



**WATER REPLENISHMENT DISTRICT
OF SOUTHERN CALIFORNIA**

COST OF SERVICE REPORT **for Fiscal Year 2011-2012**



October 2014

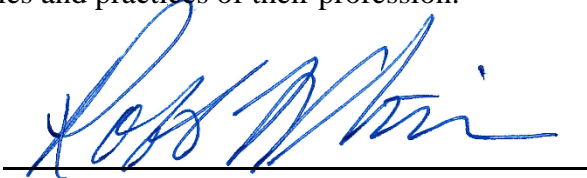
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Water Replenishment District of Southern California
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Professional Certification

This Cost of Service Report has been prepared under the direct supervision of the individuals listed below. These persons certify that the information contained in the report has been accurately represented based upon the documents reviewed or from personal knowledge and experience, and any conclusions drawn are made in accordance with the generally accepted principles and practices of their profession.



Robb Whitaker, PE 60276
General Manager



Scott M. Ota, CPA 68042, CFF 2974, CIRA 810, CGMA 110025596
Chief Financial Officer



Theodore A. Johnson, PG 6142, CHG 240
Chief Hydrogeologist

Acknowledgements

WRD would like to express its sincere appreciation to the dedicated team that put this comprehensive report together. Mr. Ted Johnson, Chief Hydrogeologist, was the overall report coordinator and lead author for Sections 3, 4, 6, 7 and 8. Mr. Scott Ota, Chief Financial Officer, was the lead for Sections 9 and 10.

Special acknowledgement is given to WRD's consultant, Mr. Michael Gagan, of Kindel Gagan. Mr. Gagan is informally known as the "WRD Historian," having researched, written and presented on the many causes and actions in the 1950s that led to the formation of WRD. Mr. Gagan was the lead author for Section 5 of this report. His contributions are very much appreciated by the District.

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2.0 LIST OF ACRONYMS

ABAC	Audit and Budget Advisory Committee
AF	Acre-Feet (equivalent to 325,851 gallons)
AFY	Acre-Feet per Year
AWTF	Advanced Water Treatment Facility
BMP	Best Management Practice
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	Consumer Confidence Report
CDPH	California Department of Public Health
CDPW	California Department of Public Works
CDWR	California Department of Water Resources
CEC	Constituents of Emerging Concern
CIP	Capital Improvement Program
CBWA	Central Basin Water Association
CPR	Common Pool Resource
CSDLAC	County Sanitation Districts of Los Angeles County
CWSC	California Water Service Company
DGB	Dominguez Gap Barrier
DTSC	California Department of Toxic Substances Control
EPA	United States Environmental Protection Agency
ESR	Engineering Survey and Report
GASB	Government Accounting Standards Board
GIS	Geographic Information System
GRIP	Groundwater Reliability Improvement Program
GSWC	Golden State Water Company
GWAM	Groundwater Augmentation Model
IRWMP	Integrated Regional Water Management Plan
LACDPW	Los Angeles County Department of Public Works (Flood Control)
LACFCD	Los Angeles County Flood Control District
LADWP	City of Los Angeles Department of Water and Power
LAMS4	Los Angeles County Municipal Stormwater Permit
LARWQCB	Los Angeles Regional Water Quality Control Board
LBWD	City of Long Beach Water Department
LRP	Local Resources Program

LUST	Leaking Underground Storage Tank
MAR	Managed Aquifer Recharge
MFI	Modified Fouling Index
MFSG	Montebello Forebay Spreading Grounds
mgd	Million Gallons per Day
MODFLOW	MODular three-dimensional finite-difference ground-water FLOW model
MOU	Memorandum of Understanding
MWD	Metropolitan Water District of Southern California
OCWD	Orange County Water District
PEIR	Programmatic Environmental Impact Report
PPA	Projects, Programs, Administration
RA	Replenishment Assessment
RHSG	Rio Hondo Spreading Grounds
SAT	Soil Aquifer Treatment
SBPAT	Structural Best Management Practices Prioritization and Analysis Tool
SCWC	Southern California Water Committee
SDLAC	Sanitation Districts of Los Angeles County
SDWP	Safe Drinking Water Program
SGSG	San Gabriel Spreading Grounds
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TITP	Terminal Island Treatment Plant
TDS	Total Dissolved Solids
UCMR	Unregulated Contaminant Monitoring Rule
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WAS	Water Augmentation Study
WBMWD	West Basin Municipal Water District
WBWA	West Basin Water Association
WIN	Water Independence Now program
WPRSF	Water Purchase and Rate Stabilization Fund
WRD	Water Replenishment District of Southern California
WRP	Water Reclamation Plant

3.0 INTRODUCTORY STATEMENT AND SUMMARY

The Water Replenishment District of Southern California (the “District”), originally known as the Central and West Basin Water Replenishment District, was established by a vote of the people in 1959 pursuant to the Water Replenishment District Act of 1955 (Section 60000 *et seq.* of the California Water Code).

In her seminal work, *Governing the Commons*, Nobel Laureate Elinor Ostrom cites the formation of the District as an example of protecting the common pool resource of the Central Basin and West Coast Basin (the “Basins”) by pumpers voluntarily organizing “to avoid the adverse outcomes of independent action.” The Replenishment District is one of a number of institutions created in the 1950s and 1960s for that purpose. Others were established to finance the delivery of imported water to the basins and to manage the apportionment of the San Gabriel River Flows between the Upper Area of the watershed (i.e., the basins above Whittier Narrows) and the Lower Area (i.e., Central and West Basins, or collectively, the “Basins”).

The purpose of the District is to manage that common pool resource that consists of two interconnecting groundwater subbasins of what the California Department of Water Resources describes as the Coastal Plain of Los Angeles Groundwater Basin. If properly maintained and preserved, the Basins serve as a massive underground water storage and delivery system. Water pumped from the Basins by municipal water utilities, investor-owned water companies, mutual water companies and private companies is used on site by some pumpers and distributed by other pumpers to millions of residents and non-residential water users throughout the District’s service area in southern Los Angeles County. It is far less expensive for these pumpers to pump groundwater from the Basins than to purchase imported surface water originating from the Colorado River or Northern California.

The Basins, though a critical part of the water supply system in southern Los Angeles County, are fragile and require management. Although pumping rights in the Basins were adjudicated decades ago, the pumping permitted under the adjudication exceeds naturally occurring replenishment. In other words, pumpers are allowed to remove more water each year from the Basins than nature adds back to the basins through natural recharge. If the Basins were not artificially replenished, water levels in the Basins would decrease.

When water levels in the Basins drop below sea level, seawater intrudes into the Basins – first along the coast and then inland. Historically, seawater intrusion has contaminated significant portions of the groundwater in the Basins. Absent artificial replenishment and active measures to stop seawater intrusion, these plumes of seawater would grow.

Excessive pumping anywhere in the Basins can cause problems throughout the Basins. The boundary between the Central Basin and West Coast Basin approximates the centerline of a geologic structure known as the Newport-Inglewood Uplift. The Uplift is not a simple straight line feature, but, rather, a complicated structure of numerous hills and discontinuous fault segments that start and stop over a 20-

mile length and over and a mile width and follows a non-linear path. Groundwater flows across the Uplift in a direction and volume that depends on the groundwater slope and tightness of Uplift sediments, which varies both spatially and at depth. In the absence of pumping activities in Central Basin, thousands of acre-feet of water would flow across the Uplift from the Central Basin to the West Coast Basin. This “underflow,” an important natural mechanism for the recharge of the West Coast Basin, is reduced by over pumping in the Central Basin. Under certain underflow conditions, seawater from the West Coast Basin can migrate across the Uplift into the Central Basin. Water levels in the Central Basin impact water levels in the West Coast Basin and water levels in the West Coast Basin impact water quality in the Central Basin.

The District’s programs ensure that the Basins remain viable water resources for the pumping activities that are permitted under the basin adjudications.

In effect, the District maintains the Basins as a complex and interconnected system from which pumpers can obtain safe, high quality water and for storing water for future extraction by pumpers. The District purchases and produces potable and recycled water that is introduced into the Basins via spreading grounds (increasing water levels in the Basins and restoring the underflow) and via injection wells (increasing water levels in the Basins and directly blocking seawater intrusion). In order to maintain the Basins as effective and economic water resources, the District actively monitors water levels and water quality throughout the Basins. The District also pumps intruded seawater directly from the Basins and desalinates this water in order to reduce the size of existing seawater plumes. These programs, and other activities of the District, are designed to ensure the maintenance and preservation of the Basins, and, thus, the availability of water for pumpers to pump. Due to the interconnected nature of the Basins, all activities of the District are provided for the benefit of pumpers throughout the service area.

The District anticipated that the net cost of its operations for Fiscal Year 2011/12 would be \$59,256,000. It anticipated that pumpers would remove 243,000 acre-feet of water from the Basins during the Fiscal Year. Therefore, the District anticipated that the cost of providing services would be \$244 per acre-foot of water removed from the Basins.

The Reason for These Proceedings

WRD is making this Cost of Service Report available to the public as part of administrative proceedings on the replenishment assessment (“RA”) for 2011/12. WRD adopted the RA for 2011/12 in 2011. Since that time, certain parties have alleged that the RA violates Proposition 218 (Articles XIII C and XIII D of the California Constitution).

The Los Angeles County Superior Court has issued two orders (one on April 25, 2011 addressing the RAs for 2006/07 through 2010/11, and one on September 6, 2012 addressing the RAs for 2006/07 through 2011/12) finding that the District’s RA is a “property-related fee” subject to the requirements of Article XIII D, Section 6 of the California Constitution. The Court has not entered a final judgment based on these orders.

In its April 25, 2011 order, the Court held that it is the District's responsibility "in the first instance" to decide the proportionality of the RAs.

The fact that the District is engaging in these proceedings should not be construed as an acknowledgment by the District or its Board that the adoption or continuation of an RA triggers obligations under Article XIII D, Section 6 of the California Constitution (which was added to the California Constitution in 1996 as a part of Proposition 218, and is referred to herein as "Proposition 218"). Nonetheless, consistent with the Court's finding that the RAs for Fiscal Years 2010/11 and 2011/12 are subject to Proposition 218, and consistent with the Court's finding that setting the RAs at a level consistent with Proposition 218 is the District's responsibility in the first instance, the Board of Directors directed that Proposition 218 proceedings be held for the RAs for Fiscal Years 2010/11, 2011/12, and 2012–2013.

The Board of Directors has directed that a protest hearing be held on October 30, 2014, on the RAs for fiscal years 2010/11, 2011/12, and 2012/13. If a majority protest (as defined by the last sentence of Article XIII D, Section 6(a)(2)) occurs with respect to a proposed RA for a fiscal year, then the RA for that fiscal year will be vacated. Following the protest hearings, if there is no majority protest for that fiscal year, the Board of Directors may ratify the RA that was the subject of the hearing at the proposed rate (i.e., \$205 per acre-foot for 2010/11; \$244 per acre-foot for 2011/12; and \$244 per acre-foot for 2012–2013) or adjust the RA to a lower rate.

This Cost of Service Report presents information regarding WRD's cost of service and the calculation of the RA. WRD adopts RAs prospectively and must estimate both its cost of services and revenues when it adopts an RA. Most of the information in this report reflects what WRD knew at the time the RA was adopted.

In Chapter 9, however, information is presented both about the estimated cost of service at the time that WRD initially adopted the RA and about WRD's actual costs and revenues since that time. Chapter 9 shows that WRD's actual costs of service were very close to its anticipated costs and that the previously adopted RA for 2011/12 is appropriate. In fact, for the three years 2010/11, 2011/12, and 2012–13, WRD had a total cumulative cash deficit (which it made up from the reserve account) of \$3,273,000, meaning that the RAs did not fully cover WRD's costs. This is a very small number in comparison with the overall estimated cost to provide service for the three years of \$168,701,000, within about 2% of the budgeted numbers.

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4.0 ORGANIZATION OF REPORT

This Cost of Service report has been prepared by the Water Replenishment District of Southern California (“WRD” or “District”) to describe the services the District anticipated performing (and, in fact, performed) in fiscal year 2011/12 and to analyze the costs of providing these services. The costs associated with those services are described using best available information, along with an evaluation of the fair and equitable RA necessary to cover those costs.

Section 5 describes the history of WRD formation. Section 6 describes the unique geology, hydrogeology, and groundwater quality of the interconnected basins underlying the district, and how groundwater recovery, pumping overdraft, and aquifer recharge activities affect this shared resource. Section 7 describes the WRD projects and programs undertaken to manage and protect the groundwater resource. Section 8 describes why the levy of an RA at a uniform rate per acre-foot of water removed from the basins is an equitable method of spreading the District’s costs amongst the pumpers who rely on the District’s services. Section 9 is the Fiscal Year 2011/12 Cost of Service and Section 10 is the proposed RA based on the Cost of Service. References utilized in preparing this document are listed at the end of each Section in which they are cited. Tables are included within the text of the report. Figures are included at the end of the report.

While this Cost of Service Report was prepared by licensed geologists, engineers, Certified Public Accountants, and other professionals acting under their direction, Chapter 5 was primarily authored by Mr. Michael Gagan, a consultant to the District, given his research and knowledge of the historical events discussed in the Chapter. That discussion of those historical events is included in this Cost of Service report to provide context for the technical issues and other matters covered in the Report as well as to set forth the relevant information in one complete document.

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5.0 WATER REPLENISHMENT DISTRICT FORMATION

Formation of the Central and West Basin Water Replenishment District (later renamed the Water Replenishment District of Southern California) was approved by the electorate on November 17, 1959. 81,719 votes were cast in favor of the proposed district; 20,860 votes were cast against. Five Directors of the District were elected by Division. ⁽¹⁾ The election was conducted pursuant to the provisions of the Water Replenishment District Act of 1955. ⁽²⁾

5.1 WRD Service Area

The WRD Service Area boundary was also established by the election. The boundary was formed as a result of the numerous studies, meetings, negotiations, settlements, and a public hearing that took place in the 1950s as groundwater pumpers in both basins recognized and developed solutions to the increasingly critical water supply and water quality problems they faced. A discussion of these problems and solutions appears in the California Department of Water Resources (“CDWR”) report on the proposed formation of the District (CDWR, 1959), and are also described in detail in the remainder of this Section and in Section 6. The final service area boundary established for WRD does not mention any groundwater basins or the Newport-Inglewood Uplift, or any other internal features, but instead the simple perimeter boundary of the WRD Service Area that follows certain geographic coordinates around the region. **Figure 5-1** shows the WRD service area as defined by the election. It encompasses an area of approximately 420 square miles, 43 cities, and a current population of 3.8 million. It overlies most of the Central Groundwater Basin (“Central Basin”) and West Coast Groundwater Basin (“West Basin” or “West Coast Basin”) as well as portions outside of these basins in the Palos Verdes Hills.

As discussed further below, before the election, the parties discussed different approaches to managing the basins, including establishing two separate Replenishment Districts. Ultimately, it was recognized that the Basins are one hydrogeological system that is interconnected. This led to the formation of a single replenishment district with a uniform assessment.

This is discussed further below, and some of the key statements are as follows:

- On February 28, 1957, the Board of Directors of the WBWA adopted a joint resolution “declaring the urgent need to obtain water for replenishment and prevention of salt water intrusion under the provision of Chapter 1514, California Statutes of 1955, and to develop an acceptable and feasible plan therefore” and instructing the respective Association Executive Committees “to jointly develop and submit such a plan.” On May 2, 1957, the CBWA approved the same resolution. The resolution acknowledges that both injection wells and replenishment are necessary to maintain the integrity of the entire system, and benefit both the Central and West Coast Basins:

“Whereas, the overdraft upon ground waters in the Central and West Basin areas of Los Angeles County has progressively increased to the extent that the entire ground water

reservoir could be destroyed because of continuing encroachment of sea water upon the coast; and ...

“Whereas, replenishment of the ground water reservoir through spreading and injection of a supplemental water supply has been tested and proved successful under Zones 1 and 2 of the Los Angeles County Flood Control District, and must at the earliest possible time be enlarged to a full scale operation to restore ground water levels and stop the intrusion of sea water....”

- According to Fossette, Central Basin pumpers supported a single replenishment district “to increase the yield of the basin by spreading and operating barriers to repel sea water intrusion. And finally, [to] adjudicate water rights and curtail pumping to the extent necessary to restore water levels and furnish reasonable underflow to West Basin — thus, avoiding another lawsuit.”
- Max Bookman, who was arguably the most knowledgeable expert on the geology of the two groundwater basins, said it succinctly: “Separate replenishment programs for the Central Basin and West Basin, wherein each basin pays their individual costs, is not practical because of the interdependence of the common water supply of the two areas and because the two basins must be conjunctively operated in order to obtain the maximum benefits of the groundwater supply.” (Bookman and Edmonston, 1963).

5.2 Groundwater Conditions

The hazards of leaving the Central and West Basins unmanaged had been recognized for some time prior to the formation of the District. The Walter Mendenhall studies on the Development of Underground Waters in the Central and Western Coastal Plains documented the production of groundwater in excess of natural replenishment in the early 1900s. Published by the United States Geological Survey (“USGS”) in 1905, the studies noted the “accelerating development” that had occurred in the area over the previous four decades. Increased stream diversion by constructed ditches and canals reduced the volume of natural replenishment, as did the increased runoff to the ocean caused by housing, businesses and roads. Mendenhall characterized these as “two disturbing elements” that were “destroying” the natural balance between water supply and water demand. As a result, formerly large swaths of artesian land (areas where the groundwater flowed naturally out of wells without pumping due to high pressure) were shrinking and depth to groundwater was increasing. ⁽³⁾

The widespread introduction of the electric pump and deep well turbine to replace windmills and steam generators made it possible to pump more water more quickly and from deeper sources as demand for groundwater continued to grow along with the population in the first decades of the 20th century. Groundwater extractions spiked upward with the new industrial demand that resulted from oil drilling in the Signal Hill and Long Beach areas in the 1920s and the Wilmington oil fields in the 1930s. Pre-War preparedness and the jobs resulting from it, including a rapidly growing military mobilization, increased

both industrial and domestic demand for water in an area that in 1940 was still the agricultural capital of California.

By 1940, groundwater extractions greatly exceeded natural replenishment. Pumpers in both basins were drawing water at ever-increasing depths and seawater intrusion was well underway in West Basin and was in the early stages of migration in Central Basin. ⁽⁴⁾

Adverse conditions surfaced earlier in West Basin than in Central Basin and, for that reason, the series of institutional steps that led to the ultimate formation of the Water Replenishment District began on the West Basin side.

“Generally speaking, water shortage problems move upstream,” former water district and association manager Carl Fossette noted. “Those farthest from the source are the first to be hurt, and those closest to the source have first chance at interception and are the last to suffer.

“By 1940, the West Coast Basin, located at the end of the San Gabriel River system, was experiencing serious water shortage problems. Overdraft on the basin was continuous. Replenishment from Central Basin was diminishing. Salt water was intruding into wells located along the coast. Water demands were rising, pumping was uncontrolled and competitive among producers.

“The water shortage had moved upstream by 1950 to the Central Basin, where pumping levels were far below sea level in the North Long Beach area. Sea water was intruding and the accumulated basin overdraft totaled 1,000,000 acre feet, with no controls on pumping.” ⁽⁵⁾

5.3 Organizing to Meet Water Supply Challenges

As Nobel Laureate Elinor Ostrom described it, the process of institutional development in both basins was incremental and sequential, one step leading to another in a more or less orderly way. While developments in the respective basins occurred at a different pace, both basins ended up in the same place with a common replenishment district and, shortly after that, with final court judgments limiting groundwater extractions and fixing the rights of those parties lawfully empowered to pump.

Organizationally, what ended in 1959 with voter approval of the Central and West Basin Water Replenishment District began in 1942, with formation of the West Basin Water Survey Committee. Viewed chronologically, one step in the institutional development process led logically to the next, with each succeeding step informed by the experience of what went before. Pumpers organized voluntarily to gather and share information. First in the West Basin, they sought court action to curtail

groundwater production and establish water rights. The West Basin court experience informed what eventually happened in the Central Basin.

Pumpers sought and successfully obtained formation of municipal water districts to bring an imported supply to the two basins. As events unfolded, it became clear that neither court action nor the introduction of imported water would protect the basins from permanent depletion and seawater intrusion or enable pumpers in either basin to pump beyond their natural safe yields. If imported water were to be used to arrest overdraft and replenish the basins, some mechanism for financing imported water purchases had to be developed. To restore and protect the groundwater basins for perpetual beneficial use, formation of a replenishment district was a logical final step.⁽⁶⁾

5.4 Separate Replenishment Districts for Each Basin Not Pursued

As was the case with the formation of the two municipal water districts (Central Basin Municipal Water District and West Basin Municipal Water District), the groundwater community took the steps necessary to create the Water Replenishment District. Groundwater producers representing the Central and West Basin Water Associations were instrumental in crafting the Water Replenishment District Act. The Associations established the purposes, boundaries and financing plan of the District, prepared the petition to place the question of District formation on the ballot, financed and managed the petition campaign, prepared the ballot language to take before the voters and financed and managed the campaign to secure voter approval.⁽⁷⁾

Within weeks of passage of the Water Replenishment District Act in 1955, the Associations formed Water Replenishment District Committees.⁽⁸⁾ Between July 1955 and July 1958, the advantages and disadvantages of two separate replenishment districts or a single district covering both basins were explored and discussed in detail by pumpers in the two basins.

Central Basin pumpers from the outset favored a single district covering both basins. A single district was not such an obvious choice for West Basin pumpers. "At first, West Basin producers presumed that they would go it alone and created a working committee with the association to draft a specific proposal to create a district," Ostrom notes.⁽⁹⁾ "The West Basin producers were physically disadvantaged because they were at the end of the groundwater 'pipeline.' They were concerned that their physical disadvantage could be exaggerated by the creation of a new public agency in which they would be politically dominated."⁽¹⁰⁾

In 1955, what pumpers in the West Basin would decide to do was not at all certain. According to the meeting minutes, Thorburn prefaced his presentation this way:

Director Thorburn said the Committee believed that a water replenishment district is needed in West Basin and that such a district should be formed. He said the Committee had considered the problem

of whether it was more desirable to form a district in the West Basin alone or with Central Basin. He pointed out that the problem in the Central and West Basins are the same and the natural water supply comes from the same source.

He stated that the West Basin receives its water from the Central Basin and the Central Basin in turn receives its water from (the) San Gabriel Valley Basin. He also stated the Upper San Gabriel Valley Basin was definitely a part of the problem and that perhaps a replenishment district should include all three basins. ⁽¹¹⁾

In a November 17, 1955 report to the West Basin Water Association (“WBWA”), R.R. Thorburn, Chairman of the WBWA Replenishment District Committee, listed some of the reasons for a district covering West Basin only, as well as for a single district covering the two basins ⁽¹²⁾:

Reasons given at the time for a West Basin Water Replenishment District:

1. The injection of replenishment water would be unique and necessary to West Basin. In a combined district, because of its much larger voting base, Central Basin would control that program in the West Basin and might not want to continue the well-injection method along the coast.
2. Pumping had been curtailed in West Basin but not in Central Basin.
3. The degree of ultimate curtailment might not be the same in the two basins.
4. Control of the local tax rate and amount of pumping assessment would be retained by West Basin.
5. A district limited to West Basin could initiate proceedings to ensure financial replenishment from Central Basin.

“In other words,” Ostrom commented with respect to the last item, “if the District comprised only West Basin, then the West Basin producers could sue the Central Basin producers to pressure them into curtailing their production.” ⁽¹³⁾

Reasons for a replenishment district covering both basins:

1. The purpose would be the same in both basins: replenishment of the groundwater supply.
2. Greater financial resources would be available; the tax rate and amount of pumping assessment could be lower.
3. A large district would have greater political strength and would be more effective in dealing with Upper San Gabriel and various state bodies.
4. The Long Beach harbor area offers a potential route for intrusion of seawater into West Basin and Central Basin and probably would be included in a combined district. It is doubtful that any of Long Beach could be included in a district comprising West Basin only.
5. Extensive recharge of Central Basin might contribute free water to West Basin. ⁽¹⁴⁾

A plan for a replenishment district limited to Central Basin did not progress because the leading Central Basin pumpers favored a combined district even before the Water Replenishment District Act took

effect. In August 1955, Brennan Thomas appeared before the Executive Committee of the West Basin Water Association. Thomas was General Manager of the Long Beach Water Department, by far the largest pumper in Central Basin. He was a member of the Central Basin Water Association (CBWA) Executive Committee and Water Replenishment District Committee.

Thomas said the “Central Basin (Water) Association was giving consideration for possible boundaries for a proposed replenishment district and that such a district should include both the areas of the Central and West Basin.” He explained that a combined district would have substantial financial resources to buy the water necessary for both basins and that he recognized “certain advantages and disadvantages of such a plan.” He believed, however, that “a larger replenishment district would be able to accomplish more in preserving and protecting the underground supply than would be the case if a smaller district were formed.” ⁽¹⁵⁾

Central Basin pumpers were aware that a combined district meant a single RA for pumpers in both basins. Under the Water Replenishment District Act, any RA adopted by a replenishment district board had to be uniform and based on groundwater production. ⁽¹⁶⁾

5.5 The Underflow

Central Basin pumpers supported formation of a single replenishment district with a uniform assessment covering both basins. The reason had to do with the volume of underflow from the Central Basin into West Basin and the prospective obligation Central Basin had to maintain it.

The 1952 *Report of Referee* in connection with the West Basin adjudication documented the hydrologic continuity of the two basins and quantified the historic underflow West Basin received from Central Basin. Excerpts from the *Report*:

- “The West Coast Basin is not a unique, independent hydrologic unit, but is dependent on adjoining areas for practically its entire ground water supply. ... Fresh water is supplied by aquifers extending into the basin across the Newport-Inglewood uplift, which aquifers have their source in remote areas of recharge.”
- “For all practical purposes, the sole source of continuing fresh water replenishment to the basin is the underflow across the Newport-Inglewood uplift. The rate of this replenishment is proportional to the hydrostatic head across the uplift, and during the period 1945–46 through 1949–50 the replenishment has averaged about 30,000 acre-feet per year. ... The volume of fresh water replenishment will also be reduced in proportion to the resulting change in water level differential across the uplift.” ⁽¹⁷⁾

The findings of the *Report of Referee* came as a “bombshell” to West Basin pumpers, leading to a recommendation to limit groundwater production to 30,000 acre-feet of underflow per year, roughly one-third of actual production in 1952. ⁽¹⁸⁾

Even before publication of the *Report of Referee*, West Basin pumpers eyed with great interest Central Basin developments that might affect underflow. “The success of the effort to form (the Central Basin Municipal Water District) and to have it annexed to Metropolitan is of special importance to the West Basin,” Fossette wrote in a May 1952 edition of *West Basin Water News*. “The Inglewood-Newport fault (sic) separates the Central Basin from the West Basin and virtually all of the groundwater replenishment to West Basin accrues by underflow across the dividing fault line. A recent report of the Division of Water Resources (Bulletin 8) indicates that the Central Basin is now subject to an overdraft of about 100,000 acre-feet per annum. It follows that as long as this overdraft continues, the replenishment to West Basin will be progressively diminished.” ⁽¹⁹⁾

Indeed, “the replenishment to West Basin” dropped precipitously in the next few years. In a February 23, 1956 presentation to the WBWA, West Coast Basin Watermaster Max Bookman said that “significant facts were being developed with reference to water levels across the Newport-Inglewood fault in Central Basin. He said water levels on the Central Basin side were still receding rapidly...He stated that when water levels on the Central Basin side were lower than levels on the West Basin side, replenishment to West Basin from Central Basin would be cut off.” ⁽²⁰⁾

In a November 6, 1958 presentation to the CBWA, State Department of Water Resources Director Harvey Banks observed that “water levels in Central Basin are now so low that the ground water flow has been reversed and is now moving from West Basin into Central Basin, contrary to the design of nature.” ⁽²¹⁾

Bookman subsequently estimated that in order to restore the underflow to anything approaching the historic volumes identified in the *Report of Referee*, pumping in the Central Basin would have to be limited to 170,000 acre-feet. ⁽²²⁾

5.6 WRD as an Institutional Alternative to Litigating the Underflow

The prospect of adjudicating the underflow was on the minds of West Basin pumpers even as the Water Replenishment District Act was being crafted. Indeed, a provision in the Act authorized a district to pay the costs of adjudicating water rights. “West Basin needed the provision in the act,” WBWA President Ben Haggott said, “to permit adjudication of the upstream system in the Central Basin and in the San Gabriel Valley in order to find some means to stop the cutting off of upstream replenishment to West Basin.” ⁽²³⁾

“West Basin threatened to sue Central Basin producers,” Fossette said, “unless they reduced pumping to allow water levels to recover, so replenishment would, again, reach the West Basin by underflow across the Fault dividing the two areas.” ⁽²⁴⁾

In his May 2, 1957 speech to the Central Basin Water Association, Metropolitan Water District (“MWD”) Board Chairman Joe Jensen advocated for the formation of a single replenishment district with a uniform RA covering both basins, stating that “a single replenishment district should be formed to include the area of both Central and West Basins rather than to form a single district in each basin.” Referring to the Orange County Water District litigation against Riverside, San Bernardino, Redlands and Colton, he noted that the judge had ordered the defendant cities to reduce pumping by 30% and to “pay back the excessive amounts of water taken since 1951.” He said that “West Basin was entitled to its fair share of the natural water...and that if a single replenishment district was formed including both West and Central Basins, the entire area could be regulated as a single unit.” ⁽²⁵⁾

In making the case for a single replenishment district to West Basin pumpers six months later, Jensen again referred to the Orange County Water District litigation. “Mr. Jensen referred to the recent court decision rendered in connection with the Orange County suit against San Bernardino, Riverside, Redlands and Colton, providing that those cities reduce pumping by 30% in order to insure that Orange County would receive its fair share of the ground water supply. He added that the decision further provided that the Upper Basin cities pay back the excessive amounts of water taken since 1951 and he compared the situation involved in that lawsuit with that existing in the West and Central Basin areas.” ⁽²⁶⁾

Two years later, Brennan Thomas solicited the participation of the WBWA in imminent litigation the City of Long Beach intended to file against pumpers in the Upper San Gabriel. He emphasized that “the geological factors were similar in the Upper San Gabriel Valley and the Santa Ana territory...the West Basin was in the same relative position as the Orange County Water District, that Riverside represented the same position as the Central Basin area and that the Upper San Gabriel Valley area occupied a position similar to that of the San Bernardino area.” ⁽²⁷⁾

In litigation over the San Gabriel River watershed, the Central Basin and West Basin were also treated as a single unit – as the “Lower Area” of the San Gabriel River watershed. Through the 1950s, rapid development and population growth in the upper part of the San Gabriel Valley dramatically reduced the surface and subsurface flows across Whittier Narrows. In the late 1950s, water users in the Main San Gabriel Basin were almost completely reliant upon local water supplies and had not gained access to a supplemental supply such as imported water. Water users in the Lower Area of the San Gabriel River watershed (Central and West Basins) tried to get upstream users in the Main San Gabriel Basin to follow the process used twice in the Lower Area: namely, to organize a water association, form a municipal water district, annex to MWD, and contribute to the cost of supplying the region with supplemental water. After early efforts at persuasion failed to yield the desired actions, Lower Area producers warned that litigation to restrain Upper Area water use was likely.

In the Spring of 1959, the Lower Area cities of Long Beach and Compton along with the Central Basin Municipal Water District filed a complaint against the Upper Area water producers in *Board of Water Commissioners of the City of Long Beach et al. v. San Gabriel Valley Water Company et al.* The plaintiffs requested a determination of the Upper Area parties' rights to water in the San Gabriel River watershed and an injunction restraining them from interfering with the rights of the Lower Area users to water from that watershed. Both sides appointed members to a joint negotiating committee and commissioned a joint engineering study to aid in the determination of water flows (both above ground and underground) between the upper and lower areas of the watershed over time. The study and negotiations continued from 1960 through 1963, resulting in a stipulation for judgment accompanied by exhibits from the engineering study. Remaining issues were resolved over the course of 1964, and the stipulated judgment in the case was entered by the Superior Court on May 1965.

The judgment called for monitoring of Upper Area deliveries of "usable water" (defined in the judgment) to the Lower Area of the watershed by a San Gabriel River Watermaster composed of Upper Area and Lower Area representatives. This arrangement between the Upper Area users and Lower Area (Central and West Basins) users of the San Gabriel River watershed has remained in effect for almost 50 years.

From a Central Basin pumper perspective, it was far less expensive to pay more for a common replenishment district than to risk significant reductions in pumping that would likely result from an adjudication of the underflow. According to Fossette, Central Basin pumpers supported a single replenishment district "to increase the yield of the basin by spreading and operating barriers to repel sea water intrusion. And finally, (to) adjudicate water rights and curtail pumping to the extent necessary to restore water levels and furnish reasonable underflow to West Basin --- thus, avoiding another lawsuit." ⁽²⁸⁾

West Basin producers came to see the formation of a single replenishment district as an attractive alternative to litigation. As noted above, West Basin producers had sought court action to curtail groundwater production and establish water rights. "After their costly experience with litigation," Ostrom wrote, "most West Basin producers hesitated to enter into prolonged adjudication concerning the respective rights of Central Basin producers and West Basin producers to the joint supply. The possibility of creating a management enterprise to include both basins offered the opportunity to negotiate a rationing agreement within the framework of a common public enterprise." ⁽²⁹⁾

5.7 Metropolitan Water District as a Certain Source of Supply

A recurring concern in replenishment district discussions had to do with the fact that the pumpers did not know whether the MWD would guarantee the delivery of sufficient water to meet the replenishment needs in the Basins. Even if there was sufficient water available, there was no Metropolitan connection to either the spreading grounds or the West Coast Basin Barrier and the future barriers planned for the Dominguez Gap and Alamosos Gap.

Pumpers began discussions with Metropolitan officials in March 1956.⁽³⁰⁾ Those discussions led to the appointment by Metropolitan Board President Joseph Jensen of a Subcommittee on Groundwater Replenishment chaired by W.C. Farquhar, President of the West Basin Municipal Water District and member of the Executive Committee of the West Basin Water Association.

The work of that Subcommittee resulted in a Statement of Policy adopted on April 16, 1957 by the Metropolitan Board.⁽³¹⁾ The policy said that Metropolitan would construct at its own expense a 45-mile distribution line and laterals to serve the coastal barriers, as well as a line and laterals to serve the spreading grounds on two conditions. One was that a future replenishment district or districts execute a contract with Metropolitan “to buy untreated Colorado River Aqueduct water for the replenishment of the local underground basins to the full amount of the revenues made available by charges on pumped water.”

The second condition was that there be organized a water replenishment district or districts in Central and West Basins no later than April 16, 1961. The cost of the distribution pipelines and laterals was estimated at \$19 million (more than \$150 million in 2013 dollars). The money was important, but so was the deadline. For the first time, pumpers had a defined window in which to form a district.

