, the Phase II study results confirmed that sequential chlorination reduced the formation of NDMA while maintaining acceptable levels of THMs and cyanide, meeting Title 22 total coliform requirements, and producing no aquatic toxicity to the receiving water.

Phase III

Chlorination Experiments

Free chlorine disinfection was tested on 16 fully nitrified secondary effluent samples collected from the San Jose Creek WRP. Chlorine doses were between 1.5 and 10 mg Cl_2/L, contact times were between 1 and 90 minutes. Free chlorine residual CT values were calculated by integrating free chlorine residual concentration over contact time. Figures 4(a) and 4(b) show MS2 and poliovirus inactivation results with free chlorine for all CT values and for low CT values, respectively. Points with a zero CT value represent conditions in which free chlorine residual was not detected, i.e., when chlorine doses were lower than the chlorine demand.

Free chlorine generally inactivated MS2 and poliovirus to a similar degree. Most disinfection occurred at or shortly after the time that free chlorine was added (Figure 4(b)). For CT values ≥ 1 mg Cl_2-min/L, MS2 inactivation was ≥ 4-log in 96% (78 of 81) of the samples and poliovirus inactivation was ≥ 4-log in 97% (29 of 30) of the samples. As CT increased above 1 mg Cl_2-min/L, MS2 disinfection increased slowly and leveled off at approximately 6-log inactivation. Poliovirus disinfection also increased slowly as CT increased above 1 mg Cl_2-min/L, but could not be quantified, because poliovirus concentrations in treated samples were below the detection limit (DL).

Inactivation of total coliform was also evaluated. At CT values above 50 mg Cl_2-min/L, disinfection of total coliform consistently met the Title 22 requirement, as indicated in Figure 5.

FIGURE 9
Laboratory Experiment Results of Total Coliform Inactivation by Sequential Chlorination

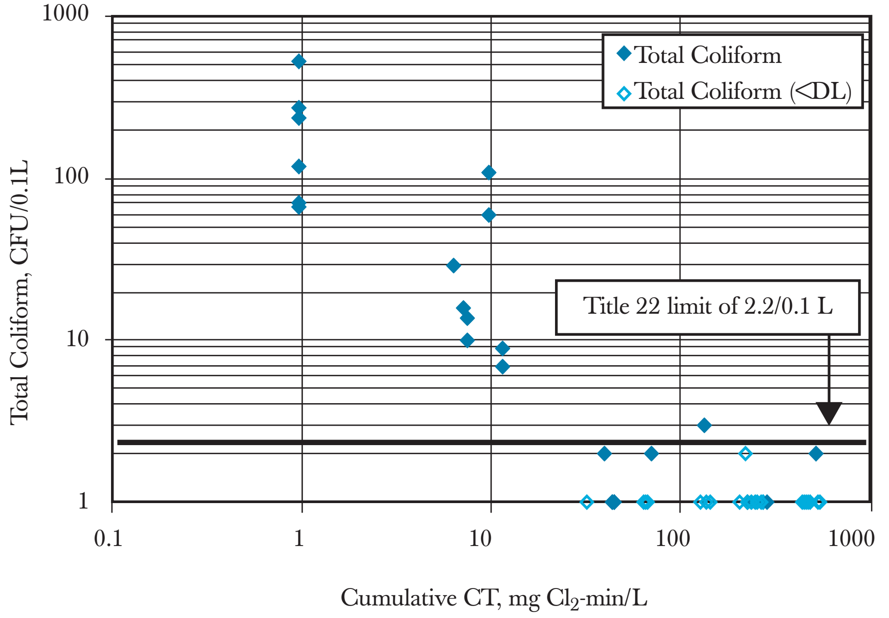
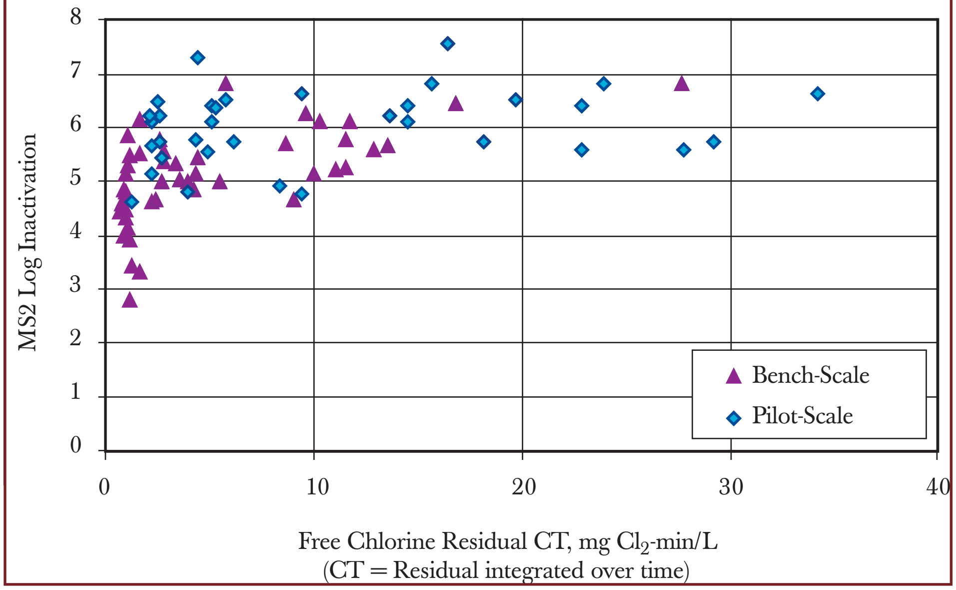


FIGURE 10
Pilot Testing Results of MS2 Coliphage Inactivation by Free Chlorine Only



Chloramination Experiments

The chloramination step of sequential chlorination was tested on 16 fully nitrified secondary effluent samples collected from the San Jose Creek WRP. These samples were dosed with 1 to 3 mg N/L followed by 5 to 10 mg Cl_2/L. The dosed chlorine to ammonia nitrogen mass ratio ranged from 3.3 to 5.3 mg Cl_2/mg N, and contact times ranged from 1 to 90 minutes. The total chlorine residual CT values, ranging from 6 to 774 mg Cl_2-min/L, were calculated as the product of total chlorine residual and contact time. As shown in Figure 6, chloramines were clearly weaker disinfectants than free chlorine, and yielded lower inactivation values for both microorganisms, especially MS2 coliphage. Disinfection of poliovirus generally increased with total chlorine residual CT values, but MS2 coliphage was resistant to chloramines. Little or no improvement in disinfection performance was observed with increasing CT values.

Chloramines effectively disinfected total coliform, as indicated in Figure 7. Total coliform concentration was consistently below the Title 22 requirement at CT value above approximately 100 mg Cl_2-min/L.

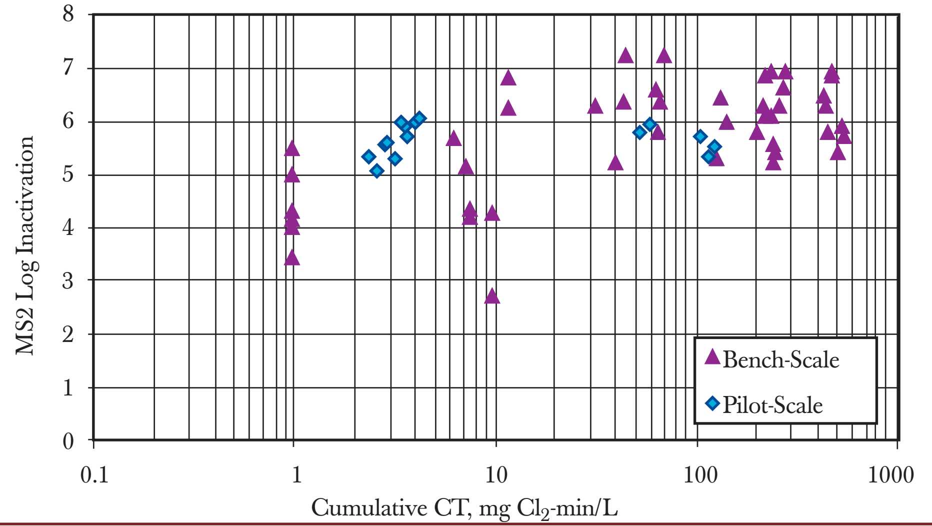
Sequential Chlorination Experiments

Eight experiments were conducted to evaluate the total virus inactivation by sequential chlorination, in which samples were disinfected in two steps. In the first step, 5 to 5.5 mg Cl_2/L of sodium hypochlorite was added to the samples for contact times up to 10 minutes (free chlorine residual CT values between 1 and 10 mg Cl_2-min/L). Ammonia was then added and followed by additional hypochlorite, to form chloramines. Ammonia doses were 0.5 to 1.5 mg N/L, hypochlorite doses were 2.5 to 5.0 mg Cl_2/L, and the dosed chlorine to ammonia mass ratio ranged from 3.3 to 5.0 mg Cl_2/mg N. Chloramine contact times were between 1 and 90 minutes. The cumulative CT values, ranging from 6 and 541 mg Cl_2-min/L, were calculated as the sum of the free chlorine CT value and the total chlorine residual CT value from chloramination.

Virus inactivation results from the sequential chlorination process are shown in Figure 8. In most cases, the first step of sequential chlorination (free chlorine) achieved >4-log inactivation of both MS2 and poliovirus, consistent with results from the free chlorine experiments discussed above. In the few cases that free chlorine did not achieve >4-log inactivation, subsequent chloramination provided additional disinfection. As indicated in Figure 8, inactivation of both poliovirus and MS2 was >5-log in all cases where the cumulative CT value was greater than 15 mg Cl_2-min/L. Beyond this CT value, virus inactivation was not strongly affected by the cumulative CT value. Poliovirus levels were below detection following chloramine addition. MS2 is resistant to chloramines, so additional chloramine contact time has insignificant effect on its inactivation.