5.8 One Replenishment District for Two Basins

As discussions with Metropolitan were in their early stages “members of both associations came to a working agreement that the benefits of a larger district would outweigh the costs. Assurances were given to West Basin producers that they would not be dominated by their eastern neighbors.”⁽³²⁾

On November 15, 1956, the Board of Directors of the WBWA authorized the Association’s Executive Committee “to work with representatives of Central Basin Water Association in drafting a joint resolution to be offered to the Board of Directors of both Associations for approval and adoption at their regular meetings to be held in February, 1957, and that such joint resolution provide authority for both Associations to jointly sponsor formation of a water replenishment district to include the areas of both Central and West Basins and such additional territory as may properly be included in such a district.”⁽³³⁾

On February 28, 1957, the Board of Directors of the WBWA adopted a joint resolution “declaring the urgent need to obtain water for replenishment and prevention of salt water intrusion under the provision of Chapter 1514, California Statutes of 1955, and to develop an acceptable and feasible plan therefore” and instructing the respective Association Executive Committees “to jointly develop and submit such a plan.” On May 2, 1957, the CBWA approved the same resolution.⁽³⁴⁾

In Speaking to the WBWA Board of Directors on May 23, 1957, Metropolitan Board President Joseph Jensen remarked that “the West Basin Water Association had voted to approve a single water replenishment district, including the areas of West and Central Basins, and he stated that in his opinion this was a wise decision because both West and Central Basin should be operated as a single unit.”⁽³⁵⁾

5.9 Proposal to Form One District for Two Basins

In response to the joint resolution adopted by the two Associations in February and May 1957, the Joint Association Committee to Form the Replenishment District worked for 14 months on the details of what became a Proposal to Form the Central and West Basin Water Replenishment District. On August 7, 1958, the CBWA approved the proposal; on August 28, it was approved by the WBWA. ⁽³⁶⁾

The Proposal provided the reasons for forming the district, described the boundaries for it, outlined the formation procedures and methods for financing the district. It acknowledged that “various public agencies are or will become involved in some phases of the replenishment work,” noting the State Department of Water Resources as Watermaster in the West Basin and the Los Angeles County Flood Control District as operator of the spreading grounds and the barrier system.

The Proposal said the new district would have authority to purchase replenishment water, but could not use property tax money for such purposes. It was anticipated that the Los Angeles County Flood Control District would continue to buy water to eliminate the estimated 700,000 acre-feet accumulated overdraft and to expand the barrier system.

The Proposal also spoke to the purposes of the proposed district. “The salvaging of the ground water basins requires the formation of a Water Replenishment District to:

- “a. Repel salt water intrusion;
- “b. Recharge the ground water basins, and
- “c. Reduce the pumping therein to safe limits.”

Elsewhere, the Proposal said, “The primary purpose of the Water Replenishment District will be to restore and maintain the depleted ground water basins. To accomplish this, the district will have responsibility for financing the purchase of the water used in halting the intrusion of sea water and in replenishing the ground water supply. To insure its purpose, the district will be responsible for bringing an action to adjudicate water rights within its area and curtail pumping to safe limits.” ⁽³⁷⁾

Ostrom characterized this Proposal as “a ‘constitution’ for a multi-agency management system to operate a coordinated program designed to make effective use of the opportunities for development of a conjunctive use of the various surface and ground water supplies available to water producers in West and Central Basins.” ⁽³⁸⁾

5.10 Formation Petition

One of the steps required to form the new district was a petition signed by 10% of the eligible voters residing within the proposed district. ⁽³⁹⁾ The Los Angeles County Registrar of Voters determined that the petition must be signed by 91,950 registered voters. Following an aggressive petition campaign

conducted by the two Associations, the Registrar determined that 116,275 valid signatures were submitted by the May 25, 1959 deadline. ⁽⁴⁰⁾

The Petition included an Explanation of Purpose, detailed district boundary descriptions and reasons for the proposed formation of the district. The Explanation of Purpose read as follows:

You are living in an area under which lie the great Central and West Basins or underground reservoirs which hold the water being pumped daily to keep you and your family alive.

This area which now contains about 2,500,000 people has grown by a million since World War II and will grow a million and a half more in the next ten years.

We are pumping out of these Basin reservoirs billions of gallons more than nature puts back. If the level gets much lower, salt water will creep in and fill our wells, as is now the case in some localities. We must immediately restore this underground supply of fresh water which is our 'bank account' on which to draw if earthquake or bombing destroyed the surface supply.

Public officials, water companies and industry leaders are sponsoring a Water Replenishment District which would obtain money for restoring water needed by taxing the pumpers of water, not you, the average citizen. All it would cost you is about 25 cents a year to administer the District office.

The final section of the petition gave the following reasons for the formation of a Central and West Basin Water Replenishment District:

The continuing long-term overdraft on the ground waters within the boundaries of said proposed district has lowered the ground water levels therein many feet below sea level, resulting in the progressive encroachment of salt water from the ocean into areas of said proposed district adjacent to the ocean, which, if continued, will destroy the basins and the waters thereof for beneficial use. Such continuing overdraft from, and the resultant depletion of, said ground waters, deprive the users within the area comprising said district of an indispensable carryover water supply that would be required to meet its needs in the event of a catastrophe caused by nature or by enemy action. The preservation of ground water storage in said proposed district to provide a reserve supply of water to meet peak demands and

water requirements during dry years is vital to the health, safety and general welfare of inhabitants therein. The formation of the proposed Water Replenishment District is required in order to:

- a) Recharge the ground waters in said district,
- b) Repel the intrusion of salt water therein,
- c) Reduce the pumping therein by all possible means, including necessary legal proceedings to adjudicate the rights of the users thereof. ⁽⁴¹⁾

5.11 Department of Water Resources Hearing

As a final step before an election could be called on the question of district formation, the Water Replenishment Act required the Director of the Department of Water Resources to conduct a hearing to determine “whether or not lands that are not included in the proposed Central and West Basin Water Replenishment District should be included, whether or not some lands that are included should be excluded, and whether the proposed district, as modified by inclusions and exclusions, will be of benefit generally to all persons or property which rely directly or indirectly upon the use of or right to use the ground water supplies within such proposed district.” ⁽⁴²⁾

The hearing was conducted by Department Director Harvey O. Banks on July 6, 1959. Four individuals requested that their properties be excluded from the proposed district. The Director denied their requests and in his July 17, 1959 Determination found that all persons and property within the boundaries of the proposed district will benefit directly or indirectly by the district. The Director adopted, without modification, the boundaries described in the formation petition. ⁽⁴³⁾

Five months later, voters approved formation of the Central and West Basin Water Replenishment District. The first meeting of the newly-elected Board was held on December 28, 1959. ⁽⁴⁴⁾

5.12 Avoiding the Tragedy of the Commons

The Legislature found that the Water Replenishment District Act was “necessary to the solution of a problem arising out of the following unique circumstances: The water supplies in the arid southern part of this State to which the provisions of this Division are applicable are insufficient to meet the water demands of the areas, and, because of the geological conditions peculiar to this area, further excessive pumping without replenishment is certain to destroy the usefulness of these basins.” ⁽⁴⁵⁾

To destroy “the usefulness of these basins” would be to bring about the “tragedy of the commons,” an expression Elinor Ostrom used to characterize the degradation or destruction of a natural “common pool resource” when individuals using the resource act independently from others who use the same resource. ⁽⁴⁶⁾

In *Governing the Commons*, Ostrom examined “how a group of principals who are in an interdependent situation can organize and govern themselves to obtain continuing joint benefits when all face temptations to free-ride, shirk, or otherwise act opportunistically.” She then examined “the general problem of individuals in CPR (Common Pool Resource) situations: how to organize to avoid the adverse outcomes of independent action.”⁽⁴⁷⁾

The formation of the Water Replenishment District is one of the case studies she used as an example of “how to organize to avoid the adverse outcomes of independent action” and “to obtain continuing joint benefits” in the face of “temptations to free-ride, shirk, or otherwise act opportunistically.”

By crafting the Water Replenishment District Act and ultimately taking to the voters a “constitution” that would guide a new district, the pumpers in the Central and West Basins turned an inevitable tragedy of the commons into a protected and perpetually sustainable resource.

“As a result of five years of intensive planning and negotiation,” Ostrom wrote 25 years before publication of *Governing the Commons*, “it appeared that public entrepreneurs in West and Central Basin had been able to design and create a management system with the appropriate boundaries and range of powers to undertake an extensive ground water basin management program. The Central and West Basin Water Replenishment District would function as the key management enterprise in shaping the program for the mixed public and private enterprise system with responsibility for the operation of an agreed upon program. The difficult task of constituting the management system was completed. Now they faced the risks and opportunities of evolving a specific program and placing it into operation. And, at the same time, they would be testing the capabilities of a decentralized political decision-making system to operate an efficient ground water basin management program in conjunction with a highly developed water industry having access to several alternative sources of water supply.”⁽⁴⁸⁾

5.13 Protecting the Commons

The 1958 Proposal for a Central and West Basin Water Replenishment District Formation of the District and its operation as a “single unit” covering both basins resulted in the relatively quick implementation of what the pumpers had in mind.

Salt water intrusion into Central Basin was mitigated with the completion of the Alamitos Barrier in 1964. Intrusion in West Basin was mitigated with the completion of the Dominguez Gap Barrier in 1969. Begun as an experimental project in 1952, the West Coast Basin Barrier was substantially completed in 1964. Except for the first experimental West Coast Basin Barrier, which was funded by the state, most of the construction costs for the three barriers were paid by the Los Angeles County Flood Control District through a special replenishment-related tax it assessed on property owners in both basins. The capital costs totaled \$9,581,973.⁽⁴⁹⁾

An aggressive program of water purchases for spreading was implemented in the district's first full year of operation. Within two years, 355,922 acre-feet of imported water was purchased for spreading, the district buying 235,622 acre-feet of that amount, the Los Angeles County Flood Control District through its special replenishment-related tax purchasing the remainder. The Flood Control District would continue to share the costs of spreading water purchases until 1971. ⁽⁵⁰⁾

On January 2, 1962, the Central and West Basin Water Replenishment District filed an adjudication action to fix extraction rights in the Central Basin. On October 20, 1965, judgment was entered. Filed in 1945, judgment in the West Basin case was entered on August 22, 1961 and upheld by the State Supreme Court on August 10, 1965. ⁽⁵¹⁾

The court did not fix "the natural safe yield" in either Judgment. The allocation of pumping rights in both Judgments presupposed a replenishment program that would make up the difference between natural replenishment and actual pumping under the respective Judgments. The allocation of extraction rights greatly exceeded any plausible determination of natural safe yield.

A 1962 California Department of Water Resources report estimated the natural safe yield of Central Basin at 137,300 acre-feet. The allowed pumping allocation under the Central Basin Judgment is 217,637 acre-feet. The same report estimated the natural safe yield in the West Basin at 36,100 acre-feet. Adjudicated rights under the West Basin Judgment total 64,468.25 acre-feet. ⁽⁵²⁾ Thus, pumping of the allowed pumping allocations in both basins is dependent upon the continuation of an aggressive replenishment program.

5.14 Footnotes to Section 5

- (1) Los Angeles County Registrar of Voters, "Results of the Official Canvass," November 27, 1959. The Board of Supervisors certified the election and declared the District duly organized on December 1, 1959. The California Secretary of State certified that "a Water Replenishment District in the County of Los Angeles has been duly incorporated according to the laws of this State and is in legal existence under the name CENTRAL AND WEST BASIN REPLENISHMENT DISTRICT." The name of the District was subsequently changed to Water Replenishment District of Southern California (Water Replenishment District of Southern California, [Board Minutes](#), November 7, 1991)
- (2) Chapter 1514, Statutes of California, 1955. Sections 60080 – 60125 of the Act specified the steps required to form a replenishment district. Petitions supporting the formation of a proposed district must be signed by 10% of the registered voters residing within the district. Assuming that requirement is satisfied, the Department of Public Works must conduct a hearing to determine whether the proposed district "will be of benefit generally to all persons or property which rely directly or indirectly upon the use of or right to use the groundwater supplies within such proposed district." If that finding is made, the Board of Supervisors must schedule an election to put the question of formation before the voters.

In 1956, the Water Resources Division of the Department of Public Works was combined with the State Engineer's Office, the Water Project Authority, and the State Water Resources Board to become the Department of Water Resources. (Chapter 52, Statutes of California, 1st Extraordinary Session, 1956) The history of the Department of Public Works and the rationale for creating the Department of Water

Resources was the subject of a May 24, 1956 presentation to the WBWA by Max Bookman, Engineer in Charge, Division of Water Resources. (WBWA, Minutes, May 24, 1956)

- (3) Walter C. Mendenhall, *Development of Underground Waters in the Central Coastal Plain Region of Southern California*. United States Geological Survey Water Supply and Irrigation Paper No. 138. 1905, p. 25.
- (4) Information on historical groundwater conditions and the overdraft can be found in California Department of Water Resources, *Planned Utilization of Groundwater Basins of the Coastal Plain of Los Angeles County*: Bulletin 104, Appendix B, Safe Yield Determinations, 1962, p. 71. Historical accounts of the period may be found in Bulletin 104, pp. 40 – 46; William Blomquist, *Dividing the Waters: Governing Groundwater in Southern California* (San Francisco: ICS Press, 1992), pp. 97 -158; California State Department of Public Works, *Report of Referee, West Basin Adjudication*, June 1952, pp. 26 - 78; Carl and Ruth Fossette, *The Story of Water Development in Los Angeles County*, (Downey, CA: Central Basin Municipal Water District, 1986), pp. 6 – 85.
- (5) Fossette (1986) pp. 4 and 5. For increasingly urgent pumper accounts of deteriorating conditions, see Fossette, “Central Basin News,” (1951 – 1956); “West Basin Water News,” (1946 – 1954). For information about Fossette, see Water Replenishment District of Southern California Ad Hoc History Committee, “Essays on District Formation: Pioneers of Groundwater Replenishment,” June 2009.
- (6) Elinor Ostrom, *Public Entrepreneurship: a Case Study in Groundwater Basin Management* (Doctoral Dissertation, University of California, Los Angeles, 1965), pp. 414 - 460; Elinor Ostrom, *Governing the Commons: the Evolution of Institutions for Collective Action* (New York: Cambridge University Press, 1990), pp. 103 – 142. Also see Blomquist (1992) pp. 97 – 158 and Fossette (1986) pp. 151 – 170). See Water Replenishment District of Southern California Ad Hoc History Committee, “Essays on District Formation: Sequence of Events Leading to the Formation of the Water Replenishment District,” March 2009.
Ostrom received the 2009 Nobel Prize in Economics for developing the theory of polycentric governance of complex economic systems as an alternative to conventional theories of the market and the state. Her theory was used to explain “how a group of principals who are in an interdependent situation can organize and govern themselves to obtain continuing joint benefits when all face temptations to free-ride, shirk, or otherwise act opportunistically.” She cites the formation of the Water Replenishment District and other institutions as an example of protecting the Common Pool Resource of the Central and West groundwater basins by pumpers voluntarily organizing “to avoid the adverse outcomes of independent action.” Ostrom (1990), p. 29.
In her December 8, 2009 Nobel Prize Lecture, Ostrom traced the origin of her “intellectual journey” to the study of “the efforts of a large group of private and public water producers facing the problem of an overdrafted groundwater basin on the coast and watching the saltwater intrusion threaten the possibility of long-term use.” (Elinor Ostrom, “Beyond Markets and States: Polycentric Governance of Complex Economic Systems,” Nobel Prize.org, 2009). She was referring to her 1965 doctoral dissertation, *Public Entrepreneurship: a Case Study in Ground Water Basin Management*, which focused on West Basin but therefore necessarily included the management arrangements that had been developed in Central Basin as well.
- (7) The role of the West Basin Water Association and the Central Basin Water Association in crafting the Water Replenishment District Act and in the formation of the Water Replenishment District is discussed in Blomquist (1992), pp. 97 - 158; Fossette (1986) pp. 151 – 170; Ostrom (1965) pp. 414 – 460 and Ostrom (1990) pp. 103 – 142.
- (8) L.J. Alexander, “Notes on Formation of Replenishment District in West Basin and Central Basin,” (Undated but based on the text, it was likely prepared in late 1955 or early 1956.); For information about Alexander, see Water Replenishment District of Southern California Ad Hoc History Committee, “Essays on District

- Formation: Pioneers of Groundwater Replenishment,” June 2009. Also see WBWA, Minutes, August 25, 1955.
- (9) Ostrom (1990) p. 129.
- (10) *Ibid.* p. 131.
- (11) WBWA, Minutes, November 17, 1955.
- (12) WBWA, Minutes, November 17, 1955. For information about Thorburn, see Water Replenishment District of Southern California Ad Hoc History Committee, “Essays on District Formation: Pioneers of Groundwater Replenishment,” June 2009.
- (13) Ostrom, *op. cit.*, p. 236.
- (14) Numerous references elsewhere in Association minutes suggest that by “free water,” Thorburn was referring to increased underflow across the Newport-Inglewood fault by virtue of increased replenishment in Central Basin.
- (15) WBWA Executive Committee, Minutes, August 18, 1955. For information about Thomas, see Water Replenishment District of Southern California Ad Hoc History Committee, “Essays on District Formation: Pioneers of Groundwater Replenishment,” June 2009.
- (16) *California Water Code*, Sec. 60317. Except for stylistic language changes made in 1990 (Chapter 389, California Statutes of 1990) that revised “ground water” to “groundwater,” for example, the language has remained the same since the Act was adopted in 1955.
- (17) California State Department of Public Works, Division of Water Resources, *Report of Referee, West Basin Adjudication*. June 1952, pp 126 - 129.
- (18) Ostrom, *op. cit.*, p. 117.
- (19) Carl Fossette, *West Basin Water News*, May 3, 1952.
- (20) WBWA, Minutes, February 23, 1956.
- (21) CBWA, Minutes, November 6, 1958.
- (22) Max Bookman, Letter to Carl Fossette, January 15, 1963.
- (23) WBWA, Minutes, April 12, 1955.
- (24) Fossette (1990), p. 126.
- (25) CBWA, Minutes, May 2, 1957. The appellate reference to the case Jensen was referring to is *Orange County Water District v. City of Riverside, et al*, 173 Cal. App. 2nd 137 (August 20, 1959).
- (26) WBWA, Minutes, November 15, 1956.
- (27) WBWA, Minutes, November 20, 1958.
- (28) Fossette (1990), p. 222.
- (29) Ostrom (1965), pp 440 - 441. West Basin pumpers had been engaged in the adjudication of their prescriptive rights since 1945. In addition to litigation fatigue, they were aware of just how costly an adjudication action can be. One participant estimated the total cost of the West Basin adjudication at \$5 million. See Albert J. Lipson, “Efficient Water Use in California: the Evolution of Groundwater Management in Southern California,” (Santa Monica, CA: Rand Corporation, 1978), p. 11.
- (30) WBWA Executive Committee, Minutes, April 18, 1956. For information about Farquhar, see Water Replenishment District of Southern California Ad Hoc History Committee, “Essays on District Formation: Pioneers of Groundwater Replenishment,” June 2009.
- (31) Reprinted in CBWA, Minutes, May 2, 1957.
- (32) Ostrom (1990), pp. 131 – 132.
- (33) WBWA, Minutes, November 15, 1956.
- (34) WBWA, Minutes, February 28, 1957; CBWA, Minutes, May 2, 1957.

- (35) WBWA, Minutes, May 23, 1957.
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- (37) CBWA and WBWA Joint Committee to Form Replenishment District, "Proposal of Central and West Basin Water Replenishment District," July 30, 1958. The Proposal is included as Appendix D in State of California Department of Water Resources, "Report on Proposed Central and West Basin Water Replenishment District," July 1959.
- (38) Ostrom (1965), p. 455.
- (39) Chapter 1514, Statutes of California, 1955. Procedures required for district formation are in Sections 60080 – 60125.
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6.0 HYDROGEOLOGY

Hydrogeology is the science that encompasses the occurrence, distribution, movement and properties of groundwater – the water beneath the earth’s surface – and its interaction and relationship with the surrounding environment. It combines the elements of hydrology with geology, geochemistry, geophysics, paleontology and geomorphology to gain an understanding of groundwater occurrence, movement, and quality. In this Section, the hydrogeology of the WRD Service Area is discussed. The information presented represents over a hundred years of scientific and engineering research and analysis on the geologic and groundwater conditions in the greater Los Angeles area that were undertaken as the region’s population grew and strong interests developed in the area’s groundwater and petroleum resources, and in the seismic (earthquake) hazard potentials.

6.1 Groundwater Basin Boundaries

A “groundwater basin,” as that term is used in this report, is an area below the earth’s surface that holds and transports substantial amounts of groundwater that can be tapped by wells to provide the overlying population with a significant percentage of its water supply needs. Groundwater basins are comprised of aquifers, which are layers of permeable rock or sediment.

Groundwater basins have definitive boundaries on the earth’s surface that can be drawn on maps. These boundaries can be based on actual geologic features such as mountains or hills or faults, or on hydrogeologic features such as groundwater divides or ocean boundaries, or on arbitrary lines based on political or judicial boundaries. Sometimes judicial or political boundaries for a basin may be drawn differently from the geologic boundary, leading to different boundaries for the same groundwater basin. Such is the case for the Central Basin and West Coast Basin in the WRD Service Area, which will be discussed in more detail below.

The CDWR performed several major investigations of the groundwater resources of the Coastal Plain of Los Angeles County (“Coastal Plain”) in the 1960s (CDWR 1961, 1962, 1966b, 1968). These reports built on earlier investigations going back as far as 1905 (Mendenhall, 1905a, 1905b) and developed the geologic and hydrogeologic framework which is still in use today. They defined the Coastal Plain as the gently sloping land between the mountains and the sea in southern Los Angeles County, bounded on the north by the Santa Monica Mountains, on the northeast by the Elysian, Repetto, Merced, and Puente Hills, on the east by the political border line between Orange County and Los Angeles County, and on the south and west by the Pacific Ocean.

CDWR subdivided the Coastal Plain into four areas based on geologic or hydrogeologic characteristics, including the Central Basin, West Coast Basin, Santa Monica Basin, and Hollywood Basin. The CDWR later defined these four areas as “subbasins” to the larger Coastal Plain of Los Angeles Groundwater Basin (CDWR, 2003). CDWR defines subbasins as a smaller unit than a groundwater basin divided using geologic and hydrogeologic barriers or, more commonly, institutional boundaries. The subbasins are

created “for the purpose of collecting and analyzing data, managing water resources, and managing adjudicated basins.” (CDWR, 2003, pg. 90). **Figure 6-1** shows a map of the Coastal Plain and subbasins as defined by the CDWR.

The two subbasins that lie wholly or partially within the WRD Service Area include the Central and the West Coast. Although CDWR considers them subbasins, the remainder of this report will refer to them as basins to be consistent with the majority of the literature and with the official names given in the Central Basin Adjudication and West Coast Basin Adjudication. When described together, the Central Basin and West Coast Basin will be referred to as the “Basins.”

6.1.1 Central Basin

The CDWR (2003) lists the Central Basin as Groundwater Subbasin Number 4-11.04, with a surface area of 177,000 acres (277 square miles). The geologic boundary of the Central Basin was defined using hydrogeologic features as follows: On the north is a surface feature called the La Brea High, which in the late 1950s was the rough approximation of a groundwater divide separating pumping in the Hollywood Basin from the Central Basin (CDWR, 1961, pg. 116); on the northeast and east by the less permeable Tertiary rocks of the Elysian, Repetto, Merced, and Puente Hills; on the southeast by the Central Basin / Orange County Groundwater Basin (and County line) which roughly follows Coyote Creek which is a regional drainage province boundary; and on the southwest by the Newport-Inglewood fault system and associated folded rocks of the Newport-Inglewood uplift.

Within the Central Basin, four subareas have been defined for descriptive purposes (CDWR, 1961), including the Los Angeles Forebay, the Montebello Forebay, the Central Basin Pressure Area, and the Whittier Area (**Figure 6-1**). The Los Angeles and Montebello Forebay areas were historically described as regions where surface water such as rain, rivers, irrigation water, and intentionally applied recharge water at spreading grounds have the potential to readily infiltrate into the subsurface and directly recharge multiple unconfined aquifers — not only to the forebays but also to the other parts of the Central Basin and West Coast Basin as groundwater moves away from the forebays and into the pressure areas. During the CDWR investigation (1961), it was discovered that the actual areas where unrestricted infiltration of surface waters to the underlying groundwater was limited to much smaller areas than previously mapped and were limited to the vicinity of the Los Angeles Narrows and the Whittier Narrows. CDWR kept the boundaries of the forebays unchanged, however, as the department deemed remapping of the forebay and pressure areas would be arbitrary and that the older delineations were still useful for historical significance and descriptive purposes (CDWR, 1961, pg. 149). The Central Basin Pressure Area was defined based on the aquifers having overlying confining beds (confined aquifers) so that the groundwater was under pressure and could not be readily recharged through infiltration of surface water. The Whittier Area was first defined in CDWR (1961) as having formerly been named the La Habra Basin, and due to a lack of production wells in the area groundwater information is generally sparse.

Another boundary was ascribed to the Central Basin when the basin was adjudicated in 1965 (Central Basin Amended Judgment, 1991). The adjudicated boundary matched the geologic boundary on the east, south, and west, but the northern boundary was drawn shorter than the geologic boundary based on an irregular line through the City of Angeles along Santa Barbara Avenue (now Martin Luther King Blvd), Stocker Street, Alameda Street, Olympic Blvd, and the base of the foot of the Merced and Puente Hills (CDWR, 2012a, pg. 1). The adjudicated Central Basin boundary is approximately 227 square miles versus the geologic boundary which is 277 square miles. **Figure 6-2** illustrates the geologic boundary and the adjudicated boundary of the Central Basin, along with the subareas Montebello Forebay, Los Angeles Forebay, Whittier Area, and Pressure Area, and the WRD Service Area boundary.

6.1.2 West Coast Basin

The CDWR (2003) lists the West Coast Basin as Groundwater Subbasin Number 4-11.03, with a surface area of 91,300 acres (142 square miles). The geologic boundary of the West Coast Basin was defined using hydrogeologic features by CDWR (2003) as follows: On the north by the Ballona Escarpment which is an abandoned erosional channel from a historic path of the Los Angeles River, on the east by the Newport-Inglewood fault zone, on the south and west by the Pacific Ocean and consolidated rocks of the Palos Verdes Hills. Unlike the Central Basin, which was subdivided into the Montebello Forebay, Los Angeles Forebay, Central Basin Pressure Area, and Whittier Area, the West Coast Basin has not been divided into descriptive subareas by CDWR.

Another boundary was ascribed to the West Coast Basin when the basin was adjudicated in 1961 (West Coast Basin Amended Judgment, 1980). The adjudicated boundary roughly matched the geologic boundary on the north, east, south, and west, but in the Palos Verdes Hills to the southwest, the adjudicated boundary was drawn on the top ridgeline of the hills to include the full watershed boundary, whereas the geologic boundary was at the base of the Palos Verdes Hills. The adjudicated West Coast Basin boundary is approximately 160 square miles (CDWR, 2012b) versus the geologic boundary which is 142 square miles. **Figure 6-2** illustrates the geologic boundary and the adjudicated boundary of the West Coast Basin, along with the WRD Service Area.

6.1.3 The Two Basins Connected

The Central Basin and West Coast Basin share a common boundary, which is the Newport-Inglewood Uplift (**Figure 6-2**). The boundary is based upon a line approximating the centerline of the Uplift. However, as will be discussed in more detail in the Section 6.2.2, the Uplift is not a simple straight line feature, but a complicated structure of numerous hills and discontinuous fault segments that start and stop over a 20-mile length and over and a mile width and follows a non-linear path. The Uplift formed over geologic time as the tectonic forces in the region caused deformation of the strata. The Uplift has created structural traps for hydrocarbon resources, and drilling for oil has been extensive in parts of the Uplift including Signal Hill, Dominguez Hill, and the Baldwin Hills.

The interconnectivities of the two basins across the Uplift is well known to those studying such matters as is documented in numerous technical documents, including California Division of Public Works (1952), Poland and Others (1959), California Department of Water Resources (1959, 1961, 1962, 2003, 2012b), and U.S. Geological Survey (2003). Groundwater flows across the Uplift depending on the slope of the water table or potentiometric (pressure) surface on either side of the Uplift and the tightness (hydraulic conductivity) of the sediments that cross the Uplift at any given point along its length. A graphic prepared by CDWR (1959) depicts a generalized cross-sectional view through the Central Basin, the Newport-Inglewood Uplift, and the West Coast Basin (**Figure 6-3**).

Groundwater professionals working in the area are aware of the interconnectivities of the Central Basin and West Coast Basin. In 2001, Mr. Desi Alvarez, Director of Public Works for the City of Downey, which is in the Central Basin, filed a declaration in a legal matter to support intervening in a desalination project being contemplated in the West Coast Basin (Declaration of Desi Alvarez, 2001). The City of Downey believed that pumping of groundwater for the desalination project in the West Coast Basin would negatively impact the City in the Central Basin due to the connection of the two groundwater basins across the Newport-Inglewood Uplift. Citing that connection, the City filed a motion to intervene in the process, even though it was not a party to the West Basin adjudication. In his Declaration, Mr. Alvarez said (Declaration of Desi Alvarez, 2001, Pg. 2, Paragraph 4):

The Central Basin is east of the West Coast Basin and they are hydrologically connected underground water basins. The extraction of additional volumes of water annually from the West Coast Basin will have a significant impact on the adjudicated rights of the other pumping in the basin, as well as on pumpers in the Central Basin.

Mr. Alvarez went on to say (Declaration of Desi Alvarez, 2001, Pg. 3, Paragraph 6, starting on line 14) that:

Replenishment water purchased by WRD, for example, is spread in the Montebello Spreading Grounds and in the bed of the San Gabriel River at the eastern end of the Central Basin. The spread water percolates or sinks into the ground, and flows in a general direction from the Central Basin aquifers into the West Coast Basin aquifers, so that groundwater elevations in both basins are maintained.

The interconnectivity of the two basins is also acknowledged by the Watermaster for the West Coast Basin. In its most recent annual report, Watermaster states the following (CDWR, 2012b, pg. 5):

Replenishment of groundwater in the West Coast Basin occurs primarily by underflow from the Central Basin, which bounds the West Coast Basin on the east. Water spread in the Central Basin percolates into aquifers there, and eventually some groundwater crosses the Newport-

Inglewood Uplift to replenish the groundwater in the West Coast Basin. Although the recharge water is not directly applied to the West Coast Basin, this recharge process returns large quantities of water to the Basin by substantially increasing the natural subsurface flow from the Central Basin to the West Coast Basin.

6.2 Geology

The geology of the WRD Service Area, which is part of the larger Coastal Plain of Los Angeles Groundwater Basin (also known as the Los Angeles Basin in geologic research papers), has been extensively documented. Considerable detail on the geology can be found in reports by the California Department of Public Works (1934, 1952), Poland, Piper and others (1956), Poland and Others (1959) Poland (1959), California Department of Water Resources (1961), Yerkes and others (1965), Wright (1991), and Reichard and others (2003). The following is a brief summary of the details that can be found in those documents. Focused attention is placed on the Pliocene and younger rocks (5.3 million years ago and younger, USGS, 2007) as this is where the groundwater used in the WRD Service Area is typically found, although it should be recognized that it is the deeper, older rocks and the structural deformation of these that helped shape the shallower and younger geologic units.

The Los Angeles Basin has a complex history of sediment deposition and accumulation on top of sedimentary, igneous and metamorphic basement rocks that have been folded and faulted, uplifted and eroded over geologic time as movements occurred along the Pacific Plate and North American Plate. The marine and non-marine sediment was (and is) derived from the erosion of the surrounding highlands, particularly to the north in the Santa Monica and San Gabriel Mountains, from numerous sea level rises and falls that covered the entire coastal plain with seawater over various times, from wind-blown sand dune deposits near the coast, and from erosional and backfilled canyons that were carved into the valleys from rivers that flowed from the mountains to the various sea levels as the oceans transgressed and regressed over geologic time.

6.2.1 Geologic Formations and Aquifers

A geologic formation is a series of consolidated or unconsolidated strata that have comparable lithologies that are distinctive enough to be mapped separately from other formations. An aquifer is a geologic formation, or a part of a formation, that can readily store and transmit groundwater. The major geologic formations containing the water-bearing aquifers in the Basins include, from deepest and oldest to shallowest and youngest, the Pico Formation, the San Pedro Formation, the Lakewood Formation, the Older Dune Sand Formation, and the Recent Series (which contains the Active Dune Sand and Alluvium Formations) (CDWR, 1961). **Figure 6-4** depicts the stratigraphic order of these formations and the named aquifers within them. **Figure 6-5** is a map showing the general geology and location of geologic cross sections prepared across the Central Basin and West Coast Basin by CDWR (1961) that show the various aquifers traversing across the coastal plain. **Figure 6-6** represents east-west trending

cross section lines C-C" and E-E" from CDWR (1961) and **Figure 6-7** represents north-south trending cross section lines J-J" and M-M". The reader is referred to CDWR (1961) to view the other cross sections. A description of the pertinent formations follows, from the deepest to the shallowest, as they were originally deposited.

6.2.1.1 Pico Formation

The Pliocene age Pico Formation is generally considered the basement of the Basins' groundwater system and typically non-water bearing for the purposes of significant groundwater resources. Most of the formation is characterized by silts and clays of marine origin with low electrical resistivities (high salinities and/or fine-grained materials), although some permeable layers of sand and gravel do occasionally occur in the Pico Formation and some wells tap into it near the basin margins where the deeper layers become shallower. The USGS has characterized the Pico as a non-transmissive zone and did not include it in its groundwater flow model of the Basins (Reichard, et al, 2003) – limiting the model to the overlying main aquifer systems. WRD has several monitoring wells constructed in the Pico Formation to measure water levels and water quality changes in the formation over time, and for potential uses as future groundwater resources.

6.2.1.2 San Pedro Formation

The Lower Pleistocene San Pedro Formation underlies all of the WRD Service area with the exception of the Palos Verdes Hills, Merced Hills, and Puente Hills, where the underlying bedrock was uplifted through faulting and folding into hills and the San Pedro was eroded to expose the older rocks and/or may have prevented deposition of the San Pedro Formation sediments on these topographically high areas. The formation contains many of the more significant aquifers in the Basins including, from bottom to top, the Sunnyside (aka Lower San Pedro), Silverado, Lynwood (aka 400-Foot Gravel), Jefferson, and Hollydale – **Figure 6-4**.

The Sunnyside Aquifer is the name given to the thick water-bearing sand and gravel situated between the overlying Silverado Aquifer and underlying Pico Formation. It is of marine origin with little weathering and consists of blue and grey coarse-grained sand and gravel separated by fine-grained interbeds of sandy clay and clay. It has a maximum thickness over 500 feet (CDWR, 1961). The Sunnyside Aquifer is a major source of groundwater for many wells in the Basins, although due to its depth is not the most utilized aquifer.

The CDWR (1961) did not extend the Sunnyside Aquifer into the West Coast Basin except between the Charnock Fault and the Newport-Inglewood Uplift (CDWR, 1961 – Section C-C") although it did acknowledge the presence of coarse deposits beneath the Silverado Aquifer near the coast that resembles the Sunnyside Aquifer in the West Coast Basin (pg. 77). The Los Angeles County Flood Control District, when investigating for the eventual West Coast Basin Barrier Project, named this sandy unit beneath the Silverado Aquifer the Lower San Pedro Aquifer (Solari and others, 1967). The USGS named the aquifer system beneath the Silverado Aquifer and above the Pico Formation as the Lower San Pedro

Aquifer System (USGS, 2003). WRD has adopted the convention of Sunnyside Aquifer for the thick aquifer beneath the Silverado and above the Pico in the West Coast Basin to be consistent with the description in the Central Basin. For the purposes of this report, the Sunnyside Aquifer and Lower San Pedro Aquifer are considered the same aquifer system.

The Silverado Aquifer is the water-bearing sand and gravel situated between the Sunnyside Aquifer and the Lynwood Aquifer. The Silverado Aquifer has been mapped by CDWR (1961) across the entire Basins and it is one of the most heavily pumped aquifers in the WRD Service area because of its areal distribution, thickness, accessible depth to drilling, high transmissivity, high well yield, high specific capacity, and typical good water quality. Sediments of the Silverado are derived from both marine and continental deposits and can be 500 feet thick or more. The continental deposits are typically yellow to brown, coarse to fine sand and gravel, whereas the marine deposits are blue to grey sand and gravel separated by interbeds of silt, and clay. Some black sand, marine shells, peat and wood fragments are also encountered in the Silverado Aquifer where marine deposition was the origin.