Total coliform was also measured in these experiments; results are shown in Figure 9. Total coliform levels decreased rapidly up to a cumulative CT value of 15 mg Cl_2-min/L. Above a cumulative CT value of 30 mg Cl_2-min/L, total coliform levels were <2.2/0.1 L in 31 of 32 samples.

FIGURE 11
Pilot Testing Results of MS2 Coliphage Inactivation by Sequential Chlorination



Phase IV

Ten experiments were conducted to test free chlorine disinfection of seeded virus in the pilot-scale contactor. Free chlorine doses ranged from 3.7 to 5.8 mg Cl_2/L, and the modal contact times ranged from 2 to 10 minutes (based on tracer test results); free chlorine residual CT values were calculated by integrating free chlorine residual concentration over contact time. As shown in Figure 10, free chlorine alone, the first step of the sequential chlorination process, achieved >5-log MS2 inactivation in all but four samples. The minimum MS2 inactivation observed was 4.6-log. These results were consistent with those obtained from the bench-scale experiments (also plotted in Figure 10 for comparison).

Five experiments were conducted to test the overall sequential chlorination disinfection of seeded virus in the pilot-scale contactor. In the first channel, chlorine doses ranged from 4.1 to 4.3 mg Cl_2/L, and the modal contact time was approximately 2.4 minutes (based on tracer test results). The cumulative CT values were calculated as the sum of the free chlorine CT value (calculated by integrating free chlorine residual concentration over contact time) and the total chlorine residual CT value from chloramination (calculated as the product of total chlorine residual and contact time). At the end of the first channel, ammonium chloride (1.1 to 1.2 mg N/L) was added to stop free chlorine reaction. Then, at the beginning of the second channel, more chlorine (3.6 to 5.5 mg Cl_2/L) was applied to form chloramines. Samples were collected at the end of each channel for virus analysis.

Figure 11 shows the results from these experiments. Free chlorine, the first step of sequential chlorination, achieved >5-log MS2 inactivation; the chloramines added in the second step had a marginal effect on MS2 inactivation. These results were in general agreement with those obtained from the bench-scale experiments, also plotted in Figure 11 for comparison.