The Lynwood Aquifer is the water-bearing sand and gravel above the Silverado Aquifer and the overlying aquifers which vary based on location. The Lynwood Aquifer is formerly known as the 400-Foot Gravel Aquifer in the West Coast Basin, but common nomenclature excludes this former name and is now only referred to as the Lynwood Aquifer. It has been found to exist throughout the Basins and into the Hollywood Basin but not Santa Monica Basin (CDWR, 1961). The Lynwood sediments are both marine and continental in origin, with the yellow, brown, and red coarse gravel, sand, silt and clay mostly found in the Montebello Forebay area with the marine deposits of blue and grey sand and gravel with black silt and clay found throughout the rest of the area. It ranges in thickness from 50 feet to around 200 feet. In the West Coast Basin, it merges with the underlying Silverado Aquifer into one thick aquifer – of which the top of the Silverado and base of the Lynwood cannot be distinguished (see western portion of cross section E-E" on **Figure 6-6**). In the Montebello Forebay area, the Lynwood Aquifer is in contact with overlying permeable sediments and recharge water from the spreading grounds readily enters the Lynwood Aquifer (CDWR, 1961), where it transmits groundwater downgradient to the rest of the Basins in addition to the underlying Silverado Aquifer in places where they merge. The Lynwood Aquifer is a major source of groundwater to wells due to the same properties as described for the Silverado Aquifer.

The Jefferson Aquifer is separated from the underlying Lynwood Aquifer by fine grained materials and has been mapped by CDWR in the Central Basin but not the West Coast Basin. The Jefferson Aquifer sediments are finer grained and thinner than the previous aquifers described, ranging from a few feet thick to 140 feet thick (CDWR, 1961). Therefore, it is less transmissive and although it does provide some groundwater to wells, it is not a primary aquifer in the WRD service area.

The Hollydale Aquifer is the uppermost defined aquifer of the San Pedro Formation. It is discontinuous in extent and is limited to the Central Basin. The Hollydale Aquifer sediments are variable in size, from yellow sand and gravel in the northern portion of the Central Basin to grey, blue and black sands with mud, clay and marine shells towards the south of the Central Basin, with thickness ranging from 10 feet to 100 feet. CDWR (1961) presumes a stream deposition (northern part) into shallow seas (southern

part) caused the meandering and lithologic nature of the Hollydale Aquifer. It is less transmissive than the Lynwood, Silverado, and Sunnyside aquifers and therefore wells perforated in this aquifer are usually perforated in other aquifers in order to get sufficient water yields (CDWR, 1961).

6.2.1.3 Lakewood Formation

The Lakewood Formation overlies the San Pedro Formation and contains all Upper Pleistocene deposits other than the Older Dune Sand. The boundary between the Lakewood Formation and the San Pedro Formation is an angular unconformity that is identified on most borehole geophysical logs by a shift in the SP log and a change in the character of the gamma log and electrical resistivity log (USGS, 2003). Deposition of the Lakewood Formation was formed from sea level rises and falls during the Upper Pleistocene.

The Lakewood Formation underlies all of the WRD Service area with the exception of the Palos Verdes Hills, Merced Hills, and Puente Hills, where these sediments have been eroded to expose the older rocks and/or the high topography of the hills may have prevented deposition of the Lakewood Formation sediments on these topographically high areas. Four aquifers have been named in the Lakewood Formation including, from bottom to top, the Gage, Gardena, Exposition, and Artesia.

The Gage Aquifer (formerly known as the 200-Foot Sand Aquifer in the West Coast Basin) is the basal aquifer of the Lakewood Formation. It has sediments of both marine and continental origin, with the continental deposits comprised of fine to coarse yellow sand and minor gravel occurring in the north near the source rock of the various hills, and mixed continental and marine to purely marine in the south-southwestern part (CDWR, 1961). The marine deposits in the south are fine to medium sand with variable amounts of gravel, sandy silt, and clay. It has a thickness ranging from 10 feet to 160 feet. CDWR (1961) reports that this aquifer is unimportant as a producing aquifer outside of the vicinity of the City of Gardena, presumably due to its thin nature and predominantly fine grained sediments.

The Gardena Aquifer was formed through the ancestral San Gabriel, Rio Hondo, and possibly Los Angeles rivers cutting through the Gage Aquifer and then depositing coarse sand and gravel during sea level rises and falls (CDWR, 1961). It is situated adjacent to and connected with the Gage Aquifer, and the two are differentiated between coarse sediments (Gardena Aquifer) and finer sediments (Gage Aquifer). It has a long, narrow orientation leading from the Whittier Narrows and Los Angeles Narrows southwesterly through the Central Basin (although disappearing briefly between Downey and Lynwood) into the West Coast Basin through Gardena and Redondo Beach to the ocean. Its thickness ranges from 40 feet to 160 feet, and the Gardena Aquifer has yielded large quantities of groundwater to wells due to its coarse sediments and continuity.

The Artesia and Exposition Aquifers are of the same age but found in different locations, which is why they are discussed in the same section. They are found above the Gage-Gardena Aquifers and below the Gaspur Aquifer of the Recent Series, although in some areas they merge with the Gaspur or have been uplifted through faulting and folding above the Gaspur. Where merged, the shallow water in the Gaspur

can move vertically downward to the Exposition and Artesia, and even deeper where these two are merged with the Gage-Gardena aquifers. **Figure 6-3** illustrates shallow groundwater migrating deeper where aquifers are merged. The Exposition Aquifer has been mapped in the Hollywood and Central Basins whereas the Artesia Aquifer has only been mapped in the Central Basin but likely extends into the Orange County Basin to the east (CDWR, 1961).

The Artesia Aquifer is comprised of coarse sand and gravel which appears to have originated from deposits of the San Gabriel, Coyote Creek, and Santa Ana rivers. Maximum thickness is 140 feet in the Long Beach area. The Exposition Aquifer is comprised of a wide range of sediment sizes, from clay to coarse gravel, with fine sediments separating lenses of sand and gravel. The source for the Exposition Aquifer has been attributed to the Los Angeles River drainage system. The maximum thickness of the Exposition Aquifer is 100 feet.

6.2.1.4 Older Dune Sand Formation

The Older Dune Sand Formation extends in a narrow band three to four miles wide from the Santa Monica Basin south into the West Coast Basin. It consists of fine to medium windblown sand that were former beach deposits exposed to the wind when the sea level retreated in late Pleistocene and the wind blew the exposed sand into hills and dunes. Time has caused some deep weathering and oxidation of iron minerals to cause red/brown discolorations, and cementation of the grains has reduced some permeability. However, deep percolation of surface water occurs in most of the Older Dune Sand until either a low permeability aquitard is encountered or until the Lakewood Formation is reached.

6.2.1.5 Recent Series

The Recent Series has been characterized as deposition over the past 15,000 years, since the beginning of the last major global rise in sea level (CDWR, 1961). Recent Series sediments were deposited on the erosional surface left behind during the last glacial stage and are generally on top of the Lakewood Formation and Older Dune Sand Formation deposits. They are relatively coarse, unconsolidated, and uncemented in nature due to their relatively young age, and were deposited by streams over most of the coastal plain except near the present day seashore where they are tidal, marine, and windblown deposits. Two formations have been defined in the Recent Series, including the Alluvium Formation and the Active Dune Sand Formation.

The Alluvium Formation contains the Semiperched Aquifer, Bellflower Aquiclude, Gaspur Aquifer, and Ballona Aquifer. The Ballona Aquifer does not exist within the WRD Service Area and therefore will not be discussed. The Semiperched Aquifer is the shallowest unit and is found at or near the ground surface in the Coastal Plain. Coarse sand and gravel make up the Semiperched Aquifer and they range in thickness from 0 to 60 feet. Where they exist in the Los Angeles and Montebello Forebays, they allow surface water to infiltrate into this unit, and then the water can move to deeper units where there is aquifer connection. Where there are fine-grained silt and clay below the Semiperched Aquifer, the water cannot move down deeper and stays shallow. Sediments comprising the Semiperched Aquifer are

mostly continental deposits from stream channels although there are some marine deposits near the coast.

The Bellflower Aquiclude is situated directly beneath the Semiperched Aquifer and has sediments of low permeability (mostly silts and clays) that somewhat impede the downward flow of groundwater. It exists throughout much of the Coastal Plain up to a thickness of 200 feet, except for much of the Los Angeles and Montebello Forebay areas where it is absent and surface water has direct access to the deeper aquifers. Although the Bellflower Aquiclude is generally fine grained, there are many areas of sandy or gravelly pockets or lenses that allow vertical movement of groundwater either up or down, depending on the hydraulic gradients. CDWR (1961) gave the name of this unit as “aquiclude,” which in modern hydrogeologic definition is a relatively impervious layer such as a tight clay or shale formation. But because the unit has sandy layers, is leaky and allows groundwater flow, the term “aquitard” would be more appropriate than aquiclude. An aquitard is a confining unit that retards but does not prevent the flow of water to or from an adjacent aquifer (Poehls and Smith, 2009). However, for consistency, this report will retain the name Bellflower Aquiclude as given by CDWR (1961).

The Gaspur Aquifer is a very coarse grained (cobbles, gravel, sand) unit at the base of the Recent Series originating from stream deposits by the Los Angeles, Rio Hondo, and San Gabriel rivers carrying sediment from the San Gabriel Mountains, San Fernando Valley and San Gabriel Valley. It follows a narrow path of recent river flows from the Central Basin, through Dominguez Gap, into the West Coast Basin and to the ocean about 23 miles long but only one to five miles wide. Thickness of the Gaspur Aquifer reaches 120 feet. It merges with surface deposits in the Montebello Forebay, allowing surface waters to readily infiltrate into this unit and move downward where aquifers are merged. The aquifer is also merged with other aquifers in the Los Angeles Forebay near the Los Angeles Narrows, but urbanization has paved over the permeable areas and there is no longer significant direct infiltration of precipitation or river water from the lined Los Angeles River (CDWR, 1961).

The Active Dune Sand Formation is wind-blown sand formed in a narrow strip up to a half mile wide running south along the coast from the West Coast Basin / Santa Monica Basin line down about nine miles to Redondo Beach. It consists of fine to medium sand ranging in thickness up to 70 feet. It is typically unsaturated, being above the groundwater table, but will allow any surface water to infiltrate downward and laterally.

6.2.2 Geologic Structure

The current shape of the land surface and underground water-bearing sediments in the WRD Service Area is a result of the depositional history of the sediments, erosional forces, and the geologic structure acting upon those deposits. **Figures 6-6** and **6-7** are geologic cross sections showing the currently defined aquifer architecture. The Los Angeles Basin, of which the WRD Service Area is a part, is located at the center of three major physiographic provinces in Southern California including the Transverse Ranges to the north, the Peninsular Ranges to the east and southeast, and the continental borderland to the south and west (Wright, 1991). The structural geologic history of the Los Angeles Basin began to

take its present day shape in late Miocene time (7 million years ago) as movement occurred on the bounding structures of the Santa Monica and Whittier faults to the north and Palos Verdes Fault and Hills to the southwest, causing subsidence and a deep basin to form which allowed accumulation of thousands of feet of marine sediments as the ocean covered the Coastal Plain (Yerkes and others, 1965).

The Peninsular Range province is characterized by northwest trending faults, including major faults outside of the WRD Service Area such as the San Andreas Fault, Elsinore Fault, San Jacinto Fault, and faults bordering or within the WRD Service Area including the Whittier Fault Zone, the Palos Verdes Fault Zone, and the Newport-Inglewood series of faults and hills (referred to as Newport-Inglewood Uplift in this report). Because the Whittier Fault Zone, Newport-Inglewood Uplift, and Palos Verdes Fault Zone help shape the geologic boundaries of the Basins, a brief discussion of these features follows in the next section, as does a discussion of the Charnock Fault in the West Coast Basin which has implications on groundwater flow. **Figure 6-8** shows the locations of these faults. However, for a full description of these faults and the numerous other structural features and geologic history of the Los Angeles Basin, the reader is referred to Wright (1991), Yerkes and others (1965), and CDWR (1961).

6.2.2.1 Whittier Fault Zone

The Whittier Fault Zone is located in the northeast portion of the WRD Service Area. Movement on the fault zone helped form the Puente Hills, which is the northeastern extent of the Central Basin. The Puente Hills were formed from vertical displacement along the Whittier Fault as well as movement along other less prominent faults. The Whittier Fault is a major structural feature running 25 miles from Whittier to the southeast where it merges with the Elsinore Fault in the canyon of the Santa Ana River (Wright, 1991). Northeast of the City of Whittier, the fault separates into a complex series of smaller faults with varying orientations and probably diminishes as it approaches the Whittier Narrows (CDWR, 1961).

6.2.2.2 Newport-Inglewood Uplift

The Newport-Inglewood Uplift is a major geologic structure trending northwest through the WRD Service Area from the City of Seal Beach through the City of Inglewood. It extends beyond the WRD Service area to the northwest to Culver City and to the southeast to Newport Beach. It is an active earthquake fault zone, with major temblors occurring at least in 1933, 1855, 1812, and 1769 (California Geological Survey, 2007). The March 10, 1933, magnitude 6.4 earthquake is known as the Long Beach Earthquake, although the epicenter was 3 miles south of Huntington Beach and about 8 miles deep. The ground shaking reportedly lasted 10 seconds and caused significant damage in Long Beach, Huntington Park, Compton, and other areas. Seventy schools were destroyed which led to the passage of the Field Act to improve design and building standards for California Schools (California Geological Survey, 2007).

Within the WRD Service Area, the Newport-Inglewood Uplift is not a single, continuous fault line but instead a series of separated hills and discontinuous, segmented faults known as en-echelon faults that together form a recognizable and mapable linear feature over a mile wide and 40 miles long (**Figure 6-**

8). Because it is not a single fault line but instead a series of hills that have been formed due to movement of the various en-echelon faults and anticlinal folding of the thick sedimentary strata, many authors researching its groundwater or petroleum effects have named it the Newport-Inglewood Uplift (e.g., CDWR, 1961; USGS 2003, CDWR, 2003, CDWR, 2012b). Other authors generally studying the geologic structure of the Newport-Inglewood have referred to the feature as the Newport-Inglewood Fault Zone (e.g., Wright, 1991; Hauksson, 1987). Other authors reporting on the earthquake history and some groundwater studies have called it the “Newport-Inglewood Structural Zone” (Barrows, 1974; Garcia, 1995). For this report, it will be referred to as the Newport-Inglewood Uplift or simply Uplift to be consistent with the major groundwater investigations and publications by government agencies.

On the land surface, the Uplift is represented by a discontinuous range of low hills. In the WRD service area, these include, from northwest to southeast, the Baldwin Hills, Rosecrans Hills, Dominguez Hills, Signal Hill, Bixby Ranch Hill, and Landing Hill (**Figure 6-8**). The named primary faults of the uplift include, from northwest to southeast, the Inglewood Fault, Portrero Fault, Avalon-Compton Fault, Cherry Hill Fault, Reservoir Hill Fault, and Seal Beach Fault (USGS, 2003). Numerous other minor faults, both named and unnamed, have been identified along the Uplift primarily from oil field investigations which further characterized the Uplift as a highly complicated geologic structure (Wright, 1991).

In the subsurface, the Newport-Inglewood Uplift bends but does not offset the various aquifers in some areas, but where faults are present and significant vertical movement has occurred, the Uplift has displaced aquifers. Refer to cross-sections C, E, J, and M on **Figures 6-6** and **6-7**. As shown on Section C-C” (**Figure 6-6**), the Uplift is on the Rosecrans Anticline which forms the Rosecrans Hills and the aquifers continue bent but otherwise unaltered from the Central Basin to the West Coast Basin. It is in areas like this where groundwater can flow unimpeded from one basin to the other. In contrast, Section E-E” (**Figure 6-6**) shows the Cherry Hill Fault offsetting the deeper Lynwood and Silverado Aquifers but not the younger Gage or Gaspur aquifers. In the areas of offset, if the grinding of the sediments by faulting has caused a significant lowering of the aquifers’ hydraulic conductivity, then the fault will be a full or partial barrier to groundwater flow, causing groundwater to find another direction of flow. In the upper part of the formation, where faulting did not offset the aquifers or if the hydraulic conductivity was not reduced, groundwater will continue to flow from one basin to the other.

This pattern is also reflected in cross sections J-J” and M-M” (**Figure 6-7**), where on J-J” the Uplift is shown to not have any faults or offset of the aquifers, allowing groundwater to move freely, whereas on M-M” the Uplift shows the Reservoir Hill Fault has cut off the aquifers. CDWR (1961) did not try to differentiate the formations and aquifers on the West Coast Basin side of the Uplift. Section 6.3 will discuss in more detail the impact of the Newport-Inglewood Uplift on groundwater flow, but in general the structure is a partial barrier to flow – stronger in some areas than others, allowing groundwater to move between the Central Basin and West Coast Basin depending on the hydraulic gradients and aquifer hydraulic conductivities across the Uplift.

6.2.2.3 Palos Verdes Fault Zone

The Palos Verdes Fault Zone is a major tectonic structure that extends about 62 miles from offshore Santa Monica Bay in a southeasterly direction onto land and through the northeastern base of the Palos Verdes Hills and then offshore through the Port of Los Angeles and terminates in an area known as Lasuen Knoll about 13 miles offshore from Newport Beach (McNeilan and others, 1996). Vertical movement on the Palos Verdes Fault Zone has been estimated at the rate of 0.3 to 0.4 mm/yr which caused uplift and formation of the Palos Verdes Hills. Primary horizontal strike-slip movement has been determined offshore on the order of 2.7 to 3 mm/yr (McNeilan and Others, 1996). The fault zone marks the southwestern geologic boundary for the West Coast Basin, whereas the adjudicated boundary of the West Coast Basin is higher up on the ridgeline of the Palos Verdes Hills. CDWR (1961) does not consider the hills an important source of groundwater, although groundwater does exist in the fractures of the bedrock as evidenced by dewatering activities in the Malaga Cove area and the Abalone Cove landslide area.

6.2.2.4 Charnock Fault

The Charnock Fault in the West Coast Basin has been mapped as a structural feature and a groundwater flow barrier for decades. Poland and Others (1959) reports that the Los Angeles County Flood Control District has included the Charnock Fault on its water-level contour maps since 1938. Although its surface presence cannot be detected, the presence of the fault was speculated due to apparent groundwater level differences across the fault. Apparent offset of the lower Pleistocene aquifers has been documented (CDWR, 1961) but not the shallower aquifers, implying that the groundwater barrier effect only impacts deeper groundwater (see Cross-Section C-C" on **Figure 6-6**).

Poland and others (1959) gave the name to the fault because it passed immediately west of the Charnock well field in the City of Santa Monica. The fault was mapped in a southeasterly direction from the Santa Monica Basin across the Ballona Gap and about a half mile into the West Coast Basin (**Figure 6-9**). The California Department of Public Works, in its investigations of the West Coast Basin as Referee in connection with the West Coast Basin adjudication (CDPW, 1952) extended the Charnock Fault into the Gardena area based on observed water level differences in wells across the fault. The Report acknowledged that the offset was greater in the Ballona Gap area than the Inglewood and Gardena areas (pg. 93).

This longer Charnock Fault orientation of CDPW (1952) has been carried through in most hydrogeologic investigations since that time, including CDWR (1961, 2012b), USGS (2003), and WRD (2012a). However, the State of California Geological Survey has mapped the Charnock Fault with a slightly different and shorter trend than CDPW and others, putting it more in a southerly direction than southeasterly and ending near the 105 freeway (CGS, 2010). This new orientation (**Figure 6-9**) is based on seismic data, some of which place active earthquake faulting (within the last 700,000 years) along this new trace (USGS, 2012).

And Wright (1991), in his detailed structural analysis of the Los Angeles Basin, questions the existence of the Charnock fault at all. He discusses it in his section on Questionable Structures, and notes that the fault is inferred based on reported water level differences in wells, but that intense seismic reflection surveying and exploratory drilling in the area of this postulated fault in the 1960s found no evidence of any significant displacements that might coincide with the Charnock Fault (Wright, 1991, pg. 90). He hypothesizes that the groundwater level offsets may be due instead to upper Pleistocene river channels formed by streams flowing south-southeast from the uplifted Santa Monica Mountains. Wright does, however, show a suspected fault structure on the base of the Repetto Formation to the west of, but in the general vicinity of, the historically mapped Charnock Fault (Wright, 1991, pg. 52). If this is a real fault structure, it could extend up into the Pleistocene strata and could be a source for some of the water level offsets observed. **Figure 6-9** shows all 4 alternative locations for potential Charnock Fault orientations. For the purposes of this report, the Charnock Fault of CDWR (1961) will be utilized.

6.2.2.5 *Other Structural Features*

The active faults and structural folding of the strata have caused the underlying aquifers to have anticlines (domes) and synclines (troughs), to be offset or continuous, and to have pinchouts and merge zones. Some of these are illustrated on **Figures 6-6** and **6-7**. Where these structures are apparent from the ground surface in the form of hills, they are often given names. The more prominent hills in the WRD Service Area include the Puente, Merced, and Repetto hills bounding the District to the northeast, the Coyote Hills in the east, the Palos Verdes Hills bounding the District to the southwest, and the interior hills of the Newport Inglewood Uplift which include, from northwest to southeast, the Baldwin, Rosecrans, Dominguez, Signal, Bixby Ranch, and Landing hills (CDWR, 1961). **Figure 6-8** shows the various hills and faults in or bordering the WRD Service Area.

6.3 Groundwater Occurrence and Movement

Groundwater in the aquifers of the WRD Service Area occurs in the open pore spaces (voids) between the grains of gravel, sand, silt, and clay. Groundwater exists everywhere in these aquifers like a massive underground reservoir filled with soil and water – it is not confined to narrow subterranean streams or lakes, but instead occupies vast areas of saturated gravel, sand, silt, and clay. Wells can be drilled anywhere in the aquifers of the WRD Service area and groundwater will typically be found, although at varying depths depending on where the wells are drilled.

Groundwater is found in both the saturated zone and unsaturated zone. Below the saturated zone, all pore spaces are filled with groundwater. The uppermost surface of the saturated zone is the water table. Above the water table is the unsaturated zone, also known as the vadose zone, which extends from the ground surface to the water table and is the pathway that infiltrating surface water takes to replenish the saturated zone. There is a mix of air and water in the vadose zone and this zone is not a target for water supply wells due to insufficient supply. In this report, groundwater is typically meant to include only water in the saturated zone unless otherwise specified.

When there is a difference in height in the water table between two or more points, creating a slope, gradient or plane, or there is a difference in pressure levels in a confined aquifer, groundwater will move from the high areas towards the lower areas. The steepness of the slope is known as the hydraulic gradient. Groundwater will move at a rate of the hydraulic gradient multiplied by the hydraulic conductivity of the material it is moving through divided by the effective porosity of the same material. Groundwater will move more slowly in an aquifer with a gentle hydraulic gradient and low hydraulic conductivity (e.g., silty fine sand) compared to an aquifer with a steep hydraulic gradient and a high hydraulic conductivity (e.g., coarse sand and gravel). Average groundwater velocities in the WRD Service Area have been derived from the computer modeling performed by the USGS (2003, p. 129 and 132). In the Central Basin, groundwater moving away from the Montebello Forebay spreading grounds in a southwesterly direction averaged approximately 960 feet per year (2.6 feet per day). In the West Coast Basin, groundwater moving away from the West Coast Basin Seawater Barriers in an easterly direction averaged 560 feet per year (1.5 feet per day).

Pumping of wells can create steeper hydraulic gradients near the wells and influence the direction and velocity of groundwater flowing near the well. Many wells pumping in close proximity to each other can have a major impact on the natural gradients. Excessive pumping beyond recharge in the Basins can lower groundwater levels below sea level, reversing the natural hydraulic gradient that would normally flow towards the ocean. The reversal of the gradient from the ocean toward the land causes the ocean water to move inland and invade the freshwater aquifers in a process known as seawater intrusion. **Figure 6-3** is a generalized cross section through the WRD Service Area prepared by the California Department of Water Resources showing the general direction of groundwater flow through the Basins' aquifers, the effect of pumping wells on the hydraulic gradient, and the concept of seawater intrusion (CDWR, 1959).

6.3.1 Sources of Groundwater

Historically, the sources of the native fresh groundwater that filled the water-bearing sediments of the WRD Service Area were derived from surface and groundwater inflows from the San Gabriel Valley and the San Fernando Valley to the north, infiltration of precipitation falling directly on the interior of the WRD Service Area, and from precipitation runoff from the bordering Palos Verdes, Puente, Merced, and Repetto hills. Mendenhall (1905c) noted that the saturated sands and gravels in the area owed their source primarily to the large streams that flow across the coastal plain which derive their water from the higher mountains where precipitation is greater than in the lowlands. He also noted that it took long periods of time for groundwater stored in the aquifers to accumulate. Today, natural recharge of groundwater has diminished due to the lining of the Los Angeles River and portions of the San Gabriel River and Rio Hondo, paving the land surface with impervious surfaces (streets, parking lots, buildings), declining downstream river flows due to upstream users of river and storm water, and sewerage of the cities instead of allowing septic tank / leach field water to return to the aquifers as in the past. Natural recharge must be augmented through the managed aquifer recharge activities of WRD to bring additional replenishment to the aquifers and make up the annual pumping overdraft. These activities will be discussed in more detail in Section 6.5.

The State of California has estimated that 35 million acre-feet (“AF”) of groundwater was stored in the Coastal Plain of Los Angeles County (CDWR, 1968), although the report recognized that the extractable amounts were limited based on physical and economic conditions. For example, between the period of 1934-35 through 1956-57, when the Coastal Plain was experiencing serious overdraft, falling groundwater levels, and seawater intrusion, the CDWR estimated that a total of 50,300 acre-feet per year (“AFY”) over the 23-year period had been lost from storage, or 1,158,600 AF total (CDWR, 1962, pg. 97-99). This represents only 3% of the 35 million AF reportedly stored in the Coastal Plain. If only 3% of the water was tapped and serious overdraft and seawater intrusion occurred, this is further evidence that the majority of the underground water supplies are not retrievable without considerable additional managed aquifer recharge activities or other mitigation measures. Modeling and analysis of potential land subsidence and the negative impacts on the Coastal Plain if groundwater levels are drawn down below previous historic lows has been reported (Reichard and others, 2010), emphasizing the need to maintain adequate groundwater levels through managed aquifer recharge.

The aquifers of the Coastal Plain contain plentiful groundwater, although not as much as 100 years ago. In 1904, Walter Mendenhall of the U.S. Geological Survey performed an extensive survey of the groundwater resources of the southern California coastal plain, including areas later to be known as the Central Basin and the West Coast Basin (Mendenhall, 1905a,b). In those investigations, he catalogued water wells, drew groundwater elevation contour maps, described the surface and groundwater and land conditions, reported rainfall data, mapped irrigated lands, and showed areas of flowing artesian wells, which covered roughly a third of the later named WRD service area.

In the Central Basin area, Mendenhall identified at least 3,300 water wells in operation, of which nearly half were flowing artesian wells (Mendenhall, 1905a, pg. 22). These wells mostly flowed unchecked throughout the year. In the West Coast Basin, he identified nearly 1,100 wells, of which only 12 were artesian (Mendenhall, 1905b, pg. 17). The developing region and increased water use in the area was having a negative impact on the groundwater supplies even at that time, with the artesian areas reducing in size by 30 percent in 1904 from their original levels (Mendenhall, 1905a, pg. 21). Even with the declines, water levels in 1904 were still above sea level everywhere in the Central Basin and West Coast Basin, and groundwater flowed naturally from the highs in the northeast to the lows in the southwest and out to the sea. Mendenhall reported, “This continuous movement seaward checks any tendency of the sea water to move inland. It is indeed so completely paramount that it is probable that wells sunk into the sea floor, at short distances off the coast, would at many points yield fresh water, and probably fresh-water springs discharge into the sea at numerous localities.” (Mendenhall, 1905a, pg. 25). **Figure 6-10** was taken from a Mendenhall map (1905b, Plate 1) showing artesian conditions in 1904, along with groundwater elevation contours. WRD has added its service area and groundwater flow direction arrows to the map to help indicate geographic boundaries and the movement of groundwater.

6.3.2 Overdraft and Recovery

Between 1900 and 1960, the population of Los Angeles County grew 3,446%, from 170,298 to 6,038,771 (U.S. Census Bureau, 2013). As the population grew, so did the use of groundwater resources for agricultural and urban use. Whereas in 1904 Mendenhall showed that all groundwater elevations were above sea level and water was flowing naturally towards the ocean with many flowing artesian wells, by 1960 due to excessive pumping that exceeded the natural replenishment (a condition known as “overdraft”) the groundwater levels throughout the Los Angeles Coastal Plain had dropped nearly 250 feet in some areas. **Figure 6-11** shows the locations of wells used for groundwater level hydrographs in the Montebello Forebay, Los Angeles Forebay, Central Basin Pressure Area, and West Coast Basin from 1904 through 1960, and **Figure 6-12** presents the hydrographs. This figure clearly shows the declining groundwater levels in the basins resulting from the severe overdraft.

The continued extraction of groundwater from the Basins in amounts that exceeded the natural supply not only caused water levels to fall, but to fall below sea level, allowing the ocean to migrate inland and contaminate the fresh groundwater with salt water near the coast. The seaward hydraulic gradient demonstrated by Mendenhall had been reversed so that the gradient along the coast was now landward, moving the seawater into the Central Basin near Alamitos Gap and in the West Coast Basin in the Dominguez Gap area and the western basin areas (Zielbauer et al., 1958, 1959, 1961, 1962). Intrusion of seawater into the freshwater aquifers contaminated the supply, making it unusable for most beneficial purposes (CDWR, 1959, pg. 1). **Figure 6-13** is a 1960 map of the WRD Service Area showing the large extent of below sea-level groundwater elevations in the WRD Service Area (Central and West Basin Water Replenishment District, 1961). The figure also shows the complicated and non-uniform groundwater flow directions caused by large pumping centers in the Los Angeles Forebay, Long Beach, Compton, Gardena, and Carson areas (flow direction on arrows added by WRD for this study).

As knowledge of the severe overdraft conditions and groundwater problems spread in the 1930s through 1960s, groundwater producers through their Associations in the Central Basin and West Coast Basin organized to take steps to overcome the problems. Access to imported water was secured to augment the local supply; the two groundwater basins were adjudicated to limit the amount of allowable groundwater pumping; seawater barrier wells were constructed by the Los Angeles County Flood Control District along the coast in both basins to halt further intrusion of seawater and to provide a replenishment source, and supplemental replenishment water was put into the Rio Hondo and San Gabriel River spreading grounds to augment the natural recharge.

Although implementation of these steps was effective in averting more serious groundwater problems in the Basins, they were limited in scope. The responsible water agencies at the time recognized that a large overdraft still remained, and they organized to create an area-wide agency to perform remedial measures to alleviate the problems. Formation of the Central and West Basin Water Replenishment District was sponsored by the Associations to implement these remedial measures (CDWR, 1959, pg. 2). Section 5 describes the events leading to the creation of the WRD.

WRD purchases supplemental recharge water (imported water and reclaimed or recycled water) to enhance natural recharge and overcome the annual overdraft. This process of performing intentional acts to supplement natural recharge with additional recharge is known as “artificial replenishment” or “managed aquifer recharge.” As will be discussed in more detail in Section 6.5, between 1959 and 2010 WRD and other agencies added over 6.6 million AF of imported and recycled water to the groundwater basins through managed aquifer recharge at the Rio Hondo and San Gabriel spreading grounds, the seawater barrier wells, and In-Lieu replenishment to augment the natural supply.

The results of managed aquifer recharge, along with the reduction in pumping and the seawater barrier wells, have worked to not only halt the declining water level trends and saltwater intrusion, but to cause groundwater levels to rebound from their 1960s low. **Figure 6-14** is the groundwater level hydrograph shown earlier as **Figure 6-12**, but with the period from 1960 through 2010 added to show the water level recovery. **Figure 6-15** is a groundwater elevation contour map for 2010 which can be compared to the 1960 map and the 1904 map to see current conditions and the success that managed aquifer recharge accomplished throughout the WRD Service Area. Groundwater elevations have recovered from 1960 levels but are still below sea level in many parts of the basins. The seawater barrier wells allow the intentional continued operation of the Basins below sea level without allowing seawater to intrude. The continued operation of the seawater barrier wells is necessary to maintain current pumping amounts in both basins and to prevent further degradation of water quality from invading seawater.

6.3.3 Newport-Inglewood Uplift: Barrier Impacts and Groundwater Underflow

The Basins share a common boundary known as the Newport-Inglewood Uplift, which in the WRD Service Area is a geological structure of discontinuous faults and hills trending in a northwest direction from the City of Seal Beach to the City of Inglewood (**Figure 6-8**). The boundary between the Basins is a simplified line drawn on the approximate centerline of the Newport Inglewood Uplift (CDWR, 1962, pg. 38), as the actual structure is a complicated geologic zone over a mile wide in places with varying hill shapes and heights and numerous short-length faults.

Overall, the Newport-Inglewood Uplift can be considered a partial barrier to ground water flow. Depending on the geology in a given reach of the Uplift, it can act as a complete barrier in some areas, a partial barrier in other areas, and no barrier in other areas. The degree to which the Uplift acts as a barrier depends on the fault or aquifer properties in the path of the groundwater at the boundary between the two groundwater basins. Barrier effects can be caused by a reduction in the transmissivity of the aquifer or hydraulic conductivity of the fault zone at the Uplift; where thinning or offsetting of the aquifers can reduce or eliminate flow, or cementation of the fault zone from grinding of sediments over time. When the groundwater hits a barrier, such as a zone of low hydraulic conductivity, it will attempt to find another path in the down-gradient direction.

The effects of the Uplift as a partial barrier were documented as far back as Mendenhall's report when he attributed the flowing artesian wells observed mostly in the Central Basin to an underground ridge that was restricting flow. According to Mendenhall (1905b, pg. 15), *"The ridge which separates these two sections is not a surface feature merely. It seems to be the surface expression of a broad fold in the sands and clays of the coastal plain – a fold that acts as a dam to waters seeking a way seaward beneath the surface, checking their course and tending to force them toward the surface in order to pass the obstruction."*

The Report of Referee for the West Coast Basin (CDPW, 1952, pages 91-93) took a detailed look at potential barrier segments and effects along the Newport-Inglewood Uplift. The Report concluded that "Its component faults and folds constitute barriers with varying degrees of effectiveness, separated by gaps which apparently allow relatively free passage of ground waters." Poland (1959) performed a detailed analysis of the water tightness of the Newport-Inglewood Uplift to determine the effectiveness of the Uplift as a barrier against intruding seawater. He compared water level elevations and patterns in wells on opposite sides of the structural zone. He found that in the shallower aquifers in the Dominguez Gap area there is no barrier to groundwater flow but in the deeper Silverado zone a barrier does exist but is not wholly watertight. In the Signal Hill area, a reasonably effective barrier to water movement was identified but not completely watertight as groundwater elevation differences of several tens of feet was enough to induce flow. In the Alamitos Gap area, the shallow aquifers had no barrier effect but the deeper aquifers in the San Pedro Formation appeared to be completely watertight.

Garcia (1995) for her Master of Science Degree in Geology at California State University, Long Beach, evaluated the impact of the Newport-Inglewood Uplift as a groundwater barrier in the Signal Hill area. She performed a detailed stratigraphic displacement of aquifers analysis along with statistical analysis of groundwater levels and groundwater geochemistry from available data. She concluded that the geochemical data did not provide robust evidence that the Newport-Inglewood structural zone is a hydrologic barrier. She also identified areas where groundwater was flowing from the West Coast Basin into the Central Basin in the Dominguez Gap area (pg. 83), which illustrates the fact that groundwater will move across the Uplift in either direction based on the relative elevations of groundwater. Reichard, et al (2003) performed detailed data collection to construct a groundwater flow model of the Coastal Plain, and included the Newport-Inglewood Uplift as a partial barrier to groundwater flow, slowing but not preventing movement of groundwater.