CONCLUSIONS

The sequential chlorination process is a new approach for disinfection of fully nitrified effluent produced by wastewater treatment and reclamation facilities. The process can be implemented using existing chloramination infrastructure with minor modifications. Plant-scale testing results have shown that the process significantly reduces NDMA formation in comparison to chloramination. By lowering the NDMA levels in the recycled effluent, sequential chlorination could help save the costs of downstream advanced oxidation process for NDMA removal in indirect potable reuse applications. The process does result in a moderate increase in THM formation, but the levels of total THMs are well below the drinking water standards. Sequential chlorination generates insignificant amounts of cyanide and does not cause aquatic toxicity.

Because of the use of free chlorine, the sequential chlorination process is more efficient than chloramination with respect to pathogen inactivation. Sequential chlorination can achieve the same level of pathogen inactivation as chloramination, but with a much shorter chlorine contact time. This could lead to savings in chlorine contact tanks construction for new projects, creation of available space in existing chlorine contact tanks for other uses (e.g., storage, flow equalization), or an increase in treatment capacity.

LITERATURE CITED

American Public Health Association (1998) Standard Methods for the Examination of Water and Wastewater, 20th ed. Washington, DC.

Choi, J. H.; Valentine, R. L. (2002) Formation of N-Nitrosodimethylamine (NDMA) from Reactions of Monochloramine: a New Disinfection By-product, *Water Res.*, 36(4), 817-824.

USEPA (2002) Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition. EPA-821-R-02-013.

Huitric, S-J.; Kuo J.; Creel M.; Tang C-C.; Snyder D.; Horvath, R.W.; Stahl, J. (2006) Reclaimed Water Disinfection Alternatives to Avoid NDMA and THM Formation, *Proc. WEFTEC.06 79th Annual Technical Exhibition and Conference*, Dallas, TX, October 21-25.

Huitric, S-J.; Tang C-C.; Kuo J.; Creel M.; Snyder D.; Ackman P.; Horvath, R.W. (2007) Sequential Chlorination for Reclaimed Water Disinfection, *Proc. WEFTEC.07 80th Annual Technical Exhibition and Conference*, San Diego, CA, October 13 – 17.

Huitric, S-J.; Munakata N.; Tang C-C.; Kuo J.; Ackman P.; Thompson S.; Friess P.; Maguin, S.R. (2008) Inactivation of Microbial Indicators by the Sequential Chlorination Process, *Proc. WEFTEC.08 81st Annual Technical Exhibition and Conference*, Chicago, IL, October 18 – 22.

Kavanaugh, M.; Dzombak, D.; Theis, T.; Young, T.; Luthy, R. (2003) *Cyanide Formation and Fate in Complex Effluents and its Relation to Water Criteria*; Water Environment Research Foundation: Virginia.

Kuo, J.; Stahl, J.; Burton, D.; El Jack, Z.; Horvath, R.; Tang, C. (2003) Chloramination of N/DN Effluent - Meeting the Ammonia, Coliform and THM Limits, *Proc. WEFTEC 2003, 76th Annual Technical Exhibition and Conference*, Los Angeles, CA, October 11-15.

Mitch, W. A.; Gerecke, A. C.; Sedlak, D. L. (2003) A N-Nitrosodimethylamine (NDMA) Precursor Analysis for Chlorination of Water and Wastewater, *Water Res.*, 37(15), 3733 – 3741.

Mitch, W. A.; Sedlak, D. L. (2004) Characterization and Fate of N-Nitrosodimethylamine Precursors in Municipal Wastewater Treatment Plans, *Environ. Sci. Technol.*, 38(5), 1445-1454.

Schreiber, I. M.; Mitch, W. A. (2005) Influence of the Order of Reagent Addition on NDMA Formation during Chloramination, *Environ. Sci. Technol.*, 39(10), 3811-3818.

Sedlak, D. L.; Deeb, R. A.; Hawley, E. L.; Mitch, W. A.; Durbin, T. D.; Mowbray, S.; Carr, S. (2005) Sources and Fate of Nitrosodimethylamine and its Precursors in Municipal Wastewater Treatment Plants, *Water Environ. Res.*, 77(1), 32-39.

Tchobanoglous, G.; Burton, F.L.; Stensel, H.D. (2003) *Wastewater Engineering Treatment and Reuse, 4th ed.*; McGraw-Hill Publishing Company: New York.