Because of the interest in water resources in the Basins and the effect of the Newport-Inglewood Uplift on these resources, numerous studies have been done on the amount of groundwater flowing from Central Basin into the West Coast Basin for different time periods. Underflow varies based on the hydraulic gradient across the uplift and the hydraulic conductivity of the sediments or fault zones at the contact of the Basins. **Table 6-1** lists the underflow values determined from previous technical studies.

**Table 6-1
Central Basin to West Coast Basin Historical Underflow Determinations**

Data Source	Yeas of Analysis	Average Underflow (AFY)	Notes
Poland and Others (1959)	1904	17,500 – 23,500	Assumed 1945 values were 85% of 1904 values.
West Basin Report of Referee (CDPW, 1952)	1932/33 – 1949/50	42,876 ¹	“Transmissibility” Method of Analysis ²
	1932/33 – 1949/50	24,355	“Trough” Method of Analysis ²
Poland and Others (1959)	1945	15,000 – 20,000	
California Water Rights Board (1961)	1950/51	23,250	Combination of Trough and Transmissibility Methods
CDWR (1962)	1934/35 – 1956/57	15,600	
	1957	10,500	
Montgomery Watson (1993)	1964/65 – 1984/85	25,000	Citing a 1989 report by CDM and JMM
Bookman Edmonston Engineering (1993)	1983/84	17,000	Citing a 1989 CDM and JMM report
Montgomery Watson (1993)	1985/86 – 1991/92	21,300	Citing a 1992 report by JMM and CDM
Bookman Edmonston Engineering (1993)	1979/80 – 1991/92	20,500	
Reichard and others (2003)	1970/71 - 1999/2000	3,200	Average computer model results – 30 yr average
	1995/96 – 1999/2000	5,900	5-year average from computer model

The amount of underflow going from Central Basin into the West Coast Basin has generally declined over time as pumping in the Central Basin drew groundwater levels down closer to the West Coast Basin elevations so that there was a reduction in the hydraulic gradient between the two, thereby reducing underflow. This is supported by statements from CDWR (2003), “Historically, groundwater flow in the Central Basin has been from recharge areas in the northeast part of the subbasin, toward the Pacific Ocean on the southwest. However, pumping has lowered the water level in the Central Basin and water levels in some aquifers are about equal on both sides of the Newport-Inglewood uplift, decreasing subsurface outflow to the West Coast Subbasin.”

In 1959, CDWR recognized the impact that both pumping reduction in the West Coast Basin and continued heavy pumping in the Central Basin had on underflow. Their report (CDWR, 1959 – pg. 36)

¹ From Table 9, pg. 99 and includes Silverado Zone underflow across Uplift, plus Gardena and Gage.

² Although CDPW recognized both methods had limitations, the department settled on the trough method on grounds that it was subject to errors of a lesser magnitude than that of the transmissibility method (CDPW, 1952, pg. 102).

states the following “In recent years, the rate of decline of water level elevations at wells in the West Coast Basin has been slower than at wells on the east side of the Newport-Inglewood uplift. This is due primarily to the voluntary curtailment of extractions by certain of the heavy pumpers in the West Coast Basin as a result of the previously mentioned ‘Interim Agreement and Petition and Order’. The effect of this curtailment, in combination with continued depression of water levels in the Central Basin has had the result of bringing ground water levels in the Central Basin increasingly nearer to levels in the West Coast Basin. This probably has effected a reduction in the quantity of groundwater moving across the Newport-Inglewood uplift from the Central Basin to the West Coast Basin.”

This information shows that the basins are connected, and that underflow between the two relies on water levels on either side of the Uplift. The West Coast Basin relies on underflow as part of its water balance, and water replenished in the Central Basin helps to maintain flow into the West Coast Basin. Conversely, over pumping without additional recharge in the Central Basin causes groundwater levels to drop and underflow to the West Coast Basin to decline. According to CDWR (1962, pg. 125), “it was found that a large portion of the safe yield of West Coast Basin was dependent upon the amount of subsurface flow into it from Central Basin.”

6.4 Groundwater Pumping

Groundwater pumping has been occurring in the Basins for over 120 years. As the population grew and water demands increased, pumping of groundwater also increased. The effect of pumping in the basins was known as far back as 1905, when Mendenhall (1905a,b,c) catalogued over 4,400 water wells in the areas later to be known as the Central Basin and West Coast Basin and reported “In general each well in the coastal plain, whether flowing or pumped, affects every other well in the same region...All drain from a common source, the body of saturated sands and gravels which underlie the wide plain between the Puente Hills and the sea and whatever reduces the amount of water in that body of alluvium affects all wells which draw from it.” (Mendenhall , 1905c, pg. 30).

As populations grew and demand for groundwater for agriculture and urban use increased, extractions exceeded natural supply and the groundwater basins were in severe overdraft. For example, the CDWR (1962, pg. 121) found that in 1957, groundwater extractions in the Central Basin were 240,500 AF yet the department determined the natural safe yield to be 137,300 AF, creating an excessive pumping overdraft for that year of 103,200 AF. In the West Coast Basin, 1957 pumping was 67,700 AF whereas the natural safe yield was determined to be 36,100 AF, creating an overdraft of 31,600 AF. And pumping between 1934/35 and 1956/57 reached a maximum of 259,400 AF in the Central Basin and 94,100 AF in the West Coast Basin (CDWR, 1962, pg. 71) likely creating greater overdraft in those years.

The results of this severe overdraft are described in Section 6.3.2 and generally included large reductions in groundwater levels and induced seawater intrusion. Solutions to the problem included collaboration of Central Basin and West Coast Basin groundwater producers to sponsor formation of the Central and West Basin Water Replenishment District to perform managed aquifer recharge, urge the

construction of seawater barrier wells along the coast of both Central Basin and West Coast Basin by the Los Angeles County Flood Control District, and the reduction of pumping through adjudication of the two groundwater basins.

To solve the over pumping problems, legal action was initiated. Both groundwater basins were adjudicated to limit groundwater extractions. The West Coast Basin adjudication was started in 1945 when the California Water Service Company, City of Torrance, and others filed a complaint to quiet title to the ground water rights of 151 named defendants, and to regulate and reduce ground water extractions from the West Coast Basin so that the supply would not be further depleted or degraded (CDWR, 1958). An interim agreement was reached effective March 1, 1955, and the final Judgment completed in 1961 (West Coast Basin Amended Judgment, 1980). The pumping rights in the basin were set at 64,468.25 AF. The court appointed CDWR as Watermaster to assist the court to administer and enforce the provisions of the Judgment. Watermaster prepares an annual report which is required by the Judgment to summarize the activities of the Watermaster. According to the Watermaster report (CDWR, 2011b pg. 1), in 2010/11 there were 65 parties to the Judgment, 25 active pumpers, and, 44,214.66 AF of groundwater pumped

The Central Basin Judgment resulted from litigation filed by the Central and West Basin Water Replenishment District against more than 700 parties on January 2, 1962 to quiet title to ground water rights and to curtail extractions to prevent further ground water supply deterioration. An interim agreement was reached effective September 28, 1962 and the final Judgment completed on October 11, 1965 (CDWR, 1966a). The pumping rights in the basin ("Allowed Pumping Allocation") were set at 217,367 AF. The CDWR was named Watermaster for the Central Basin and, in the case in the West Coast Basin, prepares an annual report of its activities. According to CDWR (2011a pg. 1), in 2010/11 there were 131 parties to the Judgment, 74 active pumpers, and 179,831 AF of groundwater pumped.

There is a significant difference between the adjudicated rights established by the courts and the 1957 natural safe yield values established by CDWR. Responsibility for making up this difference (including any changes to the natural safe yield since 1957) would be the responsibility of the Water Replenishment District of Southern California. The District undertakes managed aquifer recharge to make up the overdraft and strive for balanced basins. More details on the managed aquifer recharge activities of the District are described in the next section.

Complicating pumping in the basins is the fact that a water rights holder has the ability to drill a well anywhere in the basin in which it holds a right and pump groundwater from that location. For example, the City of Lakewood in the Central Basin can drill a well anywhere in the City, or it could go beyond city boundaries to drill a well. Several parties have done this. The City of Signal Hill, for example, has installed wells in the City of Long Beach. Investor-owned water utility companies such as Golden State Water Company ("GSWC") or California Water Service Company ("CWSC") do not operate on the basis of municipal boundaries but instead operate in water service areas in which they can install wells wherever needed. Transient pumping locations and patterns create a dynamic groundwater flow system that varies year to year.

Because numerous water agencies have boundaries that cross both the Basins, including California American Water Company, the City of Inglewood, GSWC, City of Los Angeles, CWSC, City of Long Beach, and City of Signal Hill, water pumped from one basin may go into a company's distribution system and mix with imported water and/or other groundwater pumped from the other basin making it impossible to know the source of water flowing out of any given well at any given time (Sorensen, personal communication, 2013).

A map of the water providers in the WRD Service Area and the location of current water production wells is presented as **Figure 6-16**. The groundwater basins combined are a common pool of water from which the water rights holders have the right to extract their entitlement for their beneficial use. The locations of wells and the extraction amounts will vary from year to year, and the distribution of the water can be complicated, but as long as the common pool resource is maintained through managed aquifer recharge, the overdraft will be curtailed and the resource will be available for the direct and indirect benefit of all overlying users.

6.5 Managed Aquifer Recharge

To overcome the severe overdraft in both groundwater basins in the first half of the 20th century (**Figure 6-12**), experienced and concerned water professionals came together to implement solutions to the problem. These solutions included joining the Metropolitan Water District of Southern California to bring imported water into the region to offset the need for only groundwater supplies, adjudicating the groundwater basins to limit and control pumping, construction of barrier wells along the coast to halt further intrusion of seawater that was contaminating the basins, and the creation of the Central and West Basin Water Replenishment District to provide the needed supplemental replenishment water to make up the difference between the adjudicated amounts and the natural safe yield. This process of supplementing natural recharge with additional recharge is known as artificial replenishment or managed aquifer recharge ("MAR"). The success of the various actions eliminated the annual overdraft and prevented seawater intrusion, and has restored the groundwater basins as a sustainable resource for the direct and indirect benefit of all overlying users (Johnson and Whitaker, 2004). Section 6.3.2 above discusses the overdraft and recovery in more detail, and Section 5 is a detailed discussion of how the groundwater pumping community came together to sponsor formation of WRD.

WRD was formed in 1959 and operated then as it does today under Division 18 of the California Water Code. Chapter 1 (Sections 60220 through 60226) describes the purposes and powers of a water replenishment district, including "A district may do any act necessary to replenish the ground water of said district" (Section 60220). The WRD service area covers the entire adjudicated Central Basin boundary and the vast majority of the adjudicated West Coast Basin boundary as well as the Palos Verdes Hills. As such, it is WRD's responsibility to perform any acts necessary for MAR over essentially the entire Central and West Coast Basins to help make up the annual overdraft.

However, there are only limited areas available to perform artificial replenishment of groundwater because of the geology and existing infrastructure in the WRD Service Area. These recharge facilities are shown on **Figure 6-17** and include the spreading grounds in the Montebello Forebay and the three seawater barrier injection well projects along the coast. In addition, WRD utilizes a tool known as In-Lieu Replenishment, which provides an incentive for pumpers to turn off their pumps and take imported water In-lieu of groundwater in areas that are difficult to replenish by other methods. By not pumping groundwater they help to restore water levels in that area. Since 1959, WRD and others have utilized these 3 groundwater management tools to replenish over 6.6 million AF of imported and recycled water to the depleted Basins for the benefit of all groundwater users in these areas.

Table 6-2 shows a breakdown of the replenishment activities. The sections below describe each of the replenishment areas in more detail.

**Table 6-2
Managed Aquifer Recharge in WRD Service Area 1959/60 – 2009/10**

Recharge Method	Imported Water (AF)	Recycled Water (AF)	Makeup Water* (AF)	Total (AF)
Montebello Forebay Spreading Grounds (Rio Hondo and San Gabriel River)	2,430,060	1,574,417	215,121	4,219,598
Seawater Intrusion Barriers**	1,426,462	118,301	0	1,544,763
In-Lieu Replenishment	839,503	0	0	839,503
TOTAL (AF)	4,696,025	1,692,718	215,121	6,603,864
51-Year Average (AFY)	92,079	33,191	4,218	129,488

Notes:

* Makeup water is replenishment water owed to the Lower Area (downstream of Whittier Narrows) from the Upper Area (upstream of Whittier Narrows) under the Long Beach Judgment (San Gabriel River Watermaster, 2010)

** Does not include water purchased by the Orange County Water District for the portion of the Alamitos Barrier which lies in Orange County.

6.5.1 Montebello Forebay Spreading Grounds

One of the main methods to perform MAR in the WRD Service Area is through groundwater recharge at spreading grounds or recharge ponds. These “leaky lakes” must be engineered in geologically suitable areas where surface water can be captured, held, and allowed to sink down into the subsurface through the vadose zone and down to the saturated zone. For a spreading grounds project to work, the soil beneath it down to the water table must be permeable sand or gravel so the infiltrating surface water can move downward without blockage. If less permeable silt or clay layers exist, they can act as a barrier and prevent the water from reaching the water table and aquifers.

The California Department of Water Resources described the areas suitable for surface recharge in the Basins as follows (CDWR, 1963, pg. 4):

Because of the relatively impermeable sediments comprised of clays or silty and sandy clays that overlay and separate these aquifers throughout much of the basin, very little replenishment is derived from direct precipitation or applied water. However, In the vicinity of the Los Angeles and Whittier Narrows, these relatively impermeable strata are not in evidence. At this point, the aquifers are essentially interconnected and the uppermost coarse-grained material extends to the ground surface, thereby permitting relatively free downward movement of water from the surface into the various aquifers.

The Los Angeles Forebay is generally built out and paved over, and the Los Angeles River has been lined with concrete, making the forebay not currently amenable to significant surface groundwater recharge projects. The Montebello Forebay area, however, has open unpaved areas converted to spreading grounds and the unlined San Gabriel River channel which have been utilized for intentional stormwater capture and groundwater recharge since 1938, when the Los Angeles County Flood Control District (“LACFCD”) constructed the Montebello Forebay Spreading Grounds (“MFSG” – also known as the Coastal Spreading Grounds). **Figure 6-3** is a generalized cross section showing how surface water in the MFSG area can replenish the aquifers and recharge the down-gradient aquifers in the Central Basin and West Coast Basin.

These spreading grounds, in the northeast portion of the WRD service area (see **Figure 6-17**), are the principal groundwater recharge facilities for the entire Central Basin and West Coast Basin, providing for nearly half of all the groundwater replenishment activities, both natural and artificial, in the two groundwater basins by combining natural river diversions with supplemental imported and recycled water (USGS, 2003; WRD, 2012a, Table 4).

The MFSG consists of two separate but linked facilities; the Rio Hondo Coastal Spreading Grounds (“RHSG”) and the San Gabriel Coastal Spreading Grounds (“SGSG”) (**Figure 6-18**). They are located downstream of the Whittier Narrows Dam adjacent to the Rio Hondo and San Gabriel river channels, respectively. The RHSG consists of off-channel spreading grounds, while the SGSG consists of both off-channel grounds and the river channel itself. The LACFCD owns and operates the MFSG for storm water conservation and flood control and has been doing so since 1938. Because storm water capture and recharge amounts are insufficient for the total replenishment needs in the WRD Service Area, imported water has been used as a supplemental recharge source in the MFSG since 1953/54 and recycled water since 1961/62 (WRD, 2011). **Table 6-3** lists additional information on the MFSG groundwater recharge facilities (LACDPW website, 2013).

**Table 6-3
Montebello Forebay Groundwater Recharge Facilities**

Information	Rio Hondo Spreading Grounds	San Gabriel River Spreading Grounds
Year First Used	1937/38	1938/39 in spreading grounds; 1954/55 in river channel
Size (acres)	570	128 spreading grounds; 308 in river channel
Number of Spreading Ponds	20	3 in spreading grounds; 7 in river channel using rubber dams
Infiltration (Percolation) Rate in Cubic Feet per Second, cfs	400	75 in spreading grounds; 75 in river channel
Water Holding Capacity (AF)	3,694	550 in spreading grounds; 913 in river channel

LACFCD has an extensive program of maintaining and grooming the spreading grounds to maximize groundwater recharge. During major storm events, the County works around the clock to ensure that as much runoff as possible is captured by diverting the flows to the various sub-basins instead of allowing the water to be lost to the ocean. During the times when the spreading grounds are not filled with storm water, WRD purchases imported and recycled water for managed aquifer recharge. Recycled water is the preferred source as it is available year round, is of excellent quality, and is at a considerably lower cost than imported water. For example, at the time the RA was adopted, the price of untreated Tier 1 imported water to WRD for spreading was anticipated to be \$668 per AF (includes the MWD base rate plus surcharges by the Central Basin Municipal Water District) compared to recycled water from the County Sanitation Districts, which was anticipated to be at an estimated rate up to \$34 per AF.

The amount of recycled water that can be spread, however, is limited by the California Department of Public Health (“CDPH”) and Los Angeles Regional Water Quality Control Board (“LARWQCB”). They have set a limit on the amount of recycled water that can be spread to 35% of the total water recharged in the Montebello Forebay over a 5-year period, meaning the other 65% must come from other sources, including imported water, stormwater capture, and underflow from the San Gabriel Basin.

Recognizing the importance of maintaining a reliable and cost effective groundwater replenishment source for the Montebello Forebay to help recharge the Central Basin and West Coast Basin aquifers, WRD has implemented its Water Independence Now (WIN) program with the goal of making its service area self-sustaining, eliminating the need for imported water for groundwater recharge. The WIN program is discussed in more detail in Section 7.

6.5.2 Seawater Barrier Injection Wells

Seawater intrusion was a major problem for the Basins as severe pumping overdraft caused groundwater levels to fall 100 feet below sea level in some areas which allowed the hydraulic gradient

to reverse and flow from the ocean towards the land, contaminating fresh groundwater with seawater. Groundwater in both basins was at risk due to falling water levels and advancing seawater.

To address this problem, in 1951 the Los Angeles County Flood Control District (LACFCD) used an abandoned water well in Manhattan Beach to inject potable water to test whether pressure could be built up in a confined aquifer to block the intrusion. The test worked, so LACFCD performed subsequent tests with additional wells to successfully create a pressure ridge or “wall” along the line of injection wells to overcome the pressure of the intruding seawater. The results are well documented in a report by CDWR (1957). Based on the success of the tests, the LACFCD eventually constructed the West Coast Basin Barrier Project and the Dominguez Gap Barrier Project in the West Coast Basin, and the Alamitos Barrier Project in the Central Basin (**Figure 6-17**). LACDPW owns and operates the wells and the WRD provides all of the water used for injection within its service area. The injected water not only builds up a line of pressure equal to or exceeding sea level to block the intrusion, but the injected water also moves inland in a down-gradient direction to replenish the aquifers and maintain groundwater levels higher than they would otherwise be without the injection. The barrier wells benefit both groundwater basins in this fashion. They protect against seawater intrusion, supply replenishment water and maintain elevated groundwater levels.

Table 6-4 presents updated information for the barrier projects.

Table 6-4
Seawater Barrier Injection Well Facilities

Information	West Coast Basin Barrier Project	Dominguez Gap Barrier Project	Alamitos Barrier Project*
Date Initiated	1953	1971	1964
Overall Length (miles)	9	6	2.2
Number of Injection Wells	153	94	43
Number of Observation Wells	300	257	220
2009/10 Imported Water Injection Amounts - (AF)	9,661	5,495	3,225
2009/10 Recycled Water Injection Amounts - (AF)	7,620	2,037	2,245

* includes Orange County side of barrier

The barrier projects have been successfully protecting and supplying the fresh water aquifers in the WRD Service Area for decades. Currently, both potable imported water and advanced treated recycled municipal wastewater (some combination of microfiltration, reverse osmosis, ultraviolet light and hydrogen peroxide) are used. The water is injected into the Basins’ aquifers to depths over 600 feet. As mentioned, WRD purchases all of the water injected into the barriers except for about 1,700 af per year

purchased by the Orange County Water District for a portion of the Alamitos Barrier in Orange County. The recycled water for the Alamitos Barrier is produced by WRD from the Leo J. Vander Lans facility, for the West Coast Basin Barrier by the West Basin Municipal Water District's (WBMWD) Ed Little plant, and for the Dominguez Gap Barrier by the City of Los Angeles' Terminal Island Treatment Plant. Potable water is provided by WBMWD and the City of Long Beach.

Recycled water is the preferred source as it is available year round, is of excellent quality, and costs less than imported water. For example, at the time the RA was set the anticipated price of potable Tier 1 imported water to WRD for the following year for the Dominguez Gap Barrier was expected to be \$1,010 per AF (includes the MWD base rate plus surcharges by the WBMWD). Recycled water from the City of Los Angeles was projected to be available at an estimated rate of \$431 per AF. In addition to water costs that WRD pays, the LACDPW pays for the costs for the construction, operations, and maintenance of their barrier facilities. Realizing the high cost of barrier operations, WRD and others have looked into alternatives for seawater intrusion protection (Johnson and Whitaker, 2004).

WRD has also implemented its WIN program to make its service area independent of imported water for groundwater recharge. Progress on WIN is being made at all three seawater barriers. The West Coast Basin Barrier Project has received permission from the CDPH and LARWQCB to go from 75% to 100% recycled water injection and it is finalizing its Phase V expansion to take the barrier off imported water in the near future. WRD has plans to expand from 50% to 100% recycled water use at the Alamitos Barrier from the expansion of the Leo J. Vander Lans plant by late 2014. The City of Los Angeles has expressed interest in increasing the recycled water amounts provided to WRD for the Dominguez Gap Barrier Project from 50% to 100% over the next few years. All of these measures will help ensure continued protection of the groundwater resources in the WRD Service Area from seawater intrusion and will benefit directly or indirectly all groundwater pumpers in the Central Basin and West Coast Basin.

6.5.3 In-Lieu Replenishment

The In-Lieu Replenishment Program plays an important role in the conjunctive use of the Central Basin and West Coast Basin, utilizing surplus imported water to offset groundwater demands for later use. Its goal is to replenish those areas which are not easily recharged through surface spreading due to their distance from the Montebello Forebay Spreading Grounds and/or location in deep confined aquifers.

MWD historically offered discounted water known as "Long Term Seasonal Storage" that WRD used as a basis for the In-Lieu program. WRD offered financial incentives to encourage pumpers to reduce their groundwater production in favor of purchasing the MWD seasonal imported water. The incentive payments made the imported water less expensive than pumping groundwater. When the wells are turned off, groundwater levels rise and water remains in storage that would have otherwise been pumped out.

WRD first offered the In-Lieu program in 1965/66 and has replenished 839,503 AF under the program since that time. The result has been to the benefit of both Central Basin and West Coast Basin pumpers through increased water levels and more groundwater in storage. Unfortunately, due to water shortages in MWD's system and reconsideration of its replenishment policies, MWD terminated availability of the Long Term Seasonal Storage water in May 2007. The future availability of the MWD and WRD In-Lieu program is uncertain.

6.6 Groundwater Quality

Section 60224 of the California Water Code gives WRD the responsibility to protect and preserve groundwater quality within the District by:

- (a) Preventing contaminants from entering the groundwater supplies of the District;
- (b) Removing contaminants from the groundwater supplies of the District;
- (c) Determining the existence, extent, and location of contaminants in, or which may enter, the groundwater supplies of the District;
- (d) Determine persons, whether natural persons or public entities, responsible for those contaminants; and,
- (e) Perform or obtain engineering, hydrologic, and scientific studies for any of the foregoing purposes.

The groundwater quality in the WRD Service area is susceptible to contamination from natural sources such as seawater intrusion, iron, manganese, color, odor, and arsenic, and from anthropogenic sources such as leaking underground storage tanks, legacy disposal practices, landfills, and waste disposal wells. Just as replenishment water applied at the ground surface can soak into the underground and refill the aquifers, so can contaminants leaking at or near the ground surface move down to contaminate the soil and groundwater beneath it. Once underground, the contaminants can spread and move with the groundwater flow, potentially jeopardizing the groundwater supply to downstream users.

Although the overall groundwater quality is very good and available for beneficial use with little to no treatment, there are areas of known contamination or potential contamination which WRD monitors. When serious threats are identified, WRD performs investigations and in some cases water treatment. WRD works with regulatory agencies such as the U.S. EPA and California Department of Toxic Substances Control ("DTSC") and LARWQCB to use their regulatory powers to enforce investigations and remediation. All of these actions are to protect the quality of the groundwater resources in the WRD Basins.

The number of potentially contaminating activities in a highly urbanized area such as the Los Angeles Basin can be challenging. Using government databases, WRD has identified at least 3,131 leaking underground storage tank ("LUST") sites, 7 U.S. EPA Superfund Sites, and 39 other contaminated sites, for a total of 3,177 sites in its service area. **Figure 6-19** shows the wide distribution of these sites. Many of these sites have impacted only the ground surface or soil, or shallow perched groundwater, and many

have been considered clean enough to close by regulatory agencies. However, WRD tracks the sites that have the greatest risk of contaminating and spreading in the deeper drinking water aquifers in its service area and works with the regulatory agencies to expedite the investigation and cleanup of these sites. Currently, WRD considers 46 sites to be the highest priority for contamination risks to the Central Basin and West Coast Basin. **Figure 6-20** shows the locations of these 46 sites.

Figure 6-19 also shows the approximate extent of the “Saline Plume,” the remnant seawater intrusion plume that invaded the freshwater aquifers due to overdraft in the 1900s through 1950s. Much of the plume was cut off by the West Coast Basin Barrier project when it was installed, leaving behind a legacy contamination plume. This plume continues to move inland based on the hydraulic gradient and is a risk to further groundwater supplies. The volume of this saline plume has been estimated at 600,000 AF (Bookman-Edmonston, 1986, pg. 34). WRD’s Goldsworthy Desalter program and WBMWD’s Brewer Desalter are two projects that pump out a portion of the contamination, treat the water through reverse osmosis membranes, and serve the treated water as a public water supply. These actions serve to remove the contamination for the benefit of the Basins and pumpers and to provide a new source of drinking water for the region.

WRD utilizes its network of specially designed groundwater monitoring wells, installed by the U.S. Geological Survey, to check on the condition of the aquifers and groundwater quality throughout its service area. The network currently consists of nearly 300 nested monitoring wells installed at over 50 locations. These wells range in depth from 60 feet to 1,990 feet, and tap all the major aquifers used by the groundwater producers in the Central Basin and West Coast Basin. Water quality samples are collected from the wells twice per year and the results tabulated in an annual Regional Groundwater Monitoring Report to present the latest information on the groundwater quality throughout the WRD Service Area (for example see WRD, 2012b). **Figure 6-21** shows the location of the WRD nested monitoring well network.

In addition to the Regional Groundwater Monitoring Report, WRD presents the results of its groundwater quality activities to the pumpers in its service area in Technical Bulletins, which are concise two-page documents summarizing important findings, such as how monitoring wells give aquifer specific information (WRD, 2006), battling seawater intrusion (WRD, 2007), groundwater quality in the Basins, identifying the most prevalent chemicals above drinking water standards (WRD, 2008a), how drinking water quality standards are set (WRD, 2008b), groundwater prevention and cleanup (2009), salt/nutrient management plans (2010a) and WRD’s Safe Drinking Water Program (WRD, 2010b).

Details of the many programs WRD implements to monitor and protect the quality of the groundwater in the WRD Service area are presented in Section 7. Projects such as the Goldsworthy Desalter, the Groundwater Quality Program, the Regional Groundwater Monitoring Program, and the Safe Drinking Water Program all help to ensure a high quality water resource to the direct and indirect benefit of all water users in the WRD Service Area.

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7.0 WRD PROJECTS, PROGRAMS, ADMINISTRATION AND WATER

California Water Code Sections 60220 through 60226 describe the broad purposes and powers of the District “to perform any acts necessary” to replenish, protect, and preserve the groundwater supplies of the District. In order to meet its statutory responsibilities, WRD has instituted numerous projects and programs in a continuing effort to effectively manage groundwater replenishment and quality in the Basins. These projects and programs include activities that enhance the replenishment program, increase the reliability of the groundwater resources, improve and protect groundwater quality, and ensure that the groundwater supplies are suitable for beneficial uses.

The projects and programs have had a positive impact on the basins and WRD anticipates continuing them into the ensuing year 2011/12. What follows is a discussion of those projects and programs. Additional information may be found in the District’s annual Engineering Survey and Report (“ESR”).

7.1 Water Supply Purchases

Among certain determinations and findings, the ESR identifies an estimate of the quantity, source, and cost of water available for replenishment during the ensuing water year. As detailed in the ESR, the Basins have an annual overdraft because more groundwater is pumped out than is replaced naturally. The District purchases supplemental water (artificial replenishment water) each year to help offset this overdraft through managed aquifer recharge. The purchased water enters the groundwater basins at the Montebello Forebay spreading grounds, at the seawater barrier injection wells, and through the District’s In-Lieu Program when available. The sources of artificial replenishment water include: (1) Recycled water – wastewater from the sewer systems that is reclaimed through extensive treatment at water reclamation plants (“WRP”s), and (2) Imported Water – river water from northern California (State Water Project) and the Colorado River that are imported into Southern California by the Metropolitan Water District of Southern California.

The detailed breakdown of the estimated quantity, source, and cost of replenishment water for the ensuing year can be found in Tables 1 and 2 of the 2011 ESR. The estimated costs described are for water purchases only and do not include the additional costs for projects and programs required to replenish the basins and to protect groundwater quality, as well as the administrative costs to support the various functions of the District.

In addition to the estimated quantity of replenishment water identified in the ESR, over the years, the District has occasionally not purchased the full quantity of water as estimated in the ESR. This deficit in not purchasing the full estimated amount is attributable to different circumstances, including: unavailability of replenishment water, unanticipated increases in imported water prices, revenue constraints (i.e. low RA rate), and cash flow challenges (i.e. collection/non-payment by customers). Since the early 2000s, the District has kept an accounting of the deficit in annual water purchases; the

total estimated cumulative deficit to date is also known as the makeup water, which is necessary to ensure the long-term health of the Basins.

The importance and technical details of makeup water can also be found in the ESR. Based upon technical analyses and historical groundwater levels, in 2002, the District adopted an Optimum Quantity for groundwater amounts in the Basins. The Optimum Quantity is based on the Accumulated Overdraft (AOD) concept described in the California Water Code. To ensure there is a healthy quantity to sustain the adjudicated pumping rights in the basins, in 2006, the District adopted a policy to make up the Optimum Quantity should it fall too low. The policy is as follows:

An Accumulated Overdraft greater than the Optimum Quantity is a deficit. WRD will make up the deficit within a 20 year period as decided by the Board on an annual basis. If the deficit is within 5 percent of the Optimum Quantity, then no action needs to be taken to allow for natural replenishment to makeup the deficit.

For the ensuing year, the District plans to purchase some amount of the makeup water. The actual purchase amount will depend on the decision of the Board, after considering inputs from stakeholders and conducting public meetings, and the availability of the water from suppliers and availability of the Los Angeles County Department of Public Works to spread the water for WRD.

7.2 Leo J. Vander Lans Water Treatment Facility Project (Program 001)

The Leo J. Vander Lans Water Treatment Facility provides advanced treated recycled water to the Alamitos Seawater Intrusion Barrier. The facility receives tertiary-treated water from the Sanitation Districts and provides the advanced treatment through a process train that includes microfiltration, reverse-osmosis, and ultraviolet light. The facility's operations permit was approved by the Los Angeles Regional Water Quality Control Board on September 1, 2005, and the replenishment operations of this facility started in October 2005. The product water has since been discharging to the barrier to replace up to 50% of the potable imported water currently used, thereby improving the reliability and quality of the water supply to the barrier. The plant is designed to produce approximately 3,000 acre-feet per year (AFY) for delivery to the barrier. The Long Beach Water Department (LBWD) is responsible for operation and maintenance of the treatment plant under contract with WRD.

Preliminary engineering design is in progress to potentially expand the capacity of the facility so that it can provide up to 100% of the barrier water demands thereby eliminating the need for the imported water. Expected costs for the coming year will involve operation and maintenance of the plant, final design for plant expansion, as well as groundwater monitoring at the barrier. The primary purpose of this project is to maintain the integrity of the Basins and provide a more reliable means of replenishing the basin through injection. This program is funded 100% from the Replenishment Fund.

7.3 Robert W. Goldsworthy Desalter Project (Program 002)

The Robert W. Goldsworthy Desalter has been operating since 2002 to remove brackish groundwater from a saline plume in the Torrance area that was stranded inland of the West Coast Basin Barrier after the barrier was put into operation in the 1950s and 1960s. The production well and desalting facility are located within the City of Torrance (City), and the product water is delivered for potable use to the City's distribution system. The treatment plant capacity is about 2,200 AFY. The City is responsible for operation and maintenance of the treatment plant under contract with WRD.

The District is evaluating the expansion of the treatment plant and plans to conduct feasibility studies for the expansion. Expected costs for the coming year will involve operation and maintenance of the plant and feasibility studies for the expansion. The purpose of the desalter is directly related to remediating degraded groundwater quality, and costs are thus attributed 100% to the Clean Water Fund.

Additional measures may be necessary in the future to fully contain and remediate the saline plume, which extends outside of the Torrance area. WRD is actively pursuing long-term solutions to this problem and continues to work with the City of Torrance Municipal Water Department, the pumpers' Technical Advisory Committee, and other stakeholders on the future of the saline plume removal in the West Coast Basin.

7.4 Recycled Water Program (Program 004)

Recycled water (reclaimed municipal wastewater) has been used for groundwater recharge by WRD since 1962. Using recycled water to replenish the groundwater basins provides a reliable source of high quality water for surface spreading in the Montebello Forebay and injection at the seawater intrusion barriers. In view of the drought conditions that periodically occur in California and uncertainty in the future availability and cost of imported supplies, this resource has become increasingly vital as a replenishment source.

WRD participates in various research and testing activities to ensure that the use of recycled water continues to be a safe and reliable resource for groundwater recharge. WRD, along with other stakeholders, is working closely with the CDPH to review and revise regulations on groundwater recharge using recycled water. Through this dialogue, WRD and CDPH exchange information and develop a mutual understanding of each agency's perspectives.

From an operational standpoint, the District continues to coordinate with the SDLAC with permit compliance activities, including groundwater monitoring and reporting, to ensure that the current practice and operation of replenishing with recycled water continues to be safe. Many monitoring wells and production wells are sampled frequently by WRD staff, and the results are reported as required to the regulatory agencies.

In addition to regular monitoring and sampling around the spreading grounds, WRD is partnering with others to more fully investigate the effectiveness of soil aquifer treatment (“SAT”) during recharge activities. Research is being conducted by specialists and experts and includes specific tests to characterize the percolation process and quantify the filtering and purifying properties of the underlying soil on constituents of concern such as nitrogen, total organic carbon, and emerging chemicals of concern (CECs). The District continues to be vigilant in monitoring research on the detection, significance, and treatment of CECs, such as pharmaceuticals and personal care products.

Three separate groundwater tracer studies to track and verify the movement of water from the spreading grounds and monitoring wells and production wells have been performed in 2003-2005, 2005-2006, and 2010-2011. Results showed that it is the depth and not the horizontal distance from the recharge ponds that is the key factor in arrival times of water to wells (travel time to deeper wells is greater than to shallower wells, even if the deeper wells are very near the spreading grounds). In some cases, WRD made modifications to wells to seal off their shallow perforations so that the wells only produced from the deeper aquifers. The tracer tests were then repeated to demonstrate that the travel time had been increased. These efforts, in addition to periodic studies assessing health effects and toxicological issues, are necessary to provide continued assurances that recycled water for groundwater recharge remains safe and compliant with regulatory standards.

Recycled water is also injected into the three seawater intrusion barriers in Los Angeles County (Alamitos, West Coast Basin, and Dominguez Gap). Work associated with the use of recycled water at those facilities is maintained under the specific project (e.g., Leo J. Vander Lans Water Treatment Facility) that delivers that resource to the barriers or under the program related to recycled water use at the specified barrier.

Projects under this program help to improve the reliability and utilization of an available local resource. This resource is used to help maintain the integrity of the Basins and improve replenishment capabilities. This program is funded 100% from the Replenishment Fund.

7.5 Groundwater Resources Planning Program (Program 005)

The Groundwater Resources Planning Program was instituted to evaluate basin management issues and to provide a means of assessing project impacts over the Basins. Prior to moving forward with a new project, an extensive evaluation is undertaken. Within the Groundwater Resources Planning Program, new projects and programs are analyzed based on benefits to overall basin management. This analysis includes performing an extensive economic evaluation to compare estimated costs with anticipated benefits. As part of this evaluation process, all new capital projects are brought to the District’s Technical Advisory Committee for review and recommendation.

One of the main programs currently underway under this Program is a Master Plan of the two groundwater basins. Efforts are underway to interview groundwater producers in these two basins to

identify future pumping demands so that the District can be prepared for future replenishment needs. Also under this program, District staff will continue to monitor State and Federal funding programs to determine applicability to the District's list of potential projects. The District will continue participation in Integrated Regional Water Management Planning ("IRWMP") for Greater Los Angeles County. Collaborative development of the region's IRWM plan is a requirement for entities to secure grant funding under Proposition 84 and Proposition 1E which were passed in November 2006. It is expected that this plan will play a significant role in future grant funding opportunities at the Local, State and Federal levels. District staff will also monitor the ongoing AB303 and WaterSMART grant funding programs.

Projects under the Groundwater Resources Planning Program serve to improve replenishment operations and general basin management. This program is funded 100% through the Replenishment Fund.

7.6 Groundwater Quality Program (Program 006)

This comprehensive program constitutes an ongoing effort to address water quality issues that affect WRD projects and the pumpers' facilities. The District monitors and evaluates the impacts of proposed, pending and recently promulgated drinking water regulations and proposed legislation. The District assesses the justification and reasoning used to draft these proposals and, if warranted, joins in coordinated efforts with other interested agencies to resolve concerns during the early phases of the regulatory and/or legislative process.

The District continually evaluates current and proposed water quality compliance in production wells, monitoring wells, and spreading/injection waters of the basins. If noncompliance is identified, WRD staff quickly investigates to determine the causes of noncompliance, develops recommended courses of action and estimates their associated costs to address the problem, and implements the best alternative to achieve compliance.

Effective January 1, 2007, the District assumed responsibility for the Central Basin Title 22 Groundwater Monitoring Program that had been administered previously by the Central Basin Municipal Water District. This program provides services for monitoring of drinking water wells as required by state statutes to ensure that they continue to be safe for domestic use. Currently, twenty pumpers with 80 wells are participating in this program. In addition, a new contract for sample collection and laboratory analysis was issued for this work. This program is paid for by the participants, and therefore, does not impact the District's RA.

In recent years, new CECs have been identified as potentially impacting local surface water and groundwater, not only in the Basins but also in neighboring regions such as the Main San Gabriel Basin, Orange County Basin, Chino Basin, etc. Constituents such as perchlorate, n-nitroso dimethylamine (NDMA), hexavalent chromium, and 1,4-dioxane have emerged as CECs and may pose a potential threat

to the local resources. Their detection in the environment does not necessarily mean that they pose a public health threat at their measured concentrations. Monitoring associated with surface spreading groundwater recharge facilities may increase, specifically for CECs pending future adoption of a resolution by the State Water Resources Control Board regarding its Scientific Advisory Panel's recommendations for monitoring CECs in recycled water.

WRD's service area contains a large and diverse industrial and commercial base. Consequently, many potential groundwater contamination sources exist within District boundaries. Examples of potential contamination sources include leaking underground storage tanks, petroleum pipeline leaks at refineries and petrochemical plants, and discharges from dry cleaning facilities, auto repair shops, metal works facilities, and others. Such contamination sources may pose a threat to the drinking water aquifers. Accordingly, WRD established its Groundwater Contamination Prevention Program as a key component of the Groundwater Quality Program, in an effort to minimize or eliminate threats to groundwater supplies.

The Groundwater Contamination Prevention Program includes several ongoing efforts:

- Central and West Coast Basin Groundwater Contamination Forum: In 2004, WRD established this data-sharing and discussion forum with key stakeholders including the U.S. Environmental Protection Agency, the DTSC, the LARWQCB, the California Department of Public Health ("CDPH"), the USGS, and various cities and pumpers. Stakeholders drafted and signed a Memorandum of Understanding ("MOU") agreeing to meet regularly (meetings are held 3 to 4 times per year at WRD) and share data on contaminated groundwater sites within the District. WRD has acted as the meeting coordinator and data repository/distributor, helping stakeholders to characterize the extent of contamination to identify pathways for contaminants in shallow aquifers to reach deeper drinking water aquifers and develop optimal methods for remediating contaminated groundwater.
- With the cooperation and support of all stakeholders in this Forum, WRD developed a list of high-priority contaminated groundwater sites within the District. This list is a living document, subject to cleanup and "closure" of sites, as well as discovery of new sites warranting further attention. Currently, the list includes over 45 sites across the Basins. WRD works with the lead regulatory agencies for each of these sites to keep abreast of their status, offer data collection, review and recommendations as needed, and facilitate progress in site characterization and cleanup.
- In 2003, WRD developed a scope of work with the Los Angeles County Department of Health Services ("LACDHS") to clarify the status of 217 potentially abandoned (a.k.a., "unknown status") wells located within District boundaries, as identified through researching WRD's groundwater production database. WRD completed numerous tasks to determine the status of these wells, including: distributing, collecting and tallying a survey questionnaire to all well owners associated with the potentially abandoned wells; searching through thousands of hard-copy well construction and destruction permits at the DWR, LACDHS, and City of Long Beach; conducting field

reconnaissance trips to locate and photograph wells. These efforts were successful: WRD was able to reduce the number of “unknown status” wells from 217 to 20, and most of the remaining 20 are suspected to have been paved over during development of industrial and residential neighborhoods. At this time, WRD is reviewing its groundwater production database, to identify any new “unknown status” wells, and to repeat the tasks listed above to clarify their status.

- Beginning in April 2010, WRD commenced work with the U.S. Geological Survey on the Central Basin Groundwater Contamination Study. The purpose of this study is to characterize the threat of multiple contaminant plumes moving downward through any preferential pathways to deeper potable aquifers in the Central Basin. The study area encompasses a large portion of the Central Basin, including the locations of several high-priority contaminated groundwater sites. Study tasks include compilation of existing data, sequence stratigraphic analysis, water quality sampling, geochemical analyses, and characterization of the groundwater flow system. The study was completed in 2014. WRD received AB303 grant funding to support this project.

WRD is also participating in the Water Augmentation Study (“WAS”) of the Los Angeles and San Gabriel Rivers Watershed Council. This is a multi-year investigation to evaluate the feasibility of capturing more storm runoff at localized sites in lieu of discharge into the storm drains, channels, and ultimately to the ocean. It is a potential source of new replenishment water, and would be in addition to stormwater currently captured and retained for percolation at the existing spreading grounds within the District. The underlying concept for the WAS is to retain more stormwater rather than allow it to be lost to the ocean; however, precautions must be taken to ensure that this new water does not degrade groundwater quality if allowed to percolate at local sites. More stormwater could be saved by utilizing Best Management Practices (BMPs), e.g., bioswales, infiltration basins, and porous pavements. Much of the WAS is focused on evaluating the technical feasibility of this project and the potential impacts on groundwater quality. Other aspects of the WAS include modeling to estimate the amount of water that can be percolated in the local watershed and the economic value of this additional source of water. In 2009, the Elmer Avenue neighborhood BMP demonstration project was constructed to evaluate the effectiveness and potential of a large-scale project. Extensive monitoring of the BMP demonstration project is planned for the coming years to assess the effectiveness of the BMPs in water capture and maintaining or improving groundwater quality.

WRD continues to do work involving additional investigations at well sites known to have contaminated water, continued monitoring of water quality regulations and proposals affecting production and replenishment operations, further characterization of contaminant migration into the deeper aquifers, and monitoring and expediting cleanup activities at contaminated sites. The work under this program is related to water quality and cleanup efforts; 100% of it is funded from the Clean Water Fund.

7.7 Geographic Information System (Program 010)

The District maintains an extensive database and Geographic Information System (“GIS”) in-house. The database includes water level and water quality data throughout the entire WRD service area with information drawn not only from the District’s Regional Groundwater Monitoring Program and permit compliance monitoring, but also from water quality data obtained from the CDPH. The system requires continuous update and maintenance but serves as a powerful tool for understanding basin characteristics and overall basin health.

The GIS is used to provide better planning and basin management. The system is used to organize and store an extensive database of spatial information, including well locations, water level data, water quality information, well construction data, production data, aquifer locations, and computer model files. Staff uses the system daily for project support and database management. Specific information is available to any District pumper or stakeholder upon request and can be delivered through the preparation of maps, tables, reports, or other compatible format. Additionally, the District has made its web-based Interactive Well Search tool available to selected users. This web site provides these users with limited access to WRD’s water quality and production database.

District staff will continue to streamline and refine the existing data management system and website as well as satisfy both internal and external data requests. As part of the streamlining of the data, staff will fully automate the transfer of water quality data from the laboratory directly into the District’s water quality database. Additionally, District staff will continue the development of applications to more efficiently manage and report groundwater production information. Continued use, upkeep, and maintenance of the GIS are planned on an ongoing basis. The use of the system supports both replenishment activities and groundwater quality efforts. Accordingly, the cost for this program is equally split between the Replenishment and Clean Water Funds.

7.8 Regional Groundwater Monitoring Program (Program 011)

WRD has been monitoring groundwater quality and water levels in the Basins for over 50 years. The Regional Groundwater Monitoring Program provides for the collection of basic information used for groundwater basin management including groundwater level data and water quality data. It currently consists of a network of nearly 300 WRD and USGS-installed monitoring wells at over 50 locations throughout the District, supplemented by the existing groundwater production wells. The information generated by this program is stored in the District’s GIS and provides the basis to better understand the dynamic changes in the Central and West Coast Basins. WRD staff, comprised of hydrogeologists and engineers, provides the in-house capability to collect, analyze and report groundwater data.

Water quality samples from the monitoring wells are collected twice a year. Water levels are measured in most monitoring wells with automatic data loggers daily, while water levels in all monitoring wells are

measured by WRD field staff a minimum of four times per year. On an annual basis, staff prepares a report that documents groundwater level and groundwater quality conditions throughout the District.

Ongoing work by WRD involves continuous field activities including quarterly and semi-annual data collection, continuous well and equipment maintenance, and annual reporting activities. In addition, new nested monitoring wells will be constructed. Work associated with the Regional Groundwater Monitoring Program also supports activities relating to both replenishment and water quality projects. The program is funded 50% each from the Replenishment and Clean Water Funds.

7.9 Safe Drinking Water Program (Program 012)

WRD's Safe Drinking Water Program ("SDWP") has operated since 1991 and is intended to promote the cleanup of groundwater resources at specific well locations. Through the installation of wellhead treatment facilities at existing production wells, the District hopes to remove contaminants from the underground supply and deliver the extracted water for potable purposes. Projects implemented through this program are accomplished through direct input and coordination with well owners. Two treatment facilities were constructed in 2010. Both treatment systems were constructed for the removal of iron and/or manganese. The removal mechanism is a pressurized filtration system.

The current program focuses on the removal of VOCs and offers financial assistance for the design and equipment of the selected treatment facility. Another component of the program offers no-interest loans for other constituents of concern that affect a specific production well. The capital costs of wellhead treatment facilities range from \$800,000 to over \$2,000,000. Due to financial constraints, this initial cost is generally prohibitive to most pumpers. Financial assistance through the District's SDWP makes project implementation much more feasible.

There are several current projects in various stages of completion and new candidates for participation are on the rise. A total of fifteen (15) facilities are already completed and online and one facility has successfully completed removal of the contamination and no longer needs treatment. While continued funding of this program is anticipated on an ongoing basis, the District has revised the guidelines of the SDWP to place a greater priority on projects involving VOC contamination or other anthropogenic (man-made) constituents, now classified as Priority A Projects. Further, any treatment projects for naturally-occurring constituents would be classified as Priority B Projects and funded on a secondary priority, on a case-by-case basis, and only if program monies are still available during the fiscal year. While such projects are of interest to WRD, availability of funding for them will not be determined until after the budget process.

Projects under the SDWP involve the treatment of contaminated groundwater for subsequent beneficial use. This water quality improvement assists in meeting the District's groundwater cleanup objectives. Funding for the costs of the program is drawn wholly from the Clean Water Fund.

7.10 Dominguez Gap Barrier Recycled Water Injection (Program 018)

This Project involves the delivery of recycled water from the City of Los Angeles Department of Water and Power's ("LADWP") Terminal Island Treatment Plant ("TITP") Advanced Water Treatment Facility ("AWTF") to the Dominguez Gap Barrier ("DGB"). Deliveries of recycled water to the barrier commenced in late February 2006 and have continued into 2011.

This water is being treated with microfiltration, reverse osmosis, and chlorination before being injected into the DGB. The project is permitted to maintain an overall ratio of 50% recycled water and 50% potable water to the entire barrier to satisfy regulatory requirements. Additional water quality requirements, including turbidity and modified fouling index ("MFI"), must also be met to minimize potential fouling of injection wells in the DGB, which is owned and operated by the County of Los Angeles Department of Public Works.

While LADWP is responsible for the treatment and delivery of the recycled water and all the water quality sampling associated with those activities, WRD has responsibility over groundwater monitoring compliance. As part of the permit, groundwater monitoring is required to observe water quality conditions and to anticipate potential problems before recycled water travels to downgradient drinking water wells. In addition, a tracer study was conducted at the start of recycled water injection (February 2006) through fall 2010 to determine the extent of travel and movement of the recycled water blend. The tracer study confirmed that adequate mixing and further blending in the ground is occurring and that groundwater samples being collected are representative of the recycled water blend.

Recycled water use at the seawater intrusion barriers in Los Angeles County improves the reliability of a supply that is needed on a continuous basis. Traditionally, water purchases for the barriers have been viewed as a replenishment function. This program is funded 100% through the Replenishment Fund.

7.11 Replenishment Operations (Program 023)

WRD actively monitors the operation and maintenance practices at the LACDPW-owned and operated spreading grounds and seawater barriers within the District. Optimizing replenishment opportunities is fundamentally important to WRD, in part because imported and recycled water deliveries directly affect the District's annual budget. Consequently, the District seeks to ensure that the conservation of stormwater is maximized, and that imported and recycled water replenishment is optimized.

Due to the reduction and unreliability of imported water for replenishment, WRD is working on its Water Independence Now ("WIN") program to eventually become independent from imported water for groundwater recharge. Currently, the District needs about 31,000 AF of imported water for recharge; 21,000 AF for spreading and 10,000 AF for injection at the seawater barriers. By maximizing the use of recycled water and stormwater, the amount of imported water can eventually be reduced or

eliminated, thereby providing the groundwater basins with full replenishment needs through locally-derived water.

WRD coordinates regular meetings with LACDPW, MWD, SDLAC, and other water interests to discuss replenishment water availability, spreading grounds operations, scheduling of replenishment deliveries, seawater barrier improvements, upcoming maintenance activities, and facility outages or shutdowns. The District tracks groundwater levels in the Montebello Forebay weekly to assess general basin conditions and determine the level of artificial replenishment needed. WRD also monitors the amount of recycled water used at the spreading grounds and seawater barriers to maximize use while complying with pertinent regulatory limits.

Recently, the District worked with LACDPW to complete construction of the Interconnection Pipeline. This jointly-funded project is a new, dedicated pipeline and pumping station constructed between the Rio Hondo and San Gabriel Coastal Spreading Grounds to transfer replenishment water in either direction, via gravity flow from the Rio Hondo to San Gabriel or pumping in the reverse direction. The project is expected to conserve approximately 1,300 AFY of additional stormwater on average, help maximize the amount of recycled water conserved by approximately 5,700 AFY, and provide operational flexibility to mitigate obstacles to performing replenishment at these spreading grounds. The Interconnection Pipeline project is a key component of the District's WIN.

While improvements undertaken in recent years by LACDPW/WRD (e.g., expansion of Whittier Narrows Conservation Pool, installation of rubber dams on San Gabriel River, Interconnection Pipeline) have considerably increased the stormwater portion of WRD's supply portfolio, the potential for further increasing the use of stormwater for groundwater augmentation remains significant. Results of the Water Augmentation Study (described under Project 006 above) suggest that nearly 180,000 AFY of stormwater runoff is lost to the ocean from WRD's service area. Accordingly, the District plans to work with the LASGRWC on the Stormwater Recharge Feasibility Study and Pilot Project Development effort. This effort will identify regional and parcel-based locations and pilot project concepts and their respective costs and benefits within the District to achieve maximum stormwater capture for water supply benefit. Existing but independent analyses, datasets and modeling tools will be combined to identify where potential pilot projects may be located and to provide concept designs within a focused area. The study will identify with great specificity the best locations for stormwater capture and filtration and the technologies best suited to the locations.

As its name implies, this program deals primarily with replenishment issues and its costs are borne 100% through the Replenishment Fund.

7.12 Hydrogeology Program (Program 025)

This program accounts for the projects and programs related to hydrogeologic investigations of the District and surrounding areas to ensure safe and reliable groundwater. Work performed under this

program includes the preparation of the annual Engineering Survey and Report, which incorporates the calculation and determination of annual overdraft, accumulated overdraft, change in storage, pumping amounts, and replenishment water availability into a document to help the District assess its replenishment needs and costs in the ensuing year. Extensive amounts of data are compiled and analyzed by Staff to determine these values. Maps are created showing water levels in the basins and production patterns and amounts. The updates, maintenance, and use of the Regional Groundwater Flow Model developed by the USGS and WRD are part of this program. This model is a significant analytical tool utilized by WRD to determine basin benefits and impacts of changes proposed in the management of the Central and West Coast Basins.

An ongoing effort at the District to better characterize the hydrogeologic conditions across the Central and West Coast Basins is called the "Hydrogeologic Conceptual Model." This long-term project involves compiling and interpreting the extensive amounts of data generated during drilling and logging of the WRD/USGS monitoring wells, and collected from historical information for production wells and oil wells within the District. The ultimate goal of this project is to incorporate these data in WRD's database/GIS and apply the system to generate aquifer surfaces and cross-sections for comparison with historical interpretations of basin hydrogeology. The final conceptual model will significantly improve the understanding of the aquifer depths, extents, and thicknesses throughout the District, and will assist Staff, pumpers and stakeholders with planning for groundwater resource projects such as new well drilling, storage opportunities, or modeling. The data will also be made available on WRD's website to be used as a reference source for hydrogeologic interpretations and fulfilling project-related data requests.

Hydrogeologic analysis is also needed for projects associated with groundwater quality concerns and specific cleanup projects. Staff work may include investigative surveys, data research, and oversight of specific project studies. Such efforts are used to relate water quality concerns with potential impact to basin resources. An example of this type of Staff work is the District's Well Profiling Program. The District assists pumpers in evaluating drinking water supply well contamination. Services may include existing data collection and review, and field tasks such as spinner logging and depth-discrete sampling. WRD's evaluation helps pumpers to determine the best course of action; e.g., sealing off a particular screened interval of a well, wellhead treatment, or well destruction.

Salt / Nutrient Management Plans are a new State requirement for all groundwater basins throughout California. The Plans are required as part of the Recycled Water Policy issued by the State Water Resources Control Board (SWRCB) and effective as of May 14, 2009. As stated in the Policy, its purpose is to "establish uniform requirements for recycled water use and to develop sustainable water supplies throughout the state." The SWRCB therefore "supports and encourages every region...to develop a Salt / Nutrient Management Plan by 2014." With one exception (elevated TDS concentrations near the coast due to historic seawater intrusion, now controlled through freshwater barrier injection), salts and nutrients have not been shown to be a concern in the Basins. However, since Salt / Nutrient Management Plans are required, WRD began meeting with other stakeholders and the Regional Water Quality Control Board (RWQCB, the agency responsible for bringing stakeholders' Salt / Nutrient

Management Plans to the SWRCB for approval) to initiate development of a Salt / Nutrient Management Plan for the Basins. WRD will continue to take the lead in working with the RWQCB and stakeholders to develop a Plan for the Basins.

Additional investigative research projects into the saline plume, well testing, and recycled water travel time using tracers continue to be performed, as well as a major update to the regional groundwater flow model by the USGS to incorporate new information.

The Hydrogeology Program addresses both groundwater replenishment objectives and groundwater quality matters. This dual service warrants that the cost of the program be split evenly between the Replenishment and Clean Water Funds.

7.13 Groundwater Reliability Improvement Program (Program 033)

The WRD continues to pursue projects through its WIN program that develop local, sustainable sources of water for use in groundwater replenishment. This has become increasingly important in light of the environmental and political issues limiting delivery of imported water to Los Angeles area together with the potential for a drought to hit California.

To address these issues WRD is seeking alternative sources of water to offset the imported water used for replenishment in the Montebello Forebay. This program is referred to as the Groundwater Reliability Improvement Program ("GRIP"). The effort of this program is to evaluate all feasible alternatives for replacing or offsetting the current quantity of imported water used for replenishment. One alternative being considered is the use of advanced treated recycled municipal wastewater (microfiltration, reverse osmosis, ultra-violet light with hydrogen peroxide.) from the Sanitation Districts of Los Angeles County's (SDLAC) San Jose Creek Water Reclamation Plant.

To determine the viability of this concept, a consultant was retained to perform a conceptual design of a facility for the purpose of developing preliminary cost estimates. The concept will be to deliver advanced treated water to the San Gabriel River spreading basins or a dedicated injection well field to meet a portion of WRD's replenishment requirements.

Upon finding the concept feasible, a second consultant was retained to perform an Alternatives Analysis to evaluate various options, in addition to the proposed treatment facility, for developing the additional replenishment water supply. This effort was completed in mid-2011. As of 2014, WRD had entered into a partnership with SDLAC to further develop the concept of an advanced water treatment facility. WRD has completed an environmental impact report/study (EIR/EIS). The next steps, which are ongoing as of 2014, will include regulatory permitting. Any new source of replenishment water developed through the GRIP will help to improve the reliability and utilization of an available local resource.

This resource is used to improve replenishment capabilities and is thus funded 100% from the Replenishment Fund.

7.14 Water Education

As part of its stewardship of the water basins, the District provides educational programs regarding the basins and the District's activities.

7.15 Administration

Administration generally consists of services that are necessary to support the day-to-day functions, projects, and programs of the District. Such services include policy development (Board of Directors), policy implementation and oversight (General Manager), finances, accounting and human resources.

The Board of Directors is the policy-making body of the District. The General Manager is responsible for implementing the policies of the Board, supervising the staff and managing the daily activities of the District. The finances, accounting, and human resources functions are general administrative services that support the functions of the District. Additionally, each year the District sets aside funds to partially fulfill its long-term employee retirement pension obligation, as recommended by Governmental Accounting Standards Board ("GASB") Statement 45. This annual set-aside to meet retirement fund obligations reduces the District's long-term unfunded liability and corresponding fiscal impacts.

7.16 Water Conservation

The State of California has mandated a 20% reduction in per capita water use by 2020. Given the state goal and the recurring drought in southern California, WRD has worked with the community and other stakeholders to promote water conservation, including hands-on conservation training. Providing training programs translates into effective reduction in water demand and usage in the region, and good resources stewardship by WRD reducing the need for more traditional replenishment operations.

8.0 UNIFORM RATE

Groundwater occurring in and flowing through the WRD service area, although originating from differing regions, is interrelated. Actions in one basin affect available groundwater in the other. The groundwater resources constitute a common underground pool that all groundwater pumpers in the Basins share. The service that WRD provides is to maintain the integrity of the Basins as a water resource of sufficient quantity and quality for purposes of beneficial use. It is equitable that the costs of replenishing and maintaining this resource as a safe source of water should be shared by all pumpers in proportion to the amount of water pumped. The use of a uniform rate for each acre-foot of water pumped is supported by the following reasons, among others:

- It was decided long ago that it was necessary to manage the Basins as a single system, as these important, interconnected groundwater resources were in jeopardy of being rendered unavailable to pumpers due to overdraft and saltwater intrusion. The original plan for replenishment and barrier protection has been implemented over several decades, and remains the basis for protecting the system from being destroyed, in which case economic pumping might be lost altogether. All pumpers place a stress on the system that is proportional to the amount of water withdrawn. The District imposes a uniform rate on all pumpers in light of that basic reality.
- WRD replenishment activities benefit all groundwater pumpers in both basins directly or indirectly. If the system is preserved, everyone benefits. If the system is destroyed, everyone loses. The only cognizable “service area” is the overall system itself. Max Bookman, who was arguably the most knowledgeable expert on the geology of the two groundwater basins, said it succinctly: “Separate replenishment programs for the Central Basin and West Basin, wherein each basin pays their individual costs, is not practical because of the interdependence of the common water supply of the two areas and because the two basins must be conjunctively operated in order to obtain the maximum benefits of the groundwater supply.” (Bookman and Edmonston, 1963).
- In the mid-1950s, groundwater producers in the Central and West Coast Basins considered forming separate replenishment districts. They chose to form one district overlying both basins, with a replenishment district operating as a single unit with a single, uniform RA. They did so for a variety of policy, economic and scientific reasons, which are still applicable to today’s circumstances.
- The Basins, although separately adjudicated, are subbasins to the larger Coastal Plain of Los Angeles Groundwater Basin, according to the California Department of Water Resources (CDWR, 2003). The subbasins are created “for the purpose of collecting and analyzing data, managing water resources, and managing adjudicated basins.” CDWR defines subbasins as a smaller unit than a groundwater basin that are divided using geologic and hydrogeologic barriers or, more commonly, institutional boundaries. The name “subbasin” connotes that the two are not separately isolated basins but instead are interconnected.

- The adjudicated Basins share a common boundary at the Newport-Inglewood Uplift, which is an approximate linear geologic structural feature of discontinuous small hills and broken fault segments that is roughly 40 miles long and one mile wide. Although the Uplift has been shown to be a partial barrier to groundwater flow, stronger in some areas than others, there is uniform agreement amongst the references that significant quantities groundwater move through aquifers across the Uplift. Although groundwater flow is typically from the Central Basin across the Uplift into the West Coast Basin, there can be direction reversals based on hydraulic gradients and groundwater can flow from the West Coast Basin into the Central Basin (Garcia, 1995).
- The West Coast Basin historically and presently relies on groundwater underflow across the Newport Inglewood Uplift for a significant portion of its natural water supply. The amount of underflow varies from year to year based on the hydraulic gradient present on opposite sides of the Uplift. The CDWR (2003) states that increased pumping in the Central Basin caused reduced underflow to the West Coast Basin. This further demonstrates the connectivity and reliance of the two groundwater basins on each other. As stated by a water professional in the area: “Replenishment water purchased by WRD, for example, is spread in the Montebello Spreading Grounds and in the bed of the San Gabriel River at the eastern end of the Central Basin. The spread water percolates or sinks into the ground, and flows in a general direction from the Central Basin aquifers into the West Coast Basin aquifers, so that groundwater elevations in both basins are maintained.” (Declaration of Mr. Desi Alvarez, Director of Public Works for the City of Downey, 2001).
- An analogy can be given to blowing up a beach ball – the WRD has four valves to “blow” replenishment water into the two basins to “inflate” the aquifers for the benefit of all – not just those who are closest to the valves. Geographic locations to provide artificial replenishment water to the WRD Service Area are very limited. The facilities available must be used to replenish the groundwater for everyone’s use, not just the groundwater pumpers closest to the facilities. Only facilities owned and operated by the Los Angeles County Department of Public Works, including the Montebello Forebay Spreading Grounds and Alamitos Seawater Barrier in the Central Basin, and the West Coast Basin Barrier Project and the Dominguez Gap Barrier in the West Coast Basin, are available to WRD for direct delivery of replenishment water.
- In-lieu replenishment is another tool that WRD has used in the past to manage aquifer recharge, and is another reason for a single service area. In-lieu replenishment can potentially occur anywhere within the service area that is difficult to replenish by other means. It has been used successfully in both basins in the past including the Los Angeles Forebay, the lower Central Basin Pressure area, and the West Coast Basin. When pumping of a well is turned off by the In-lieu program, groundwater levels rebound at the well and near the well, and the unpumped groundwater remains in the aquifers for others to use or to move downgradient to other potential users further away.

- There are no complete physical barriers to groundwater flowing from one basin to the other in WRD's Service Area. There are partial barriers to groundwater flow in some places, such as certain segments of the Newport-Inglewood Uplift, the Charnock Fault in the West Coast Basin, the Coyote Hills in the Central Basin, and the thinning of aquifers in places in both basins, but as groundwater flows and encounters a barrier, it changes course and continues moving down gradient until it eventually gets pumped out by a well or finds some other exit from the groundwater basins. Because of this, there is no practical way to subdivide the WRD Service Area into zones of influence or zones of recharge benefit, or zones of recharge cost due to the holistic nature of the aquifer systems.
- Trying to define zones of benefit leading away from the spreading grounds towards the confined aquifers in the Central Basin, or away from the seawater barriers wells in the Central Basin or in the West Coast Basin, is not practical from a management or scientific standpoint. The water recharged at these facilities either directly or indirectly provides benefit to all of the groundwater users in both basins. Replenishment at the spreading grounds helps maintain a high water table to create a steep hydraulic gradient so groundwater will flow to the rest of the Basins. Barrier well injection along the coast not only protects the groundwater quality in both basins from further degradation from seawater, but the elevated groundwater levels they provide allow pumping to continue at adjudicated levels.
- An adjudicated rights holder is entitled to its share of groundwater and can construct a well to pump from wherever it deems necessary within the groundwater basin for which it holds rights. The rights holder can also lease out all or some of its rights to another party that can install a well and pump from its own well location. Because of this, pumping patterns and amounts are very transient, changing from year to year, complicating the groundwater flow system and changing hydraulic gradients. Well locations are variable not only in geographic locations but also vary by aquifers from which they draw. Water demands are not predictable and can change year to year. Precipitation patterns are also unpredictable, requiring WRD to manage based on a long-term hydrologic cycle, but flexible to adapt to extremely wet or extremely dry years. Groundwater "pumping holes" are transitory and lead to wide swings in water levels and groundwater flow conditions. These factual variables illustrate the complexities of trying to subdivide a large groundwater reservoir into a set of fixed subareas when the conditions inside of the groundwater reservoir are continually changing. This is another reason why WRD has established its service area as a single service area.
- A recent study by PPIC provides an important assessment of how costs of service analysis should be done. As noted by the PPIC, "because the various components of a water system—including the management of native surface water and groundwater supplies, the acquisition of imported water, recycled water programs, stormwater capture, conjunctive ground and surface water management, and demand reduction strategies—cannot be segregated from one another, it is lawful to charge

individual property owners and water users a share of all of the system costs.”³ The PPIC concludes that an accurate cost-of-service analysis cannot be accomplished by a molecular-level accounting of water units by cost and location. An accurate cost-of-service analysis would need to account for the external costs of pumping by one user on all other users of the basin, for instance the implications of overdraft by inland groundwater users on saltwater intrusion facing coastal users, rather than to consider only the physical cost of delivering the individual water unit to the property owner.

WRD has evaluated claims that there should be a split assessment and has rejected them because, among other reasons, they are inconsistent with management of the Basins as a single system and the service that the District provides, and do not reflect the hydrogeology, connectivity and interdependency of the Central and West Coast groundwater basins. For example, HF&H Consultants, LLC prepared report on the allocation of cost through the RA. The report, which claims that the Central Basin is currently subsidizing the West Coast Basin, is unrealistic and results in incorrect conclusions. The report ignores the hydrogeology of the Basins by explicitly assuming that Central and West Coast Basins are geologically distinct and independent Basins. As the discussion in Section 5 of this report describes, the Basins are fundamentally linked through underflow across the Newport Inglewood Uplift. Groundwater pumping in the Central Basin affects the underflow across the NIU to the West Coast Basin and pumping in the West Coast Basin affects the underflow across the NIU from the Central Basin. When pumping in one Basin affects the amount of groundwater available to users in the other Basin, it is not feasible to independently attribute cost to each Basin without consideration of the hydrogeology that connects water supply and determines replenishment needs for each of the two Basins. The HF&H report was funded by parties including the City of Downey, which had previously provided testimony to the court about the interconnection of the Central and West Coast groundwater basins (Declaration of Mr. Desi Alvarez, Director of Public Works for the City of Downey, 2001).

8.1 References Cited for Section 8

Bookman and Edmonston, 1963, Letter to Mr. Carl Fossette, General Manager of the Central and West Basin Water Replenishment District regarding the effect of elimination of assessment on the safe yield of the ground water resources within the Replenishment District: dated January 15, 1963.

California Department of Water Resources, 2003, California’s GROUNDWATER: Bulletin 118, 246 p. Supplemental information on the Central Basin found at www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/4-11.04.pdf (accessed 1/17/2013). Supplemental information on the West Coast Basin found at www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/4-11.03.pdf (accessed 1/17/2013).

³ Public Policy Institute of California (PPIC), “Paying for Water in California,” March 2014 (p. 31) <<http://www.ppic.org/main/publication.asp?i=1086>>.

Declaration of Desi Alvarez, 2001, Superior Court of the State of California for the County of Los Angeles, California Water Service Company, et al., Plaintiffs v. City of Compton, et al., Case No. 506 806, Declaration of Desi Alvarez in Support of the City of Downey's Motion to Intervene: dated August 30, 2001, and filed in LA Superior Court September 5, 2001.

Garcia, D.H., 1995, Impact of the Newport-Inglewood Structural Zone on Groundwater Flow in the Area of Signal Hill, California: A Thesis Presented to the Department of Geological Sciences, California State University, Long Beach, in partial fulfillment of the requirements for the degree of Master of Science, 183 p.

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9.0 COST OF SERVICES

The total annual revenue requirements, net of revenue credits from miscellaneous sources, are by definition the cost of providing service. This Chapter provides a review of the projects, programs, administration and water as well as other related costs that are necessary to support the District's functions. A general description of the District's other revenue sources will also be presented.

As noted in chapter 3, this chapter presents information both about the estimated cost of service at the time that WRD initially adopted the RA and about WRD's actual costs and revenues.

All estimated costs and revenues contained herein are considered preliminary estimates, reflecting the costs associated with the proposed levels of services. Every year, the District conducts a series of public budget meetings to seek comment pursuant to the Water Code and other applicable regulatory requirements. To ensure transparency, accountability, and fiscal responsibility, the District has two committees with representatives from stakeholders. The two committees are: Budget Advisory Committee ("BAC") formed in 2013 by SB620 and Technical Advisory Committee ("TAC"). The Committees are charged with providing guidance and advice on budgetary, finance, and technical matters relating to the District's projects and programs.

Furthermore, the District, through its Finance/Audit Committee and the Board of Directors, conducts additional meetings and solicits comments and takes testimony from the groundwater community and stakeholders. After considering the recommendations from the BAC and TAC, as well as the public, the Finance/Audit Committee makes budget recommendations to the Board of Directors. Upon final approval by the Board, the preliminary estimates contained herein will be revised accordingly to reflect the approved budget amounts and corresponding levels of services.