Zheng, A.; Dzombak, D. A.; Luthy, R.G.; Kavanaugh, M.C.; Deeb, R.A. (2004a) The Occurrence of Cyanide Formation in Six Full-Scale Publicly Owned Treatment Works, *Water Environ. Res.*, 76(2), 101-112.

Zheng, A.; Dzombak, D. A.; Luthy, R.G (2004b) Formation of Free Cyanide and Cyanogen Chloride from Chloramination of Publicly Owned Treatment Works Secondary Effluent: Laboratory Study with Model Compounds, *Water Environ. Res.*, 76(2), 113-120.

SANITATION DISTRICTS OF LOS ANGELES COUNTY

STEPHEN R. MAGUIN
Chief Engineer and General Manager

Memorandum

Date: August 9, 2010

To: Anthony Mahinda

Through: Mark McDannel

From: Andre Schmidt

Subject: **San Jose Creek WRP Process Air Compressor Efficiency Study R1**

Summary

A study was performed to evaluate the potential energy savings of replacing the process air compressors (PACs) at San Jose Creek WRP. The study included power monitoring of all eight existing PACs, analysis of plant data, determination of the energy usage of new compressors, and gathering of equipment cost estimates.

Results of the analysis are shown in Table 1. With an estimated equipment cost of $4.8 million, an annual energy savings of $1.0 million can be achieved. Excluding design and construction costs, and including the energy efficiency rebate incentive from Southern California Edison, the project has a simple payback period of less than four years.

Table 1: San Jose Creek WRP PAC Replacement Payback Period

Area of Plant	Turblex Models	Number of Duty Units	Number of Standby Units	Total Price	Annual Power Savings	SCE Rebate Incentive	Equipment Payback Period (Years)
SJC WRP East & West PACs	KA66 & KA80	4	1	$4,755,000	$1,003,289	$834,009	3.9

Background and Objectives

The PACs at San Jose Creek WRP consume 62 percent of the total plant power at a cost of $3.6 million per year. There are three sets of PACs that were installed at different stages of plant development (see Table 2). These compressors range in age from 18 years to 39 years. At the request of Wastewater Management, Energy Recovery Engineering conducted an energy efficiency study for the PACs. The objectives of the study were:

- Accurately monitor the power usage of the existing PACs
- Compare this energy usage to new high efficiency compressors
- Determine the potential financial savings associated with new equipment

Table 2: San Jose Creek WRP Existing Process Air Compressor Data

Area of Plant	Number of PACs	Duty	Standby	Horsepower Each	Capacity Each (scfm)	Age (Years)
East Stage One	3	2	1	1750	44,000	39
East Stage Two	2	2	0	900	20,000	28
West	3	1	2	1750	44,000	18

The PACs are high voltage equipment (4160 V) and therefore require specialized equipment for power monitoring. Southern California Edison (SCE) provided equipment and personnel to monitor the power of all eight compressors at no charge to the Districts. At the direction of SCE personnel, Districts staff connected the power monitoring equipment to the PAC electrical panels on December 17, 2009. Power was monitored on all eight compressors at 15-minute intervals for almost three months. The monitoring equipment was removed on February 11, 2010.

PAC Performance Data

Plant performance data for the same period of time was collected including plant flows, PAC airflow rate, and PAC discharge pressure. The data was compiled into average diurnal profiles for the entire three month test period. The diurnal profiles for power and airflow are compared in Figure 1 for each of the three sets of PACs. Power usage vs. airflow is plotted in Figure 2. The ratio of airflow to power is an energy efficiency metric that enables a direct comparison of the efficiency of each set of PACs. The diurnal profiles for airflow per kW are presented in Figure 3. Airflow per kW vs. influent flow is plotted in Figure 4.

Even though the West compressors are the newest of the three sets of PACs, they had the lowest average efficiency rate (see Figure 3). The West compressors actually have relatively good efficiencies of 34 to 37 icfm per kW between 5:00 a.m. and 10:00 a.m. when airflow is about ten percent less then peak airflow. But during the afternoon and early evening when airflow peaks at around 35,000 icfm, the efficiency rate drops to about 27 to 28 icfm per kW. This effect is also displayed in Figure 2, where the power usage of the SJC West compressors increases significantly when airflow increases just slightly. This increase is much more dramatic than the increase for the Stage 1 and Stage 2 compressors. At SJC West, it appears that the peak airflow demand is beyond the optimal range for one compressor operation (only one West PAC runs at a time). A compressor with slightly higher airflow capacity would be much more energy efficient.