9.1 Projects, Programs, Administration & Water Costs

The Projects, Programs, and Administration ("PPA") and water costs are generally considered as operational expenses for budgetary purposes, and their detailed descriptions are provided in Chapter 7 of this report. **Table 9-1** summarizes the estimated PPA & water costs, totaling \$62,651,000 for Fiscal Year 2011/12 (FY2011/12). Water and water related costs make up \$48,485,000 or 77 percent of operational expenses for budgetary purposes.

The District's actual amount spent for FY2011/12 was \$52,018,000 with \$39,460,000 making up the water and water related costs, or 75.8 percent of the operational expenses.

Table 9-1
Summary of FY2011/12 Estimated Projects, Programs and Administration & Water Costs

FY2011/12 PPA & Water Costs	Estimated Amount	Actual Amount Spent	Difference
Water Supply Purchases	\$44,318,000	\$36,187,000	\$8,131,000
Water Conservation	\$981,000	\$460,000	\$521,000
Leo J. Vander Lans Water Treatment Facility Project (Program 001)	\$3,186,000	\$2,813,000	\$373,000
Water and Water Related Costs	\$48,485,000	\$39,460,000	\$9,025,000
Robert W. Goldsworthy Desalter Project (Program 002)	\$1,496,000	\$1,122,000	\$374,000
Recycled Water Program (Program 004)	\$572,000	\$247,000	\$325,000
Groundwater Resource Planning Program (Program 005)	\$1,521,000	\$1,393,000	\$128,000
Water Quality Improvement Program (Program 006)	\$536,000	\$573,000	-\$37,000
Geographic Information Systems (GIS, Program 010)	\$266,000	\$86,000	\$180,000
Regional Groundwater Monitoring Program (Program 011)	\$922,000	\$807,000	\$115,000
Safe Drinking Water Program (Program 012)	\$184,000	\$101,000	\$83,000
Dominguez Gap Barrier Recycled Water Injection (Program 018)	\$391,000	\$187,000	\$204,000
Replenishment Operations (Program 023)	\$797,000	\$587,000	\$210,000
Hydrogeology Program (Program 025)	\$1,101,000	\$808,000	\$293,000
Groundwater Reliability Improvement Program ("GRIP") (Program 033)	\$458,000	\$70,000	\$388,000
Water Education	\$1,100,000	\$719,000	\$381,000
Board of Directors	\$370,000	\$356,000	\$14,000
General Manager	\$355,000	\$380,000	-\$25,000
Administration	\$3,470,000	\$4,553,000	-\$1,083,000
Retirement Fund Obligation (GASB 45)	\$627,000	\$569,000	\$58,000
PPA Costs	\$14,166,000	\$12,558,000	\$1,608,000
Total (PPA and Water) Costs:	\$62,651,000	\$52,018,000	\$10,633,000

Water and Water Related Costs

As indicated in Table 9-1, the District underspent funds related to water purchases by \$8,131,000. Further analysis shows that the District was under budget in water purchases from the Metropolitan Water District for Tier 1 Imported Spreading Water and for the In Lieu replenishment and therefore, \$12,278,000 was encumbered to the Water Purchase Carryover Fund. The District also did not spend the budgeted amount for imported and recycled water purchases to the Alamitos, West Coast and Dominguez Gap Barrier Projects in the amount of \$8,214,000, accounting for the majority of the \$8,131,000 difference.

The District also underspent funds related to Water Conservation by \$521,000 and to the Leo J. Vander Lans – Water Supply Production category by \$373,000.

Project, Programs and Administrative Costs

The remaining difference is a net under budget amount of \$1,608,000.

9.2 Other Special Programs and Supportive Costs

In addition to the PPA & water costs, the FY2011/12 estimated expenses include other special programs and support cost components, as described below.

- Litigation. The District is presently engaged in a number of lawsuits. The annual litigation expense varies greatly depending on actual litigation activities; the estimated litigation cost contained herein represents the District's good faith estimate based on anticipated litigation activities.
- Election Expense. The District is governed by a five - member elected Board. The District's elections of Board members are held in November of even calendar years, during which either two or three members are elected by the voters. Each year, the District sets aside funds for upcoming election expenses, based on a 2-year election cycle and the number of seats up for election.

For other special programs and supportive costs, **Table 9-2** summarizes the estimated FY2011/12 expenses.

Table 9-2
Summary of FY2011/12 Other Special Projects and Supportive Costs

FY2011/12 Other Special Programs and Supportive Costs	Estimated Amount	Actual Amount Spent	Difference
Litigation	\$915,000	\$1,617,000	(\$702,000)
Election Expense	\$600,000	\$0	\$600,000
Total Costs:	\$1,515,000	\$1,617,000	(\$102,000)

The District over spent funds related to litigation by \$702,000. As for the District's election expense, the District budgets one-half of the anticipated election expenses each year but pays the County Registrar of Voters every two years. The next payment to the County is not due until fiscal year 2012/13.

9.3 Capital Improvement Program/Plan

The WRD's primary responsibilities are to protect the Basins by replenishing groundwater, deterring sea water intrusion, and removing contaminants from the groundwater. With the recent drought and future uncertainty of imported water, the District is moving forward with the Water Independence Now ("WIN") program, a series of projects that will fully utilize stormwater and recycled water sources to protect the Basins and to ensure a sustainable, reliable local groundwater supply. The District's Capital Improvement Plan ("CIP") serves as a comprehensive planning document that identifies capital project expenditures in conjunction with anticipated revenue sources (e.g., grant funding, etc.), for the current and the next five fiscal years. In consultation with stakeholders and as additional information becomes available, expenditure and revenue estimates for the later fiscal years will be amended as appropriate to reflect changing conditions.

For the purpose of financial and budget planning, the CIP accounts for common capital projects that generally meet one or more of the following criteria:

- Typically non-recurring, one-time expenditures.
- Expenditures spanning over two fiscal years or longer.
- Total project cost exceeding \$20,000.

Not included in a CIP account are operation, maintenance, or capital outlay items (e.g., computer software, office furniture, etc.), which are necessary to support the day-to-day functions of the District.

The District's Five-Year CIP contains the detailed descriptions of the capital projects, including financial analysis, estimated project costs, and funding sources. Construction projects are primarily funded by capital funds, or more specifically, proceeds from the sale of Water Revenue Certificates of Participation. The capital funds are sometimes supplemented by federal and state grant funds, when successfully secured by the District. For partnership projects, funds may also be contributed by the District's project partners, such as the Los Angeles County Sanitation Districts or Los Angeles County Department of Public Works. For non-construction projects, such as the Whittier Narrows Conservation Pool Study, the District's share of the study expenditures will be primarily RA funds (non-capital funds).

CIP - Debt Service Requirements. Debt service requirements consist of principal and interest payments on existing debt. The District currently has debt service obligations associated with the outstanding 2004, 2008, and 2011 Certificates of Participations ("Certificates"). Over the years, the District issued different Certificates, with a 30-year payment term, to finance capital improvement projects. When economically feasible, the District may apply available, limited property tax revenue and/or interest earned toward reducing the annual debt service payment. For FY2011/12, the estimated net debt service amount was \$7,309,000.

9.4 Reserve Fund (Replenishment)

Pursuant to the California Water Code, the District has established an annual reserve fund to meet ongoing cash flow requirements, purchase water, and serve emergency needs. On an as-needed basis, the District collects revenue to replenish the reserve fund. For FY2011/12, there is no estimated amount being collected to replenish the reserve fund.

9.5 Summary of Budgetary Cost Estimates

The estimates for the various cost components (PPA & Water, CIP, etc.) are described above. **Table 9-3** provides a summary the aforementioned cost components, including the total cost (total revenue requirements).

Table 9-3
Summary of FY2011/12 Budgetary Cost Estimates

FY2011/12 Budgetary Cost Components	Estimated Amount	Actual Amount Spent	Difference
Projects, Programs, Administration & Water	\$62,651,000	\$52,018,000	\$10,633,000
Other Special Programs and Supportive Costs	\$1,515,000	\$1,617,000	(\$102,000)
Capital Improvement Program/Debt Service	\$7,309,000	\$7,230,000	\$79,000
Water Purchase Carryover Fund	(\$10,000,000)	(\$10,000,000)	\$0
Reserve Fund (replenishment)	(\$5,000)	(\$5,000)	\$0
Total Revenue Requirements/Costs	\$61,470,000	\$50,860,000	\$10,610,000

In FY2011/12, the Board of Directors chose to utilize \$10,000,000 from the Water Purchase Carryover Fund in accordance with California Water Code §60328.1 to lessen the impact of the increased debt service payments to the RA. Along with the use of \$8,270,000 from the Water Purchase Carryover Fund in FY2010/11, the District has used a total of \$18,270,000 for RA rate relief.

9.6 Revenue From Other Sources (Capital Revenue)

The District annually receives revenue from operating and delivering high quality, treated water from the two capital assets, namely: the Leo J. Vander Lans Water Treatment Facility and the Robert W. Goldsworthy Desalter. The basis for the capital revenue estimates are explained below for each. The total estimated FY2011/12 capital revenue from the two capital assets was approximately \$2,214,000.

Leo J. Vander Lans Water Treatment Facility – Water Supply. The advanced treated recycled water (product water) from the treatment facility is delivered to the Alamitos Barriers for injection into the aquifer(s), in order to prevent ocean water intrusion from damaging the health

of the groundwater basin. To the extent insufficient advanced treated water is available, imported water is purchased from the Long Beach Water Department to supplement water supply to the barriers. Since the water injected at the barrier partially benefits the Orange County Water District's ("OCWD") service area, revenue is collected from OCWD for its fair share of the costs. Additionally, the District receives a subsidy through MWD Local Resources Program ("LRP"). The estimated total revenue from this treatment facility is approximately \$1,214,000 for FY2011/12.

Robert W. Goldsworthy Desalter – Water Supply. The Goldsworthy Desalter ("Desalter") treats brackish groundwater to a level that can be used for potable purposes. While the Basin realize the water quality benefits from operating the Desalter, the product water from the Desalter is sold to the City of Torrance for beneficial use. Additionally, the District receives MWD's LRP subsidy through the City of Torrance, a MWD member agency. The estimated total revenue from this treatment facility is approximately \$1,000,000 for FY2011/12.

9.7 Cost of Providing Service

The various cost components for providing water replenishment services are described above. The total cost or revenue requirement, net of revenue credits from capital revenue, is the estimated cost to provide service. **Table 9-4** provides the cost of providing service.

Table 9-4
Cost of Providing Service

FY2011/12 Cost of Service	Estimated Amount	Actual Amount Spent	Difference
Total Revenue Requirements (Cost):	\$61,470,000	\$50,860,000	\$10,610,000
Less Capital Revenue:	(\$2,214,000)	(\$2,551,000)	\$337,000
Estimated Cost of providing Service:	\$59,256,000	\$48,309,000	\$10,947,000

The District's original estimate was that it would need to collect \$59,256,000 in RA Revenue to provide service for fiscal year 2011/12. The District had actual expenses of \$48,309,000, including a \$12,278,000 encumbrance to the Water Purchase Carryover Fund, resulting in a difference of \$10,947,000.

Of the estimated \$59,256,000 in revenue from the RA, the District only received \$55,615,000⁴ (June 30, 2012 Comprehensive Annual Financial Report), a revenue shortfall of (\$3,641,000). When comparing

⁴ Comprehensive Annual Financial Report of \$45,571,109 plus deferred revenue under GASB 62 of \$10,043,715 million for a total revenue for FY2011/12 of 55,615,000 (rounded). *The District implemented certain provisions of Government Accounting Standards Board (GASB) Statement Number 62, Codification of Accounting and Financial Reporting Guidance Contained in Pre-November 30, 1989 FASB (Financial Accounting Standards Board) and AICPA (American Institute of Certified Public Accountants)*

the revenue shortfall of (\$3,641,000) to the amount underspent during FY2011/12, there is a surplus of \$7,306,000.

During FY2011/12, the cities of Downey, Cerritos, Signal Hill, Bellflower and Pico Rivera did not pay their RA as follows: City of Cerritos \$2,165,000, City of Downey \$3,936,000, City of Signal Hill of \$517,000, City of Bellflower of \$62,000 and the City of Pico Rivera of \$978,000 for a total of \$7,658,000 of uncollected revenue.

In summary, in the 2011/12 year:

- Expenses were \$10,947,000 more than was originally anticipated;
- Revenues were \$3,641,000 less than was originally anticipated
- Non-payment of \$7,658,000 by the cities of Downey, Cerritos, Signal Hill, Bellflower, and Pico Rivera for water they pumped

In total, WRD operated at a total cash deficit of \$352,000 for the 2011/12 year. This money was made up by WRD drawing down its unrestricted reserve account. For the 2011/12 year, WRD's projected cost to provide service after adjustments were within 0.59% of its actual costs.

Note that WRD makes its cost and revenue projections prospectively, and there is some variation from the projections. When WRD experiences a deficit, it must make up the deficit by drawing on its unrestricted reserve account. When WRD experiences a surplus, the surplus is added to the unrestricted reserve account. For the three years 2010/11, 2011/12, and 2012/13, WRD had a total cumulative cash deficit (which it made up from the reserve account) of \$3,115,000. This is a very small number in comparison with the overall estimated cost to provide service for the three years of \$168,701,000, within 1.85% of the budgeted numbers. It should also be noted that in these three years, WRD used a total of \$21,270,000 for rate relief pursuant to California Water Code § 60328.1.

Though RA funds added to the unrestricted reserve account are not used by WRD in the year for which they are collected, these funds may only be used (once drawn from the account) for the purposes for which the RA was charged.

Pronouncements, specifically the accounting for rate-regulated activities which allows deferral of the recognition of revenues until the related costs or charges associated with the rates assessed is incurred. The amount of the Deferred Revenue – Replenishment Assessment for FY2011/12 was \$10.0 million

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10.0 COST ALLOCATION ANALYSIS

The District's perimeter boundary represents a single service area for which all groundwater pumping within its service area is subject to a common rate, known as the Replenishment Assessment (RA). Pursuant to the Water Code and applicable regulations, the RA is established annually by the Board of Directors. Mathematically, the RA is estimated based on the cost allocation analysis which includes assessing the beneficiaries their proportional share of the cost to provide water replenishment services.

As required by the Water Code, the District annually prepares the Engineering Survey & Report (ESR), which contains the following key components:

- A discussion of groundwater production within the District;
- An evaluation of groundwater conditions within the District, including estimates of the annual overdraft, the accumulated overdraft, changes in water levels, and the effects of water level fluctuations on the groundwater resources;
- An appraisal of the quantity, availability, and cost of replenishment water required for the ensuing water year; and
- A description of current and proposed programs and projects to accomplish replenishment goals and to protect and preserve high quality groundwater supplies within the District.

Specifically, the ESR provides an estimate of the total groundwater pumping quantity for the ensuing year, which is approximately 243,000 AF in the District's service area. Furthermore, the ESR identifies the quantity of supplemental water required to replenish and protect the groundwater basins, from pumping. The replenishment services, including descriptions of individual cost components, are provided in the previous chapters of this report. The total estimated cost of services for FY2011/12 is approximately **\$59,256,000**; which is necessary to service the estimated 243,000 AF of groundwater pumped in the basins. Therefore, the estimated total cost of service is allocated in proportion to the estimated total groundwater pumped. The unit cost per AF of water pumped, also known as Replenishment Assessment (RA), can be calculated as follows:

$$\text{Total Cost of Service (\$/Total Groundwater Pumped (AF) = Unit Cost (\$/AF pumped)}$$

For FY2011/12, the estimated unit cost, or Replenishment Assessment (RA), is as follows:

$$\text{Replenishment Assessment (\$/AF pumped) = } \$59,256,000 / 243,000 \text{ AF = } \$244.00 / \text{AF (rounded)}$$

To fund the services described in this report (cost of services), the District collects RA from operators of “water-producing facilities.” Such operators include municipal water utilities, water companies, and others who use wells to pump groundwater from the basins. Many of these operators pass through RA expenses to homeowners, businesses, schools, public properties, retail water customers, and others. The amount of RA charged to an operator is calculated based on the quantity of water pumped by the individual operator multiplied by the RA (unit cost of \$244/AF of water pumped). For example, if an operator pumps a total of 1,000 AF, that operator will be charged a total of \$244,000 (1,000 AF x \$244/AF).

11.0 DROUGHT

Droughts are a recurring phenomenon in Southern California, and the activities that WRD funds through its RAs provide a benefit to all pumpers by maintaining a reliable, drought-resistant supply of water.

As an example, continued dry conditions in the State led Governor Jerry Brown to declare a drought emergency on January 17, 2014. For California, calendar year 2013 was the driest year on record since the state started measuring rainfall in 1849, and in Los Angeles, the 3.6 inches of rainfall fell below the previous 1953 record of 4.08 inches and was over 11 inches below the average rainfall total of 14.93 inches.⁵ As of September 16, 2014, 95.4% of the Counties in California are in conditions of severe drought, 81.9% in extreme drought, and 58.4% exceptional drought, with Los Angeles County among the regions classified as under exceptional drought.⁶

For 55 years, WRD has served to prevent the depletion of groundwater by providing groundwater replenishment services to pumpers in the Basins. Sustainable management of groundwater supplies made possible by the replenishment operation of WRD results in multiple benefits to the pumping community.

First, the District's activities help to ensure the integrity of the Basins as an economic and beneficial water resource. The District was created to prevent the destruction of the Basins from over pumping and seawater intrusion. The continued existence of the Basins 55 years after the District was created demonstrates the long-term success of the District's replenishment and groundwater quality programs.

Second, replenishment activities of WRD reduce the average cost of service as pumpers are able to adjust their water portfolios to replace high-cost imported water with cheaper sources of groundwater replenished with water derived from stormwater capture, recycled water, and, when available, from cheaper sources of imported replenishment water.

Third, WRD provides pumpers in the Basins with a water source that is more reliable than imported water. The ability to utilize groundwater allows pumpers to decrease their exposure to supply rationing imposed on imported water during periods of extreme droughts.

Fourth, greater flexibility of groundwater use through carryover provisions provides a "last line of defense" against water shortages under conditions of extreme drought. Groundwater carryover provisions, which allow pumping rights that aren't used in one year to be carried over for use in another year, make it possible for pumpers to reduce pumping water during wet years when water is relatively abundant and extract it during drought conditions when imported water supplies are relatively scarce. This benefits all residents of California by reducing demand for imported water within the WRD service

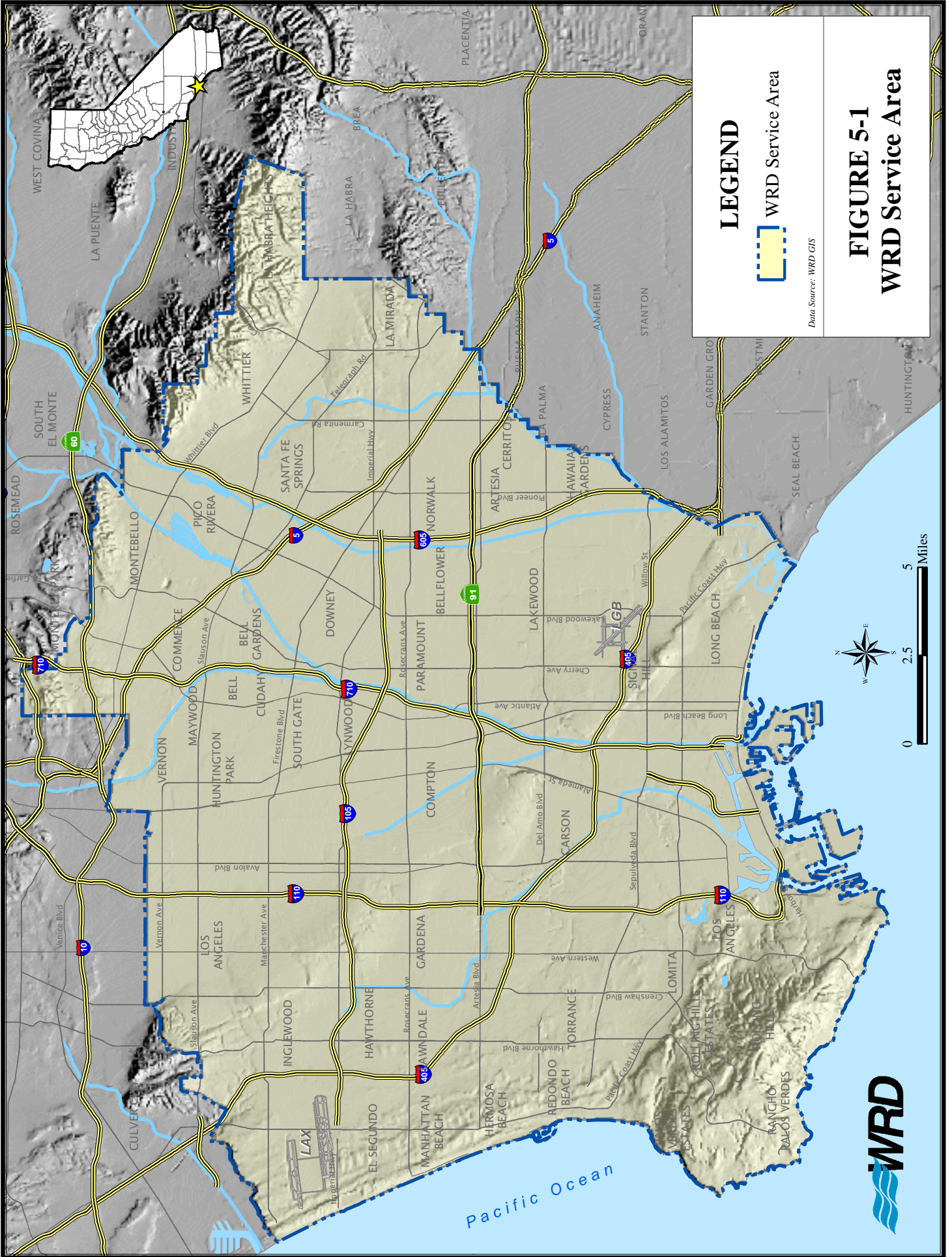
⁵ University Corporation for Atmospheric Research, AtmosNews
<<http://www2.ucar.edu/atmosnews/perspective/10879/california-dryin>>.

⁶ National Oceanic and Atmospheric Administration (NOAA)
<<http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?CA>>.

area, increasing availability of imported water to other regions of the State that cannot rely on groundwater during periods of extreme drought.

FIGURES

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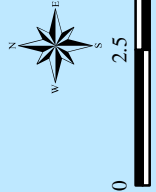
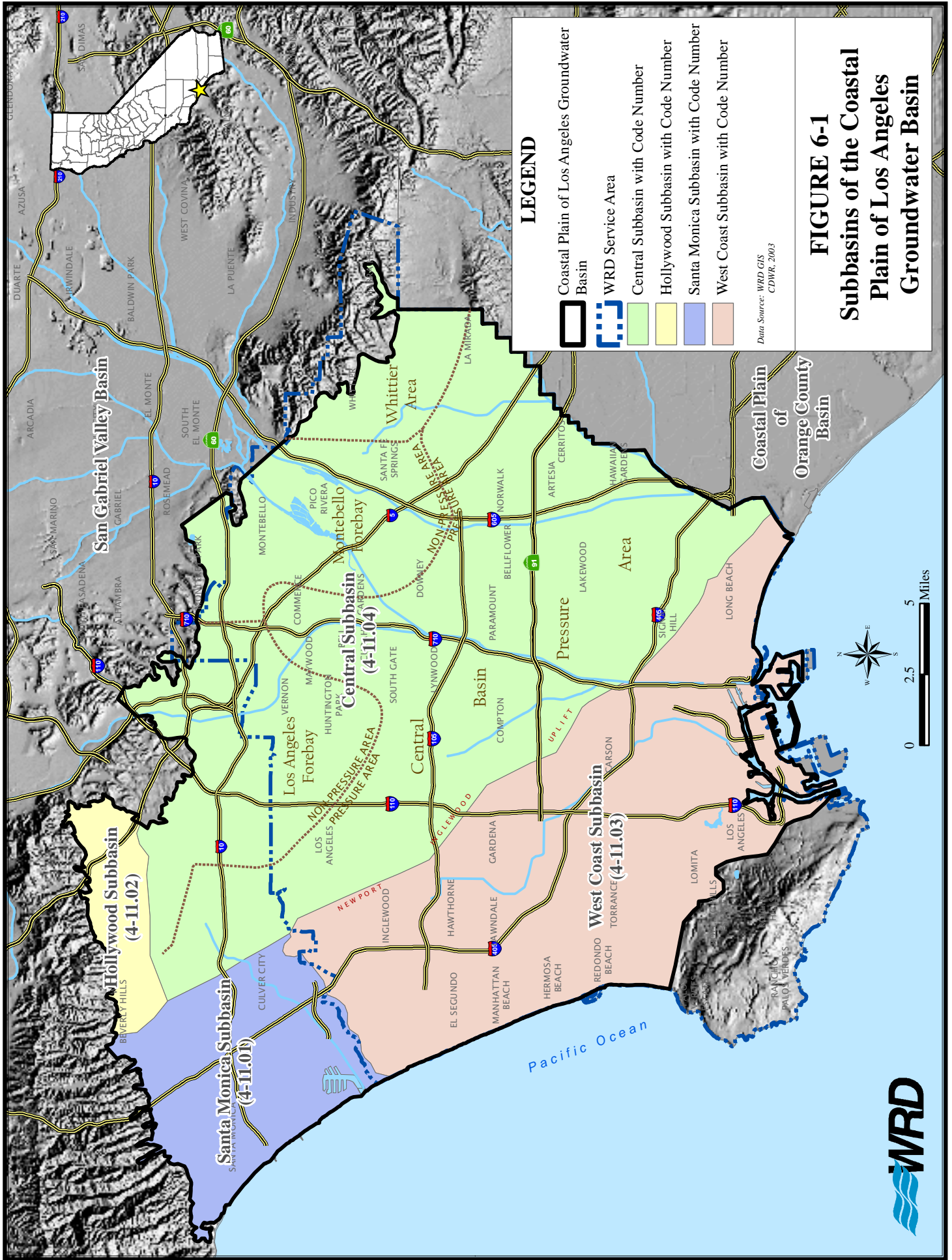
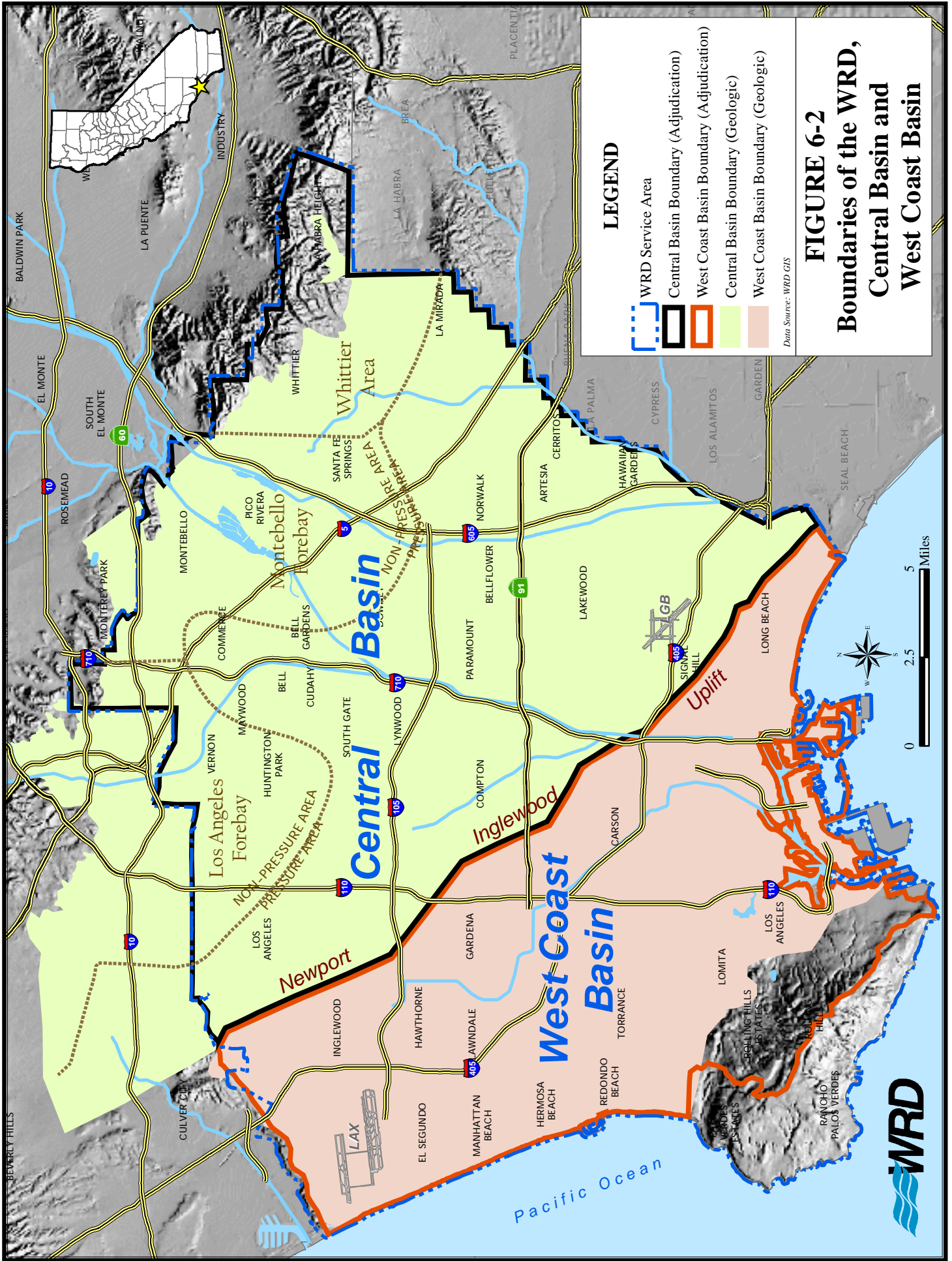
 WRD Service Area

FIGURE 5-1
WRD Service Area

Data Source: WRD GIS







LEGEND






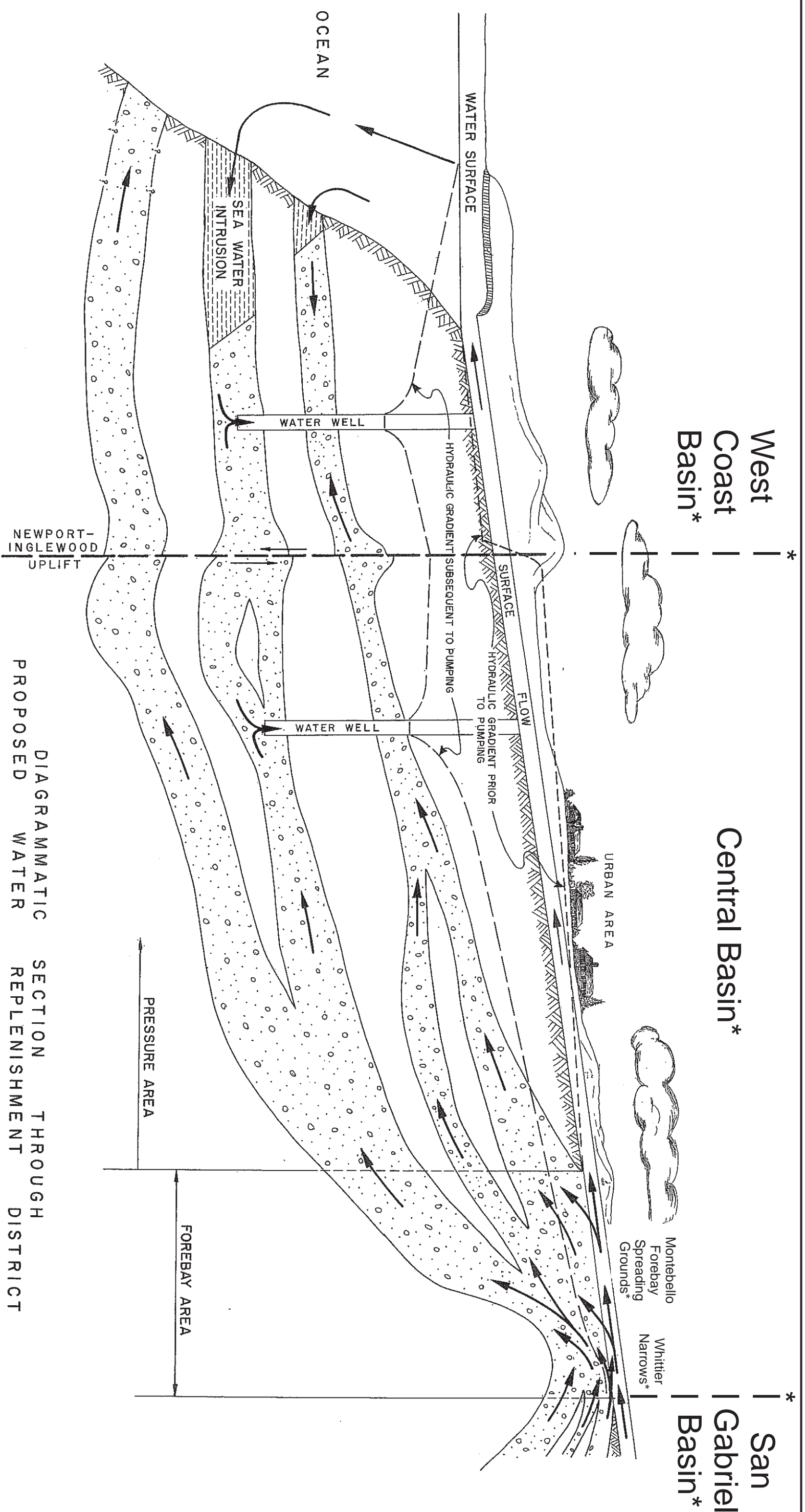
-  WRD Service Area
 -  Central Basin Boundary (Adjudication)
 -  West Coast Basin Boundary (Adjudication)
 -  Central Basin Boundary (Geologic)
 -  West Coast Basin Boundary (Geologic)
- Data Source: WRD GIS*