The East Stage Two compressors had the opposite efficiency profile of the West compressors. During the afternoon and early evening, the compressors operated at about 33 icfm per kW. But during late night and early morning the efficiency dropped down to 24 icfm per kW. This is primarily due to the fact that only one compressor is needed at night, but rather than shutting down the second compressor, it is allowed to idle for 4 to 6 hours per night without providing any air. This is due to experience with premature mechanical coupling failure on the Stage Two compressors when they are shut down and restarted on a regular basis. The compressor idles for an average of 5 hours per night at an average power usage of 240 kW, costing approximately $50,000 in electricity per year.

Power was also compared to influent flow in Figure 5. It was found that the power usage of the PACs drops only slightly at night, while the influent flows drop much more substantially. This can be quantified by looking at the PAC energy usage per influent flow (Figure 6). For both the East and the West, the PAC energy usage was about 800 to 900 kWh per mgal during the day. But at night, the energy usage jumped to 1500 kWh per mgal for the West, and to 2000 kWh per mgal for the East. This points to the fact that the existing system has much lower efficiency during low flow periods.

The air ratios help examine the causes of the poor low flow system efficiency (see Figures 8 and 9). During the afternoon and early evening, the air ratio for both the East and West was about 1.5 icfm per gpm. But during early morning, the air ratio increased to 3.5 icfm per gpm on the East side, and 3.2 icfm per gpm on the West side. It appears that that there may be opportunity to increase the efficiency of the system by reducing the airflow during low flow periods.

Energy Savings of New PACs

The PAC performance data was analyzed to compare the energy usage of the existing equipment to new high efficiency compressors. A comparison between the existing equipment and new equipment was accomplished by breaking down the average diurnal airflow curve into four regimes based on airflow ranges (see Figures 13 thru

15). The average performance, including airflow, discharge pressure, and power was determined for each regime (see Tables 4 thru 6). The number of hours of operation per day was also determined for each regime. This established four discrete points of operation for each set of PACs that could be used to compare the existing compressors to new high efficiency compressors at the existing operating conditions.

Turblex was contacted to provide selection of new PACs, including projected energy usage and equipment costs. The various options for replacement of the existing compressors with Turblex compressors are presented in Table 3. The detailed energy usage calculations are provided in the appendix. Note that the payback periods in Table 3 are for the equipment costs only and do not take into account design, installation, or auxiliary equipment costs. The payback periods do take into account energy efficiency rebate incentives offered by SCE . Also, the equipment cost estimates include the typical features that the Districts have specified for other recent projects.

Table 3: San Jose Creek WRP PAC Replacement Payback Period

Area of Plant	Turblex Model	Number of Duty Units	Number of Standby Units	Price per Unit	Total Price	Annual Power Savings	SCE Rebate Incentive	Equipment Payback Period (Years)
East Stage One								
Option 1	KA66	2	1	$881,000	$2,643,000	$394,364	$327,825	5.9
Option 2	KA100	1	1	$1,438,000	$2,876,000	$380,969	$316,690	6.7
East Stage Two	KA66	1	1	$881,000	$1,762,000	$175,297	$145,720	9.2
East Stage One & Two Combined	KA66	3	1	$881,000	$3,524,000	$556,266	$462,410	5.5
West								
Option 1	KA80	1	0	$1,231,000	$1,231,000	$447,024	$371,599	1.9
Option 2	KA80	1	2	$1,231,000	$3,693,000	$447,024	$371,599	7.4
TOTAL - East Stage One & Two Combined and West Option 1	KA66 & KA80	4	1	n/a	$4,755,000	$1,003,289	$834,009	3.9

For Stage One, it is less expensive and more efficient to install two duty compressors with one standby than one duty and one standby, with a payback period of 5.9 years in comparison to 6.7 years. This replacement would save $394,000 per year in energy costs. Stage Two has a longer payback period of 9.2 years with $146,000 in annual energy savings. But since Stage One and Stage Two can use the same compressor model, the PACs for these could be combined for use of a common standby compressor. This combined option would require some ducting modifications, but would cut the equipment payback period for Stage One and Stage Two to 5.5 years.

For the West side, replacement of all three compressors would have a payback period of 7.4 years. However, Operations has indicated that the existing equipment is considered to be well within its useful life. Therefore, a better alternative may be to replace just one of the existing compressors, while keeping the other two as standby machines. This would have a payback period of just 1.9 years with a power savings of $447,000 per year. In total, replacement of all three sets of compressors would have an annual power savings of $1.0 million with a payback period of as low as 3.9 years.

Recommendations and Other Possible Energy Saving Measures

Operations has indicated that it does not have plans for extensive renovations to the aeration system for the West side of the plant. This being the case, it recommended to fast track installation of one duty compressor for the

West as a separate project. This separate project would provide $447,000 in annual energy savings. The equipment cost of $1.23 million would be offset by a rebate incentive from SCE of approximately $370,000, bringing the actual cost down to $860,000 and resulting in an equipment payback period of just 1.9 years. A project of this size may also be able to qualify for special financing. The California Energy Commission conducts a low interest energy efficiency financing program, which provides 3% interest loans of up to $3 million per application. This program is currently on hold due to lack of funds, but it is expected that new funding will be available in the future.

In addition to replacing the PACs, there may be other opportunities for further improvements to the energy efficiency of the aeration system. Advanced DO control could help cut down on excess aeration that may be occurring during late night and early morning low flow periods. If the average daytime air ratio of 1.5 cfm per gpm were maintained during low flow, it is estimated that with the Turblex units, the West plant could save an additional $100,000 in energy costs per year and the East plant an additional $180,000. Advanced DO control could also help optimize the amount of air being delivered to different stages of the aeration system, thereby improving the overall treatment efficiency.

Other possible energy saving measures for the aeration system include the following:

- Similar to DO control, some plants have also begun to adjust airflow based on ammonia levels, enabling the reduction of air where ammonia has already reached an acceptable level and providing further energy savings.

- The May 2010 issue of Water Environment & Technology discussed modifications that were made at the 167 mgd San Jose/Santa Clara Water Pollution Control Plant. The plant recently replaced continuous aeration in its anoxic compartments and mixed liquor channel with pulsed aeration for maintaining solids in suspension. This reduction in aeration demand has resulted in approximately $800,000 in annual energy savings.

- Some plants have optimized the performance of their primary clarifiers by providing improved baffling and hydraulics. This reduces the loading on the secondary treatment system and can cut plant energy use by as much as five percent.

- Improvements to diffuser cleaning represent another energy saving opportunity. The installation of power monitoring devices on the PACs would enable a comparison of energy use before and after diffuser cleaning to determine the impact of cleaning on energy usage. This could help optimize the methods and interval of diffuser cleaning. In addition, Sanitaire markets an in-place cleaning system that aspirates chemical into the aeration distribution system to clean the diffusers while tanks are in service. This enables uninterrupted cleaning of the diffusers at optimum intervals.

- Operations has indicated the need for higher DO levels in the first pass of the aeration system, with the possibility of converting to coarse bubble aeration in the first pass to accomplish this need. An alternative to coarse bubble aeration to provide more DO may be a FlexAir system offered by Environmental Dynamics Incorporated (represented by Pacific Process). Their MiniPanel Diffuser provides the efficiency of fine bubble diffusion, but has higher floor coverage than traditional ceramic disc diffusers, thereby providing more oxygen transfer per square foot. This system is apparently being used at Valencia WRP for side stream treatment of filtrate.

Energy Recovery Engineering is available to provide assistance with the development of a PAC replacement project at San Jose Creek WRP, including investigation into any promising related technologies that may help further improve the efficiency of the secondary treatment system. In addition, Energy Recovery Engineering can work with SCE to conduct energy efficiency analyses of the PACs at other WRPs to determine the potential savings associated with replacement of those compressors.