FIGURE 6-2
Boundaries of the WRD,
Central Basin and
West Coast Basin



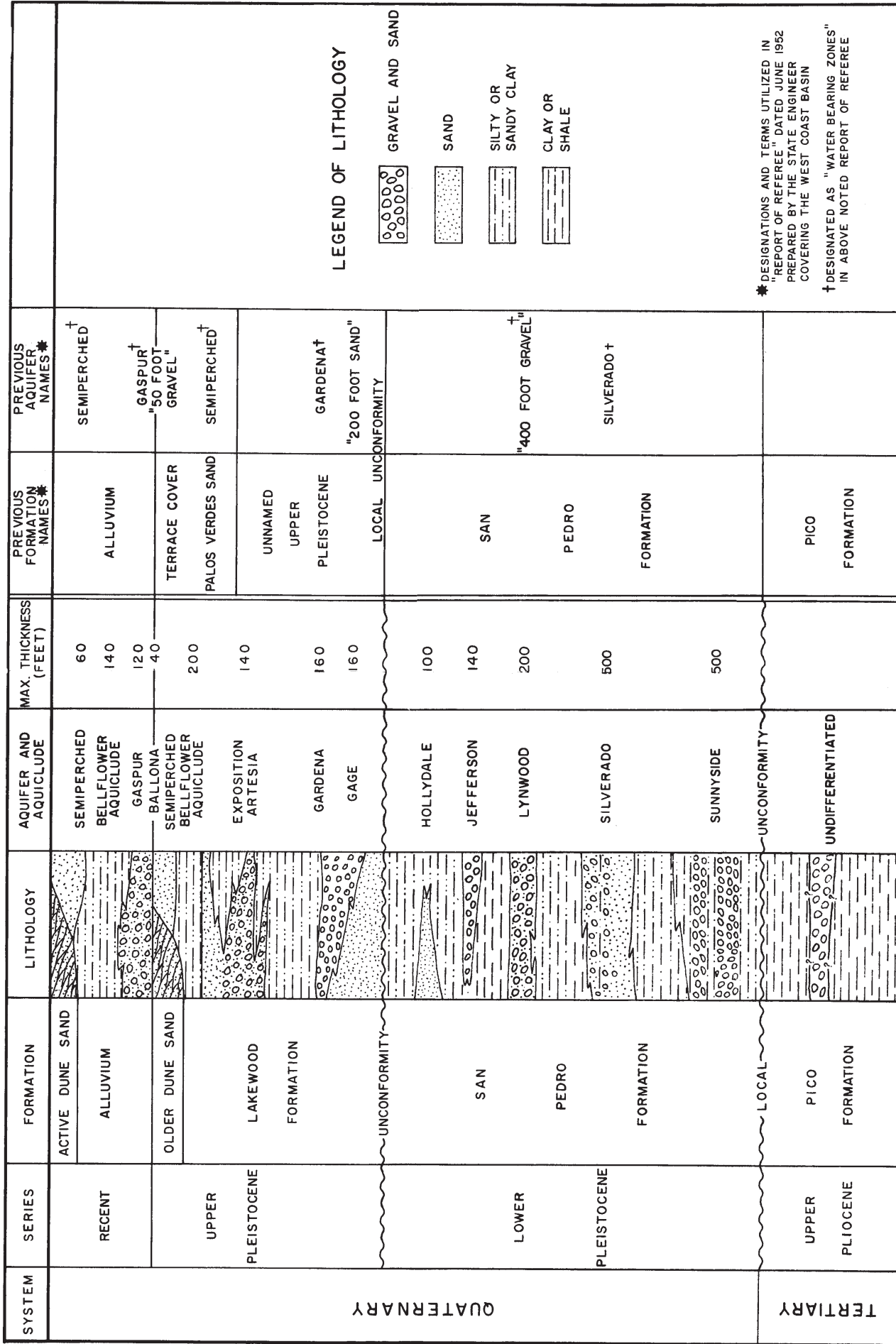
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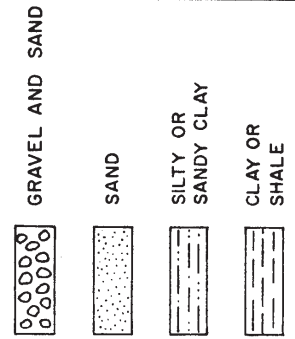
Data Source: CDWR, 1959
 * Text and Lines added by WRD for Clarity

Figure 6-3

Generalized Cross-Section



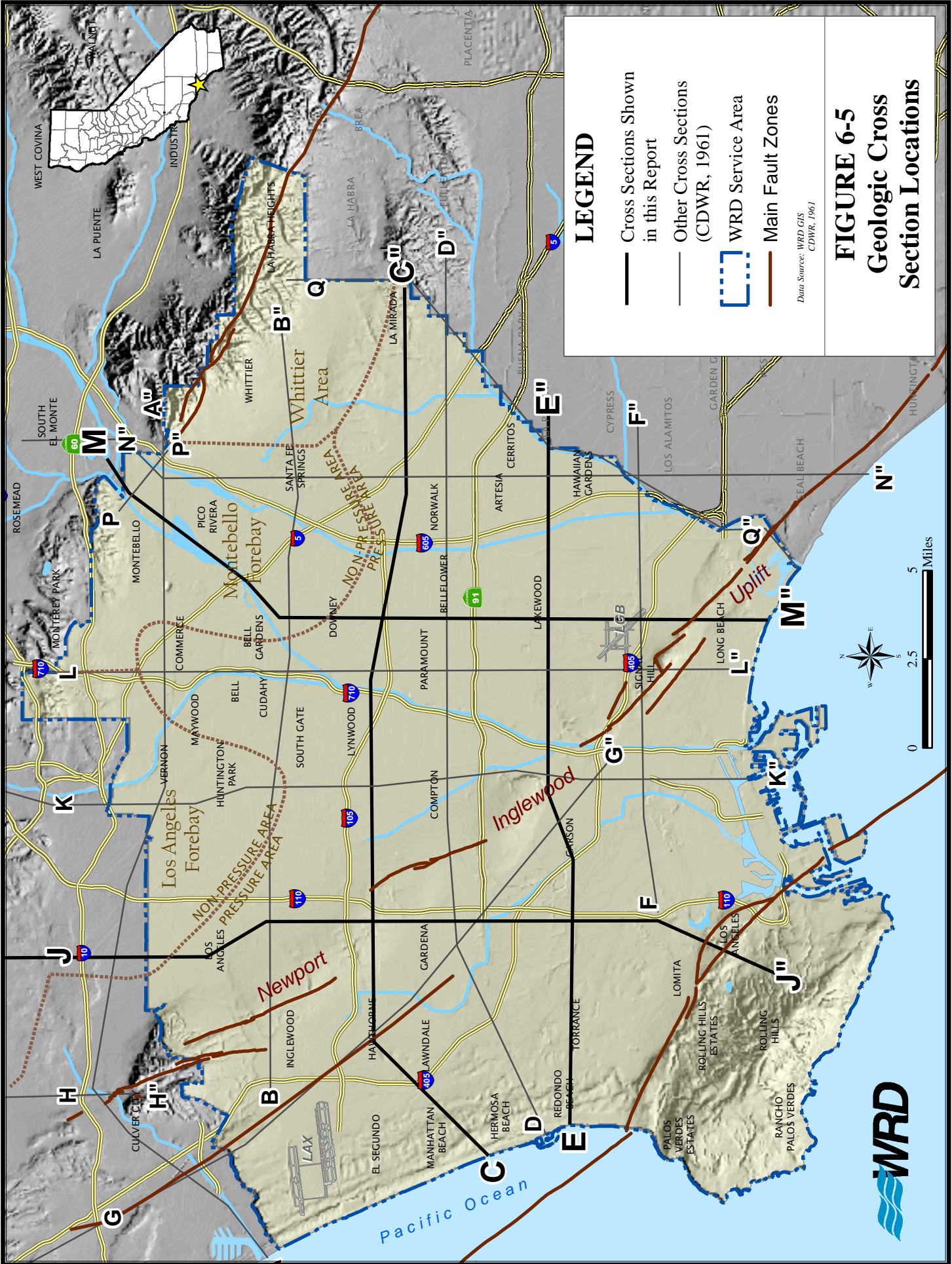
LEGEND OF LITHOLOGY



* DESIGNATIONS AND TERMS UTILIZED IN "REPORT OF REFEREE" DATED JUNE 1952 PREPARED BY THE STATE ENGINEER COVERING THE WEST COAST BASIN
[†] DESIGNATED AS "WATER BEARING ZONES" IN ABOVE NOTED REPORT OF REFEREE

Figure 6-4
 Data Source: CDWR, 1961 - Plate 5

GENERALIZED STRATIGRAPHIC COLUMN
 COASTAL PLAIN OF LOS ANGELES COUNTY



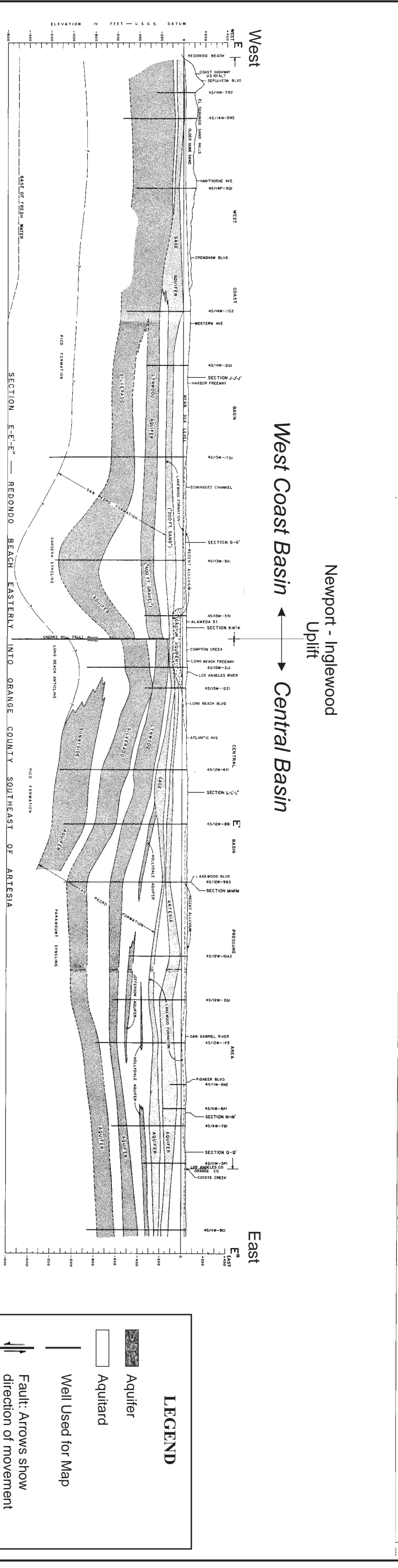
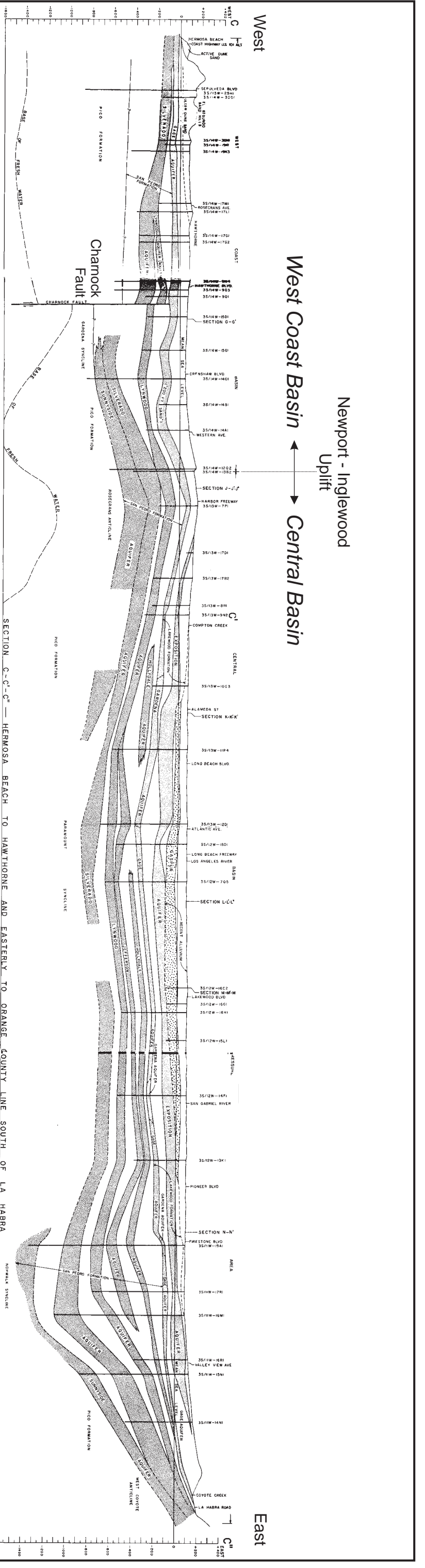
LEGEND

- Cross Sections Shown in this Report
- Other Cross Sections (CDWR, 1961)
- ▭ WRD Service Area
- Main Fault Zones

Data Sources: WRD GIS, CDWR, 1961

FIGURE 6-5
Geologic Cross
Section Locations





LEGEND

- Aquifer
- Aquitard
- Well Used for Map
- Fault: Arrows show direction of movement

0 6,000
Horizontal Scale (feet)

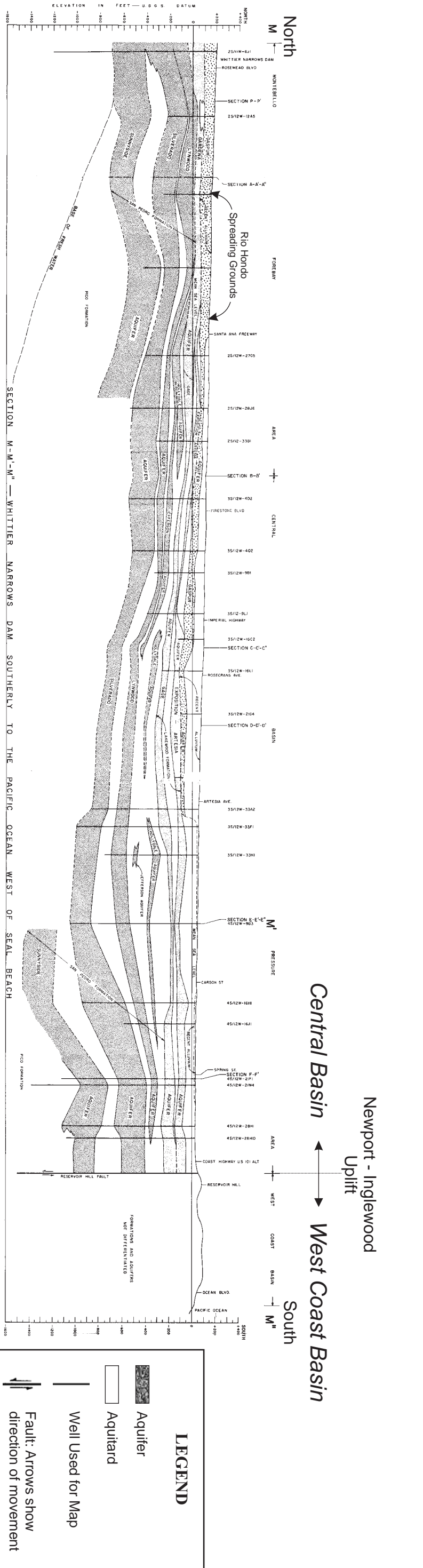
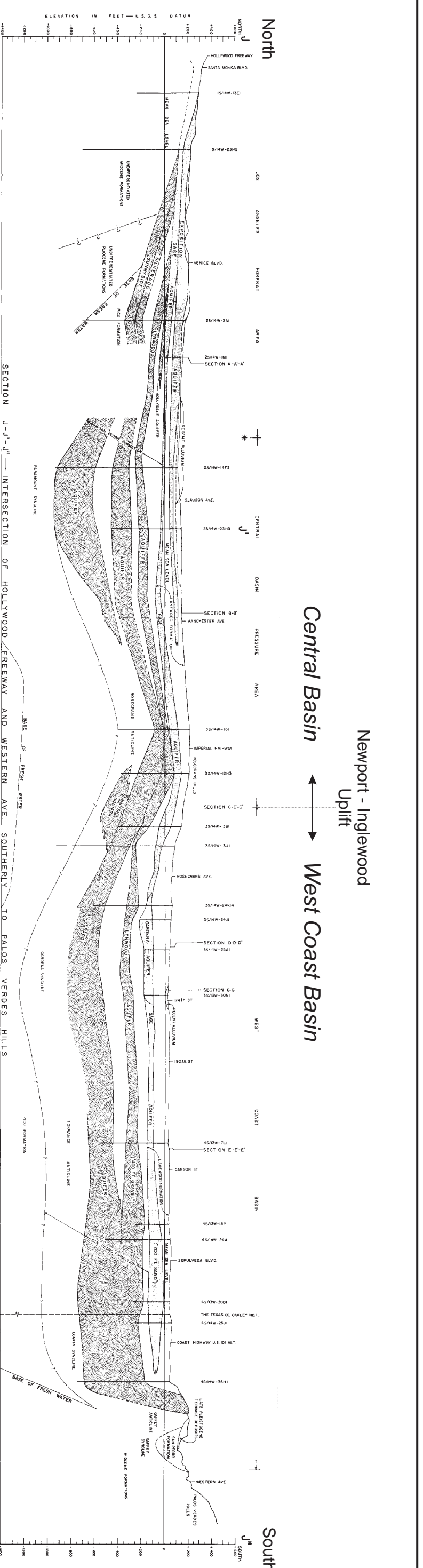
Data Source: CDWR, 1961

Text added by WRD for Clarity: West Coast Basin, Central Basin, Newport-Inglewood Uplift, East and West, Chamcock Fault, and arrow lines

Top Cross Section C-C'": Note that aquifers cross the Newport-Inglewood Uplift from the Central Basin into the West Coast Basin without any geologic offset of the aquifers. No separation.

Lower Cross Section E-E'": Aquifers are depicted as being partially cut off and separated by the Newport-Inglewood Uplift.

Figure 6-6
Geologic Cross Sections C & E



Text added by WRD for Clarity: West Coast Basin, Central Basin, Newport-Inglewood Uplift, South and North, J J' M M', Rio Hondo Spreading Grounds, and arrow lines.

Top Cross Section J-J': Note that aquifers cross the Newport-Inglewood Uplift from the Central Basin into the West Coast Basin without any geologic offset of the aquifers. No separation.

Lower Cross Section M-M': Aquifers are depicted as being cut off by the Newport-Inglewood Uplift and the aquifers on the West Coast Basin side have not been differentiated in this part of the basin.

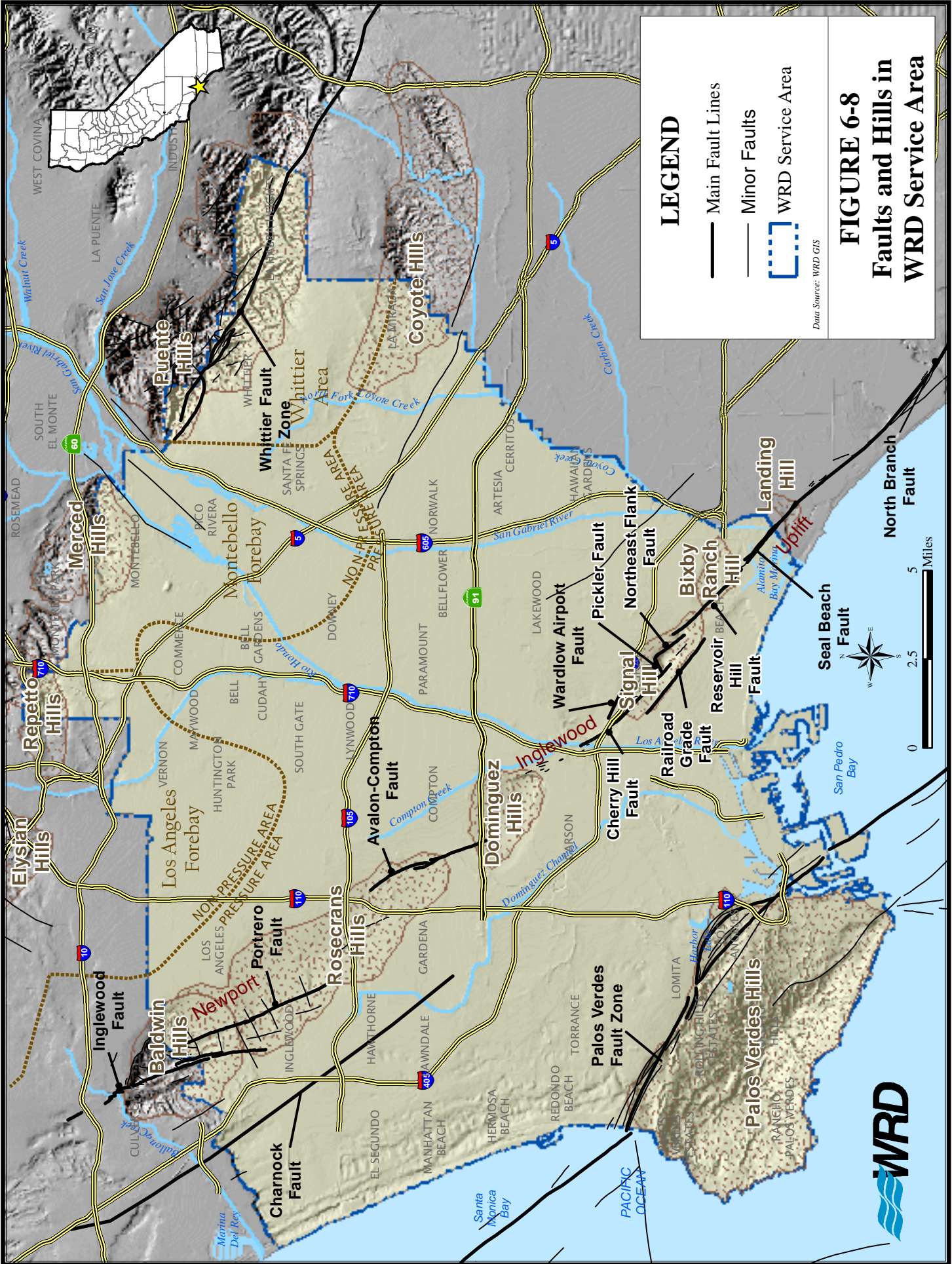
LEGEND

- Aquifer**
- Aquitard**
- Well Used for Map**
- Fault: Arrows show direction of movement**

0 6,000
Horizontal Scale (feet)

Data Source: CDWR, 1961

Figure 6-7
Geologic Cross
Sections J & M



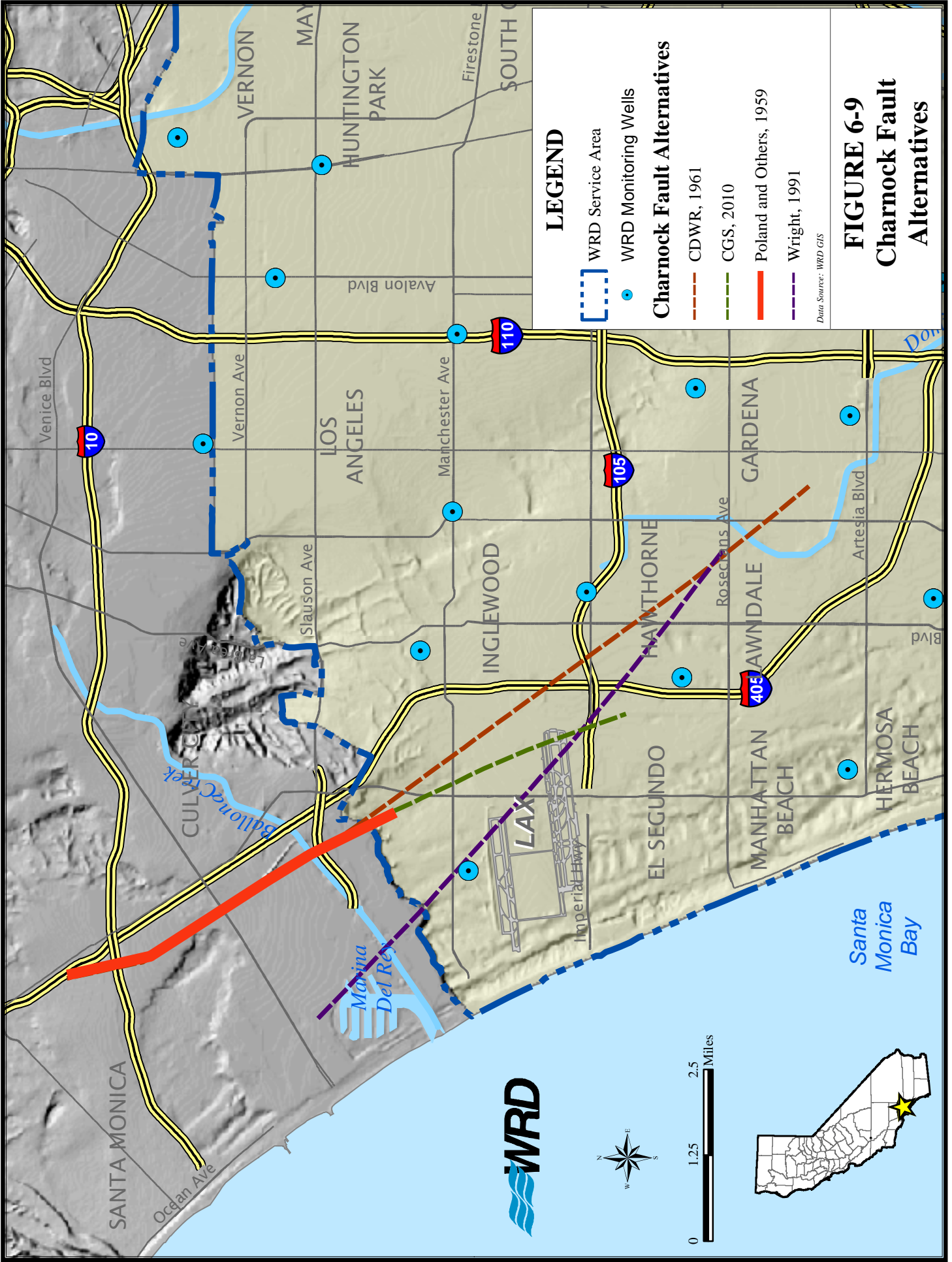
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- Main Fault Lines
- Minor Faults
- ▭ WRD Service Area







FIGURE 6-8
Faults and Hills in
WRD Service Area

Data Source: WRD GIS



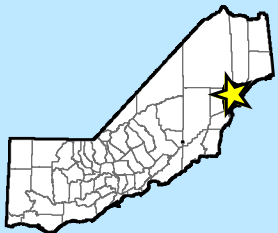


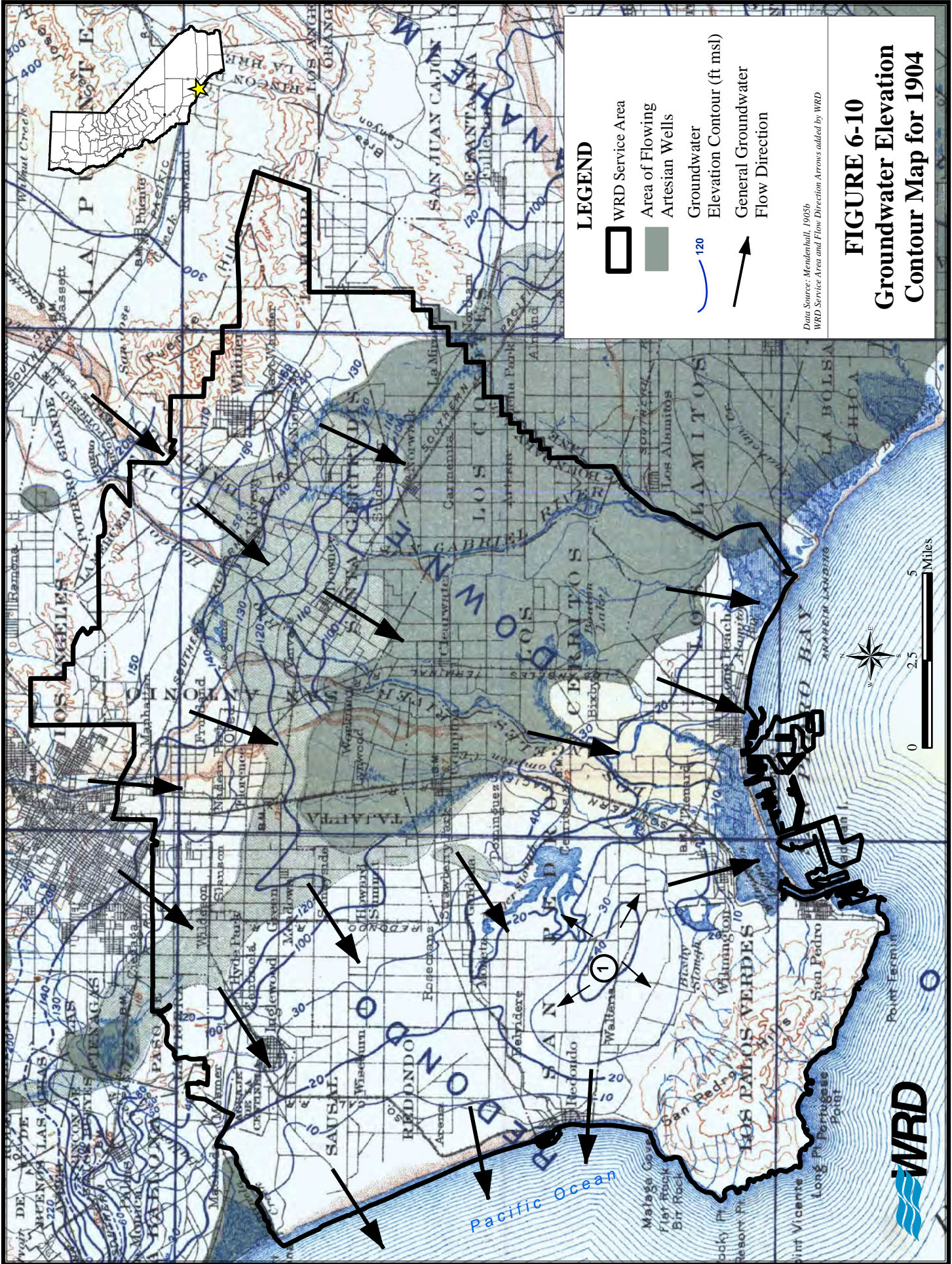
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-  WRD Service Area
 -  WRD Monitoring Wells
- Charnock Fault Alternatives**
-  CDWR, 1961
 -  CGS, 2010
 -  Poland and Others, 1959
 -  Wright, 1991

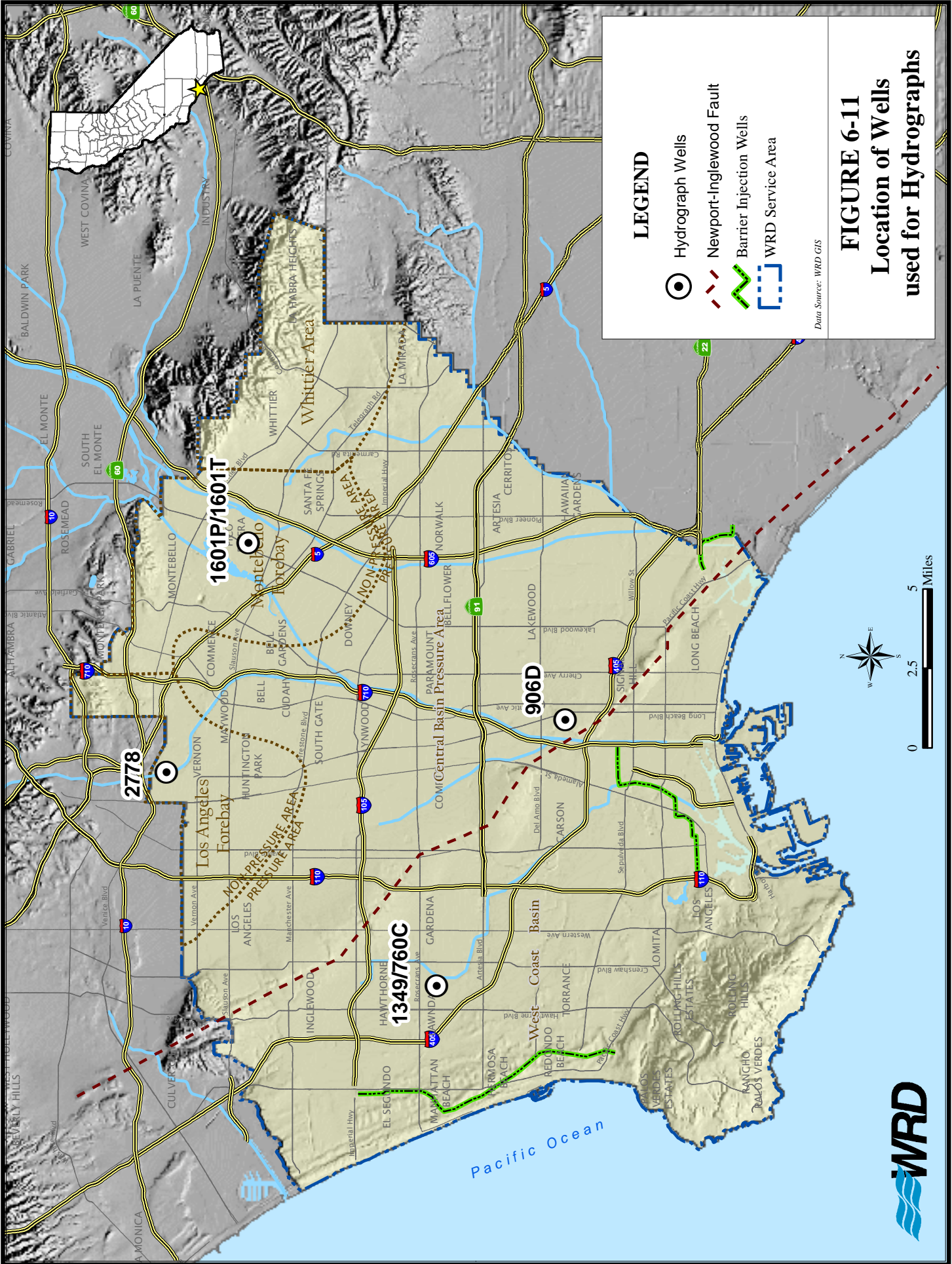
Data Source: WRD GIS

FIGURE 6-9
Charnock Fault
Alternatives





① Mendenhall (1905b) showed this apparent water level mound, but CDPW (1934-footnote on page 67) explained that this was an error due to incorrect topography used on the Mendenhall map. The mound does not exist when the correct topography is used.



LEGEND

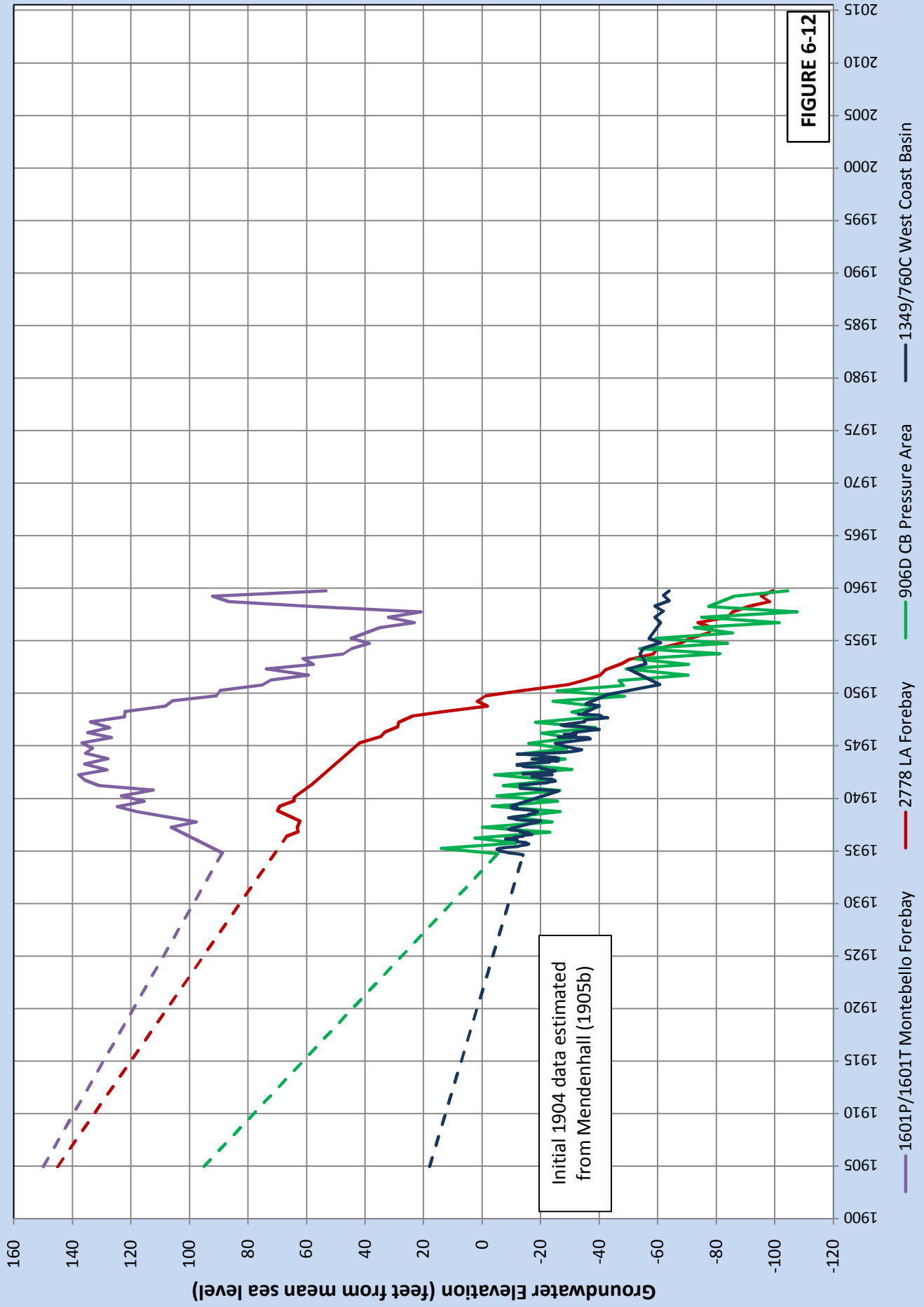
- Hydrograph Wells
- Newport-Inglewood Fault
- Barrier Injection Wells
- WRD Service Area

Data Source: WRD GIS

FIGURE 6-11
Location of Wells
used for Hydrographs



Groundwater Level Hydrographs - 1904 - 1960



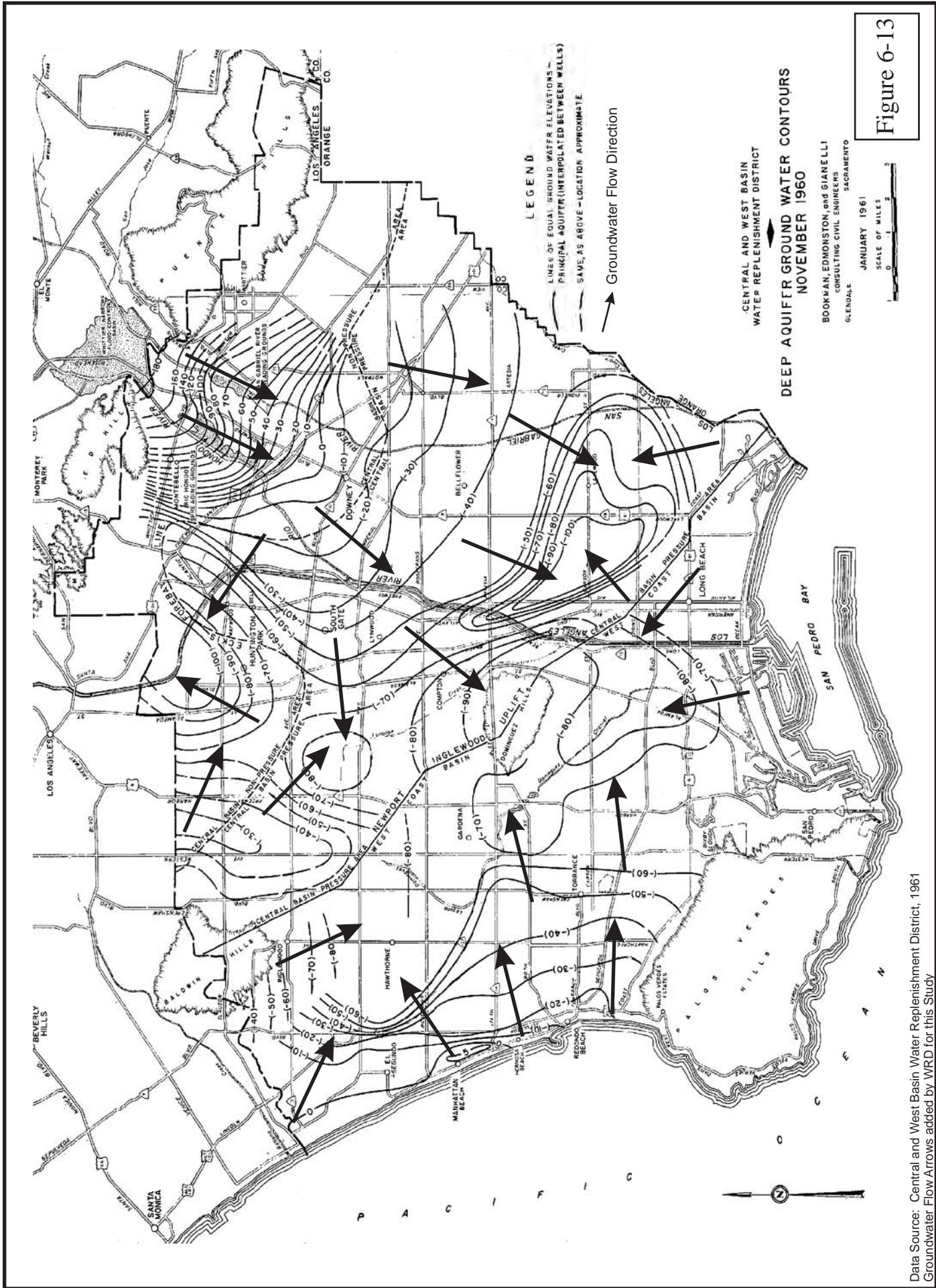


Figure 6-13

Data Source: Central and West Basin Water Replenishment District, 1961
 Groundwater Flow Arrows added by WRD for this Study

Groundwater Level Hydrographs - 1904 - 2011

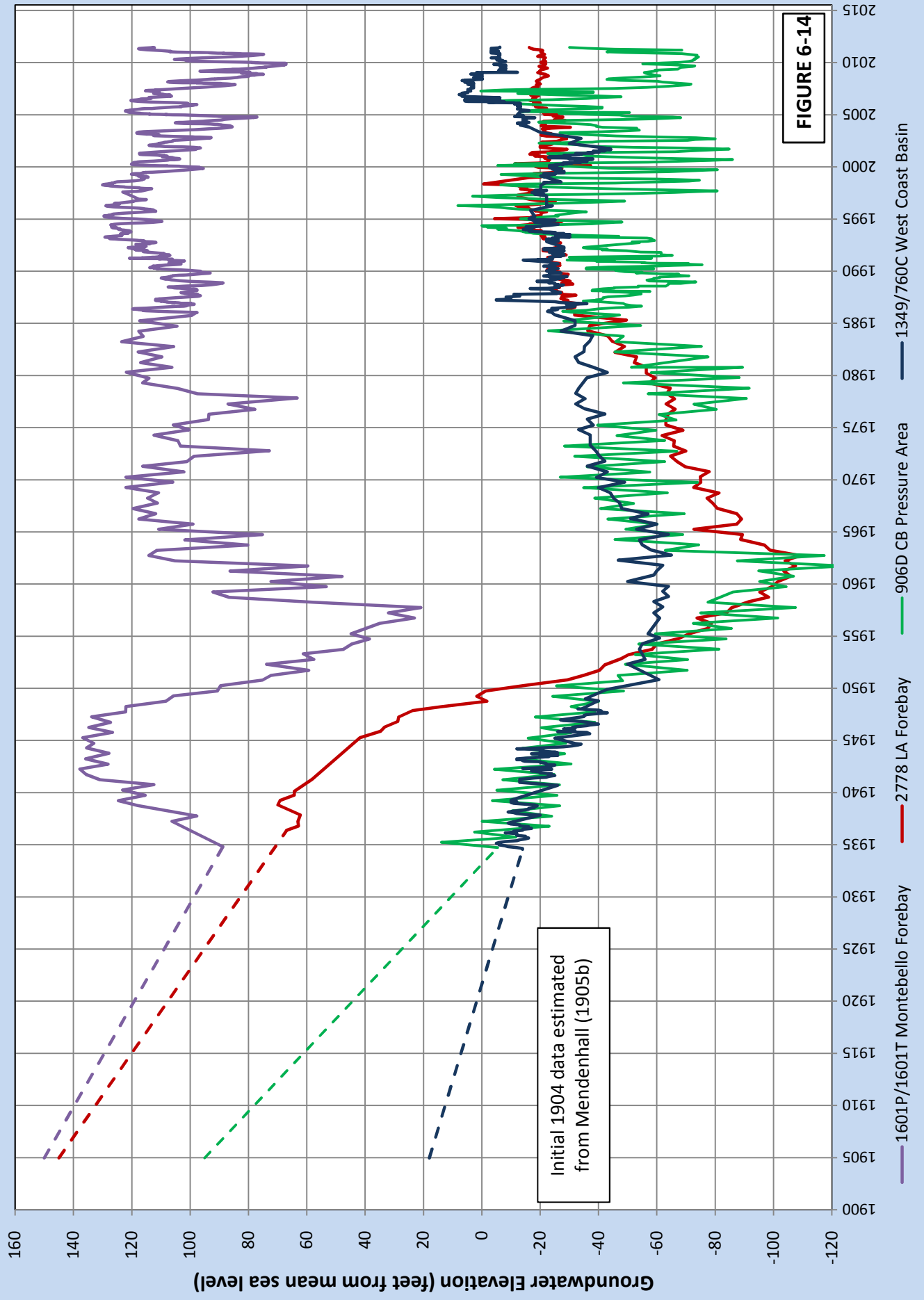
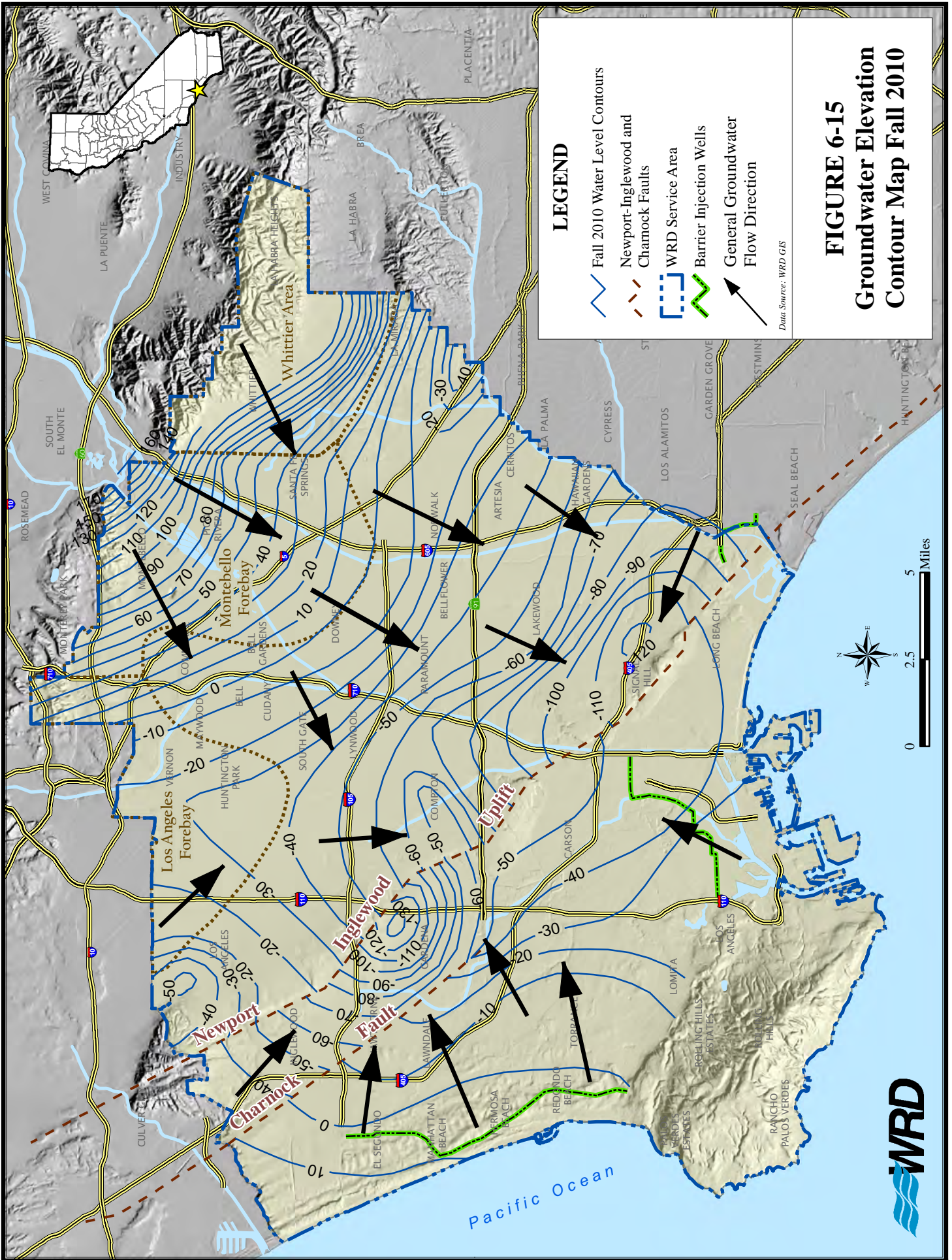







FIGURE 6-14



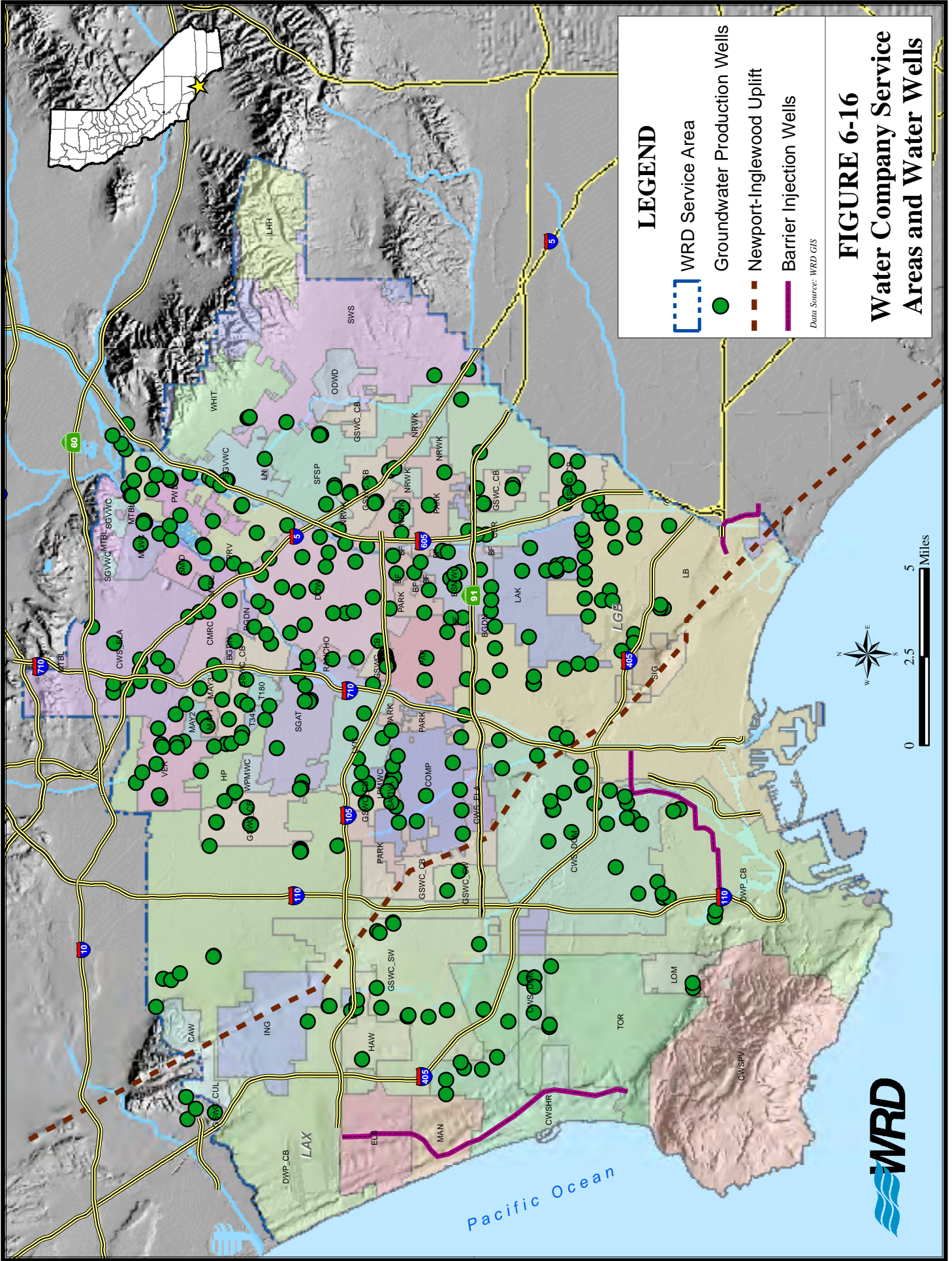
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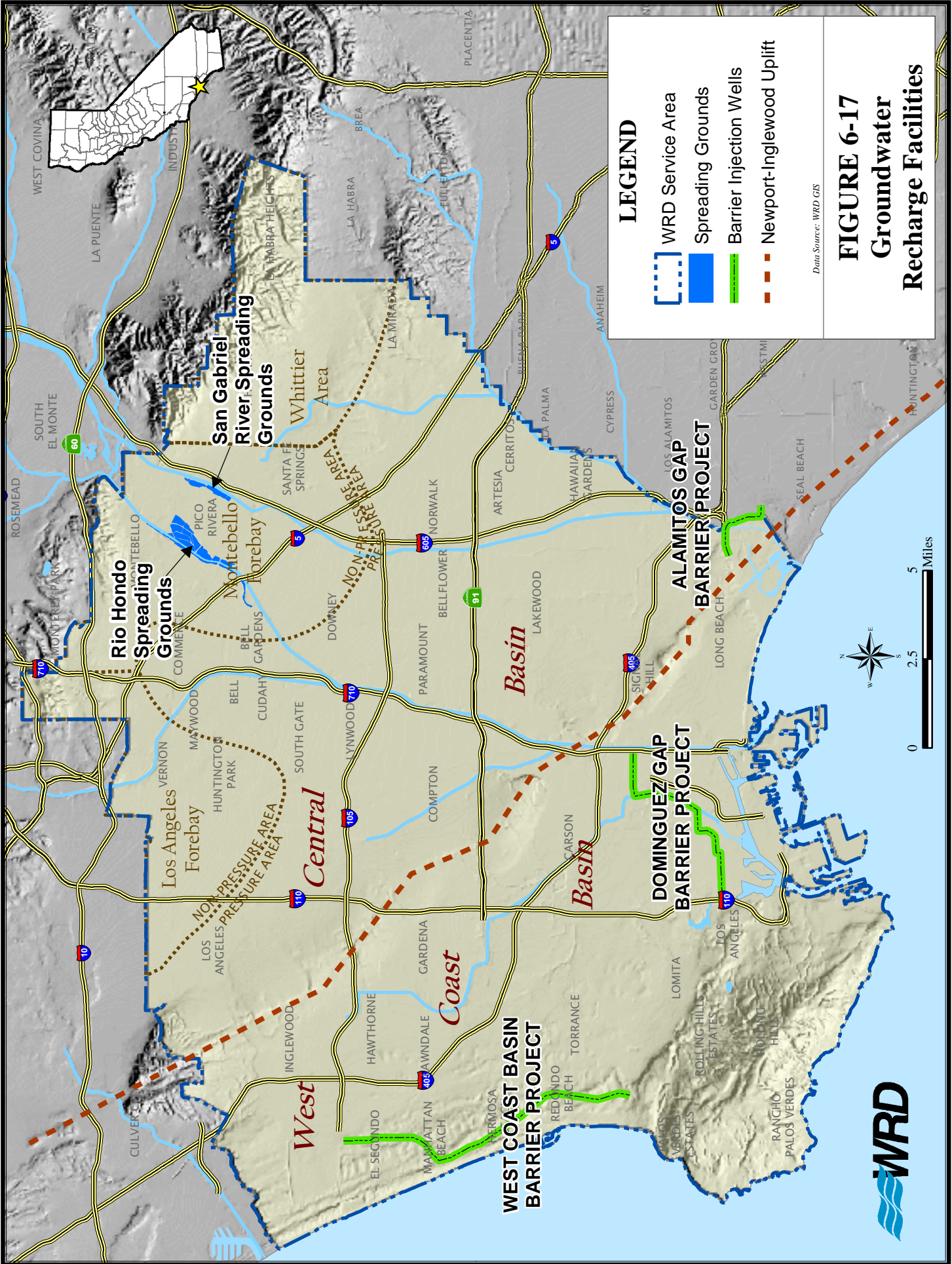
-  Fall 2010 Water Level Contours
-  Newport-Inglewood and Chamock Faults
-  WRD Service Area
-  Barrier Injection Wells
-  General Groundwater Flow Direction

Data Source: WRD GIS

FIGURE 6-15
Groundwater Elevation
Contour Map Fall 2010





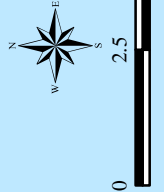


LEGEND

- WRD Service Area
- Spreading Grounds
- Barrier Injection Wells
- Newport-Inglewood Uplift

Data Source: WRD GIS

FIGURE 6-17
Groundwater
Recharge Facilities



Rio Hondo Coastal Spreading Grounds



Spreading grounds owned and operated by LACDPW. Stormwater captured and spread by LACDWP. Imported and recycled water for spreading purchased by WRD.

San Gabriel Coastal Spreading Grounds

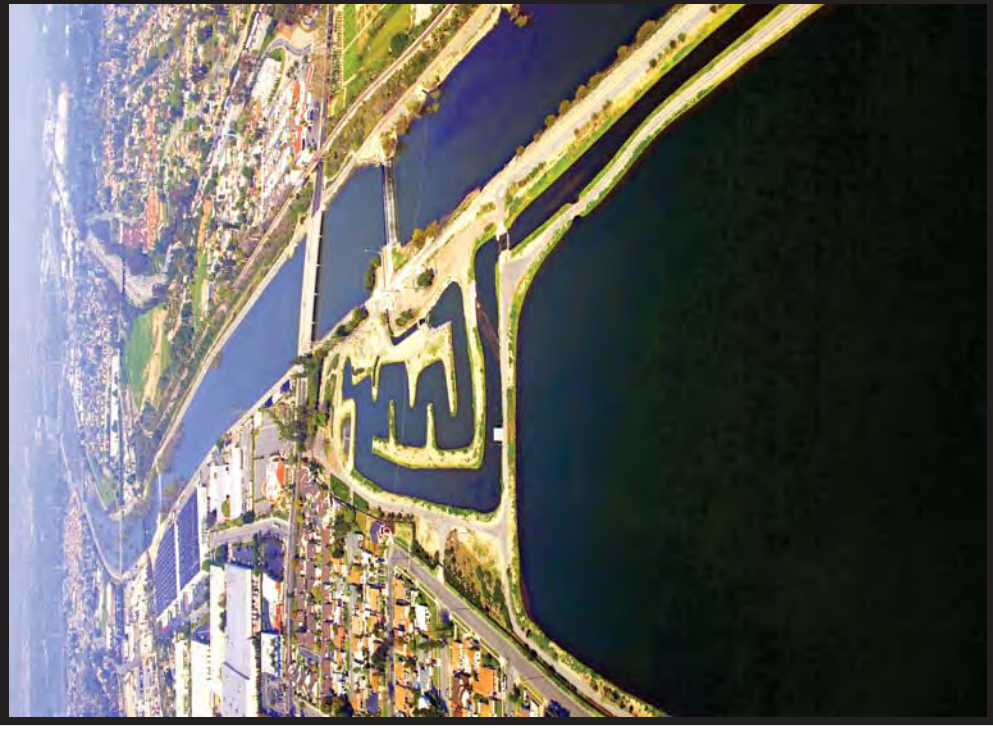
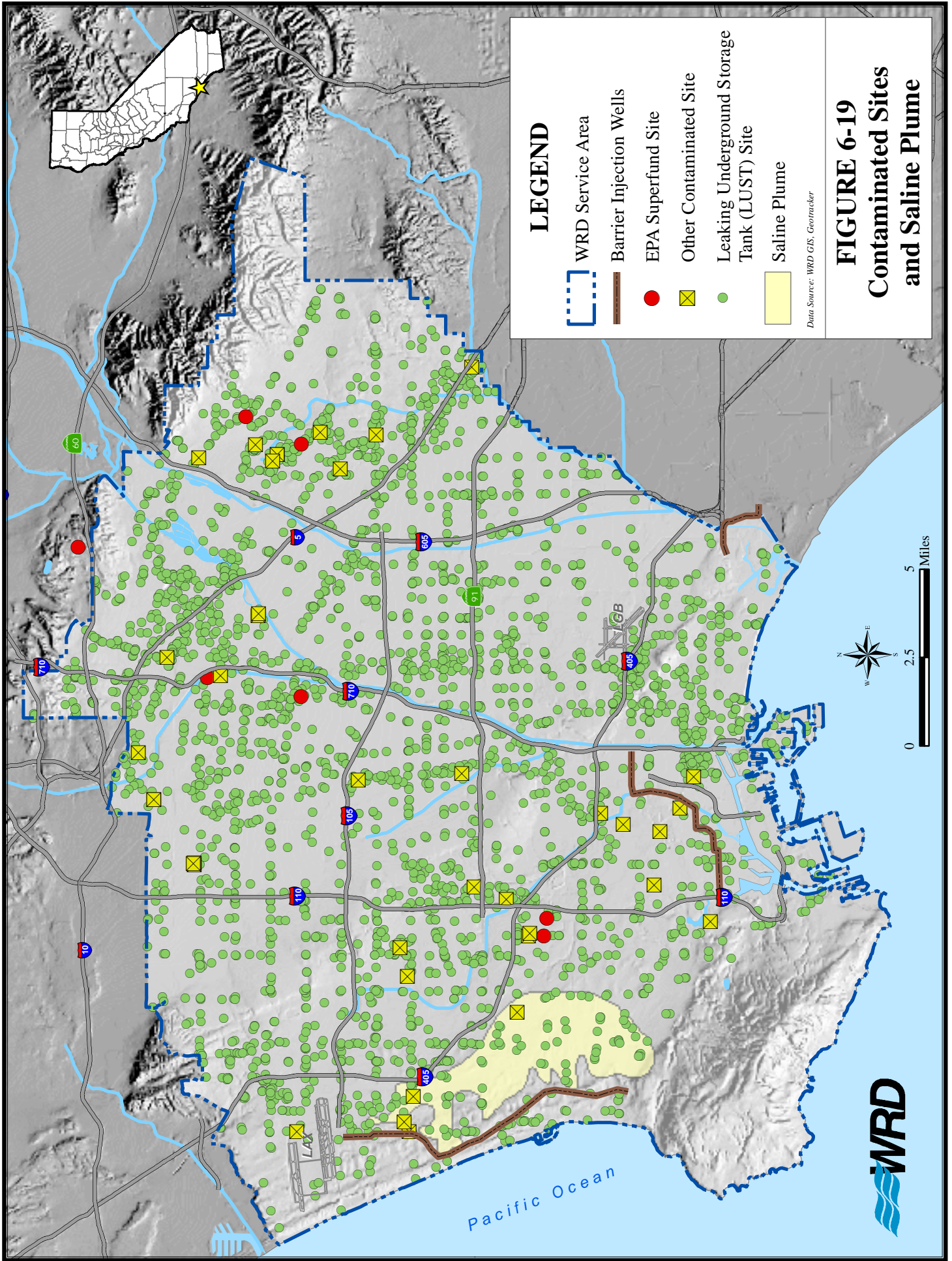








Figure 6-18
Rio Hondo and San Gabriel
Coastal Spreading Grounds



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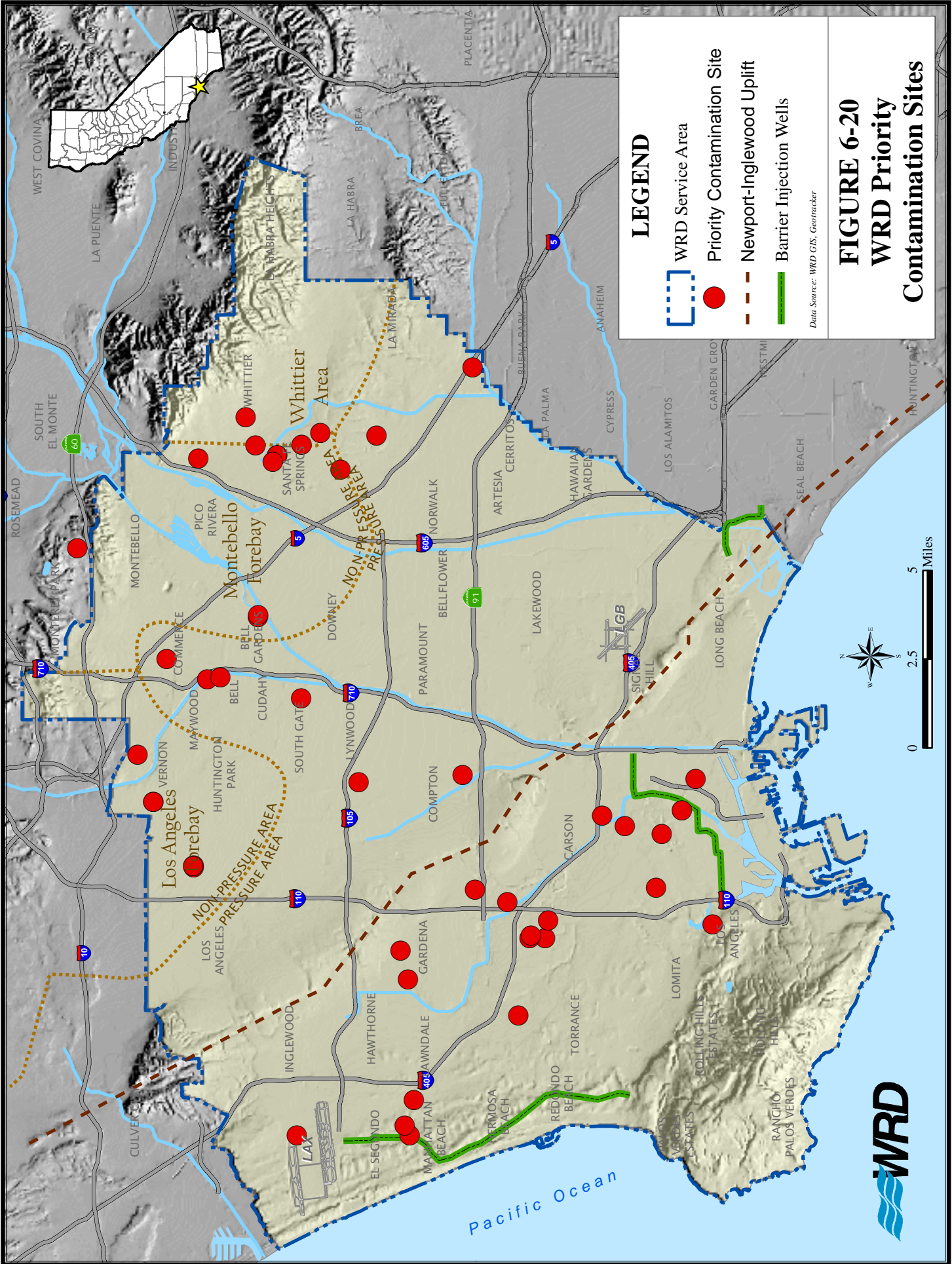
-  WRD Service Area
-  Barrier Injection Wells
-  EPA Superfund Site
-  Other Contaminated Site
-  Leaking Underground Storage Tank (LUST) Site
-  Saline Plume

Data Source: WRD GIS, Geotracker

FIGURE 6-19
Contaminated Sites
and Saline Plume



Pacific Ocean

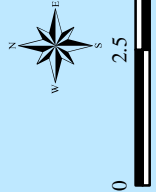


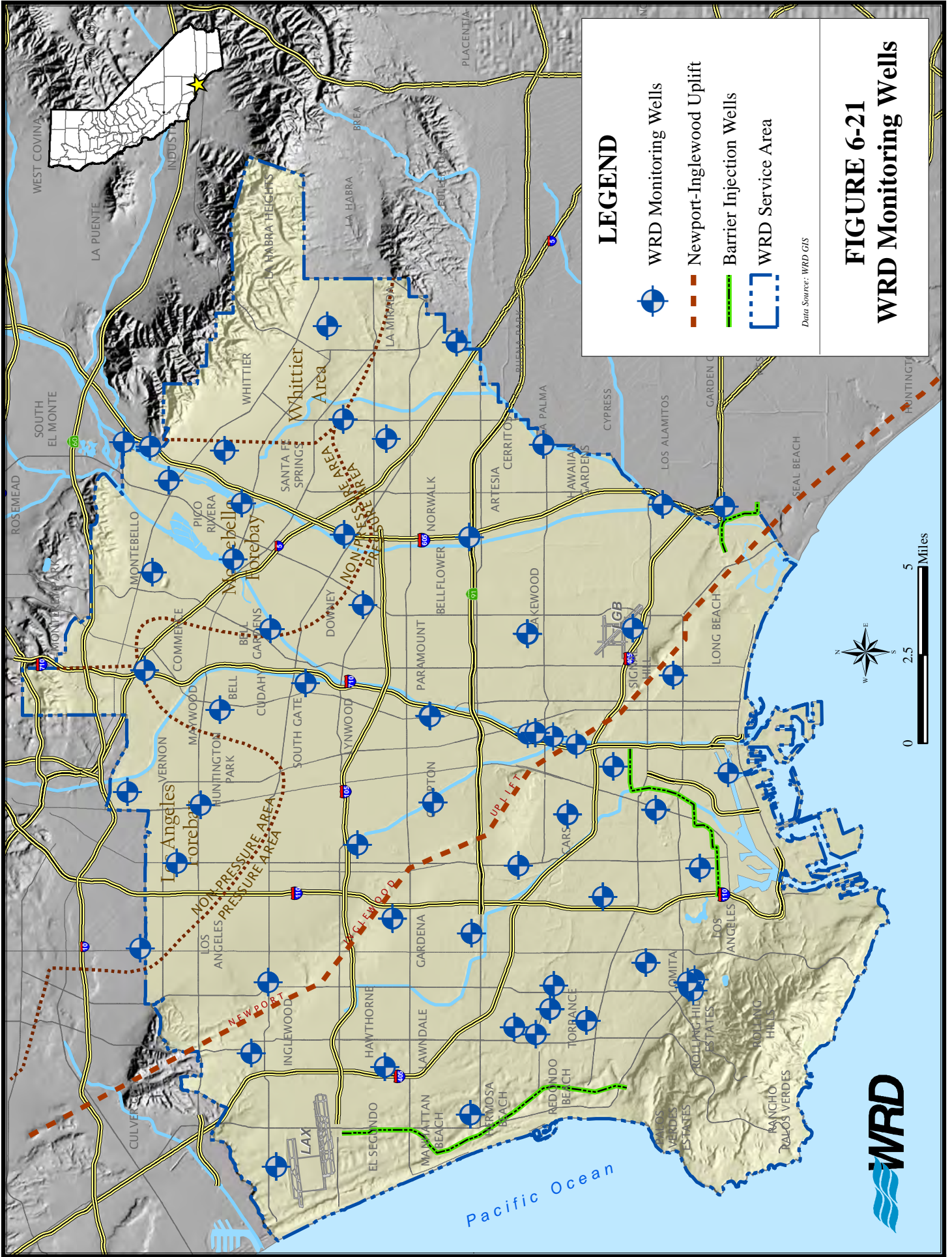
LEGEND

- WRD Service Area
- Priority Contamination Site
- Newport-Inglewood Uplift
- Barrier Injection Wells

Data Source: WRD GIS, Geotracker

FIGURE 6-20
WRD Priority
Contamination Sites





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Water Replenishment District of Southern California
4040 Paramount Blvd., Lakewood, CA 90712
(562) 921-5521 www.wrd.org