WRD

WATER REPLENISHMENT DISTRICT
OF SOUTHERN CALIFORNIA

Cost of Service Report

April 3, 2014

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Water Replenishment District of Southern California

COST OF SERVICE REPORT

April 3, 2014

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.

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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
CBWCB	Central Basin and West Coast Basin
CPR	Common Pool Resource
CSDLAC	County Sanitation Districts of Los Angeles County
CWS	California Water Service Company
CWSC	California Water Service Company
DGB	Dominguez Gap Barrier
DTSC	California Department of Toxic Substances Control
EPA	U.S. 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
RWQCB-LA	California Regional Water Quality Control Board – Los Angeles
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
USEPA	United States Environmental Protection Agency
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

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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 Ostrum 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 purpose of the District is to manage that common pool resource that is really two interconnecting groundwater subbasins of what the California Department of Water Resources describes as the Coastal Plain of Los Angeles Groundwater Basin. In effect, the Basins serve as a massive underground water storage system. Millions of residents and non-residential water users throughout the District's service area in southern Los Angeles County rely on water pumped from the Basins by municipal water utilities, investor-owned water companies, mutual water companies and private companies that pump for their own use. It is far less expensive 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 moves 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 larger and larger.

Excessive pumping anywhere in the Basins can cause problems throughout the Basins. The boundary between the Central Basin and West Coast Basin is based upon an arbitrary line approximating the centerline of a geologic structure known as the Newport-Inglewood Uplift. However, 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 allows groundwater to flow across the structure depending on the groundwater slope and tightness of sediments across the Uplift which varies both spatially and at depth. Indeed, in the absence of pumping activities, tens of 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, can be reduced by overpumping in the Central Basin. When the underflow is sufficiently reduced, seawater from the West Coast Basin can intrude into the Central Basin notwithstanding the presence of the Uplift. Thus, 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 the availability of water in the Basins for the pumping activities that are permitted under the basin adjudications.

In effect, the District uses the Basins as a mechanism for delivering safe, high quality water to 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 an effective delivery system, 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 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 District.

The District anticipates that the net cost of its operations for Fiscal Year 2014-15 will be $64,850,000. It anticipates that pumpers will remove 242,000 acre-feet of water from the Basins during the Fiscal Year. Therefore, the cost of providing services will be $268 per acre-foot of water removed from the Basins.

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 anticipates performing in fiscal year 2014-15 and 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 replenishment assessment 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 a Replenishment Assessment 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 2014-15 Cost of Service and Section 10 is the proposed Replenishment Assessment 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 Coast Basin) as well as portions outside of these basins in the Palos Verdes Hills.

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 U.S.G.S. 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 Ostrum 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. 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?

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, 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.

While Central Basin pumpers from the outset favored a single district covering both basins, it 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,” Ostrum 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 a November 17, 1955 report to the West Basin Water Association (WBWA), R.R. Thorburn, Chairman of the WBWA Replenishment District Committee, listed reasons for a district covering West Basin only as well as for a single district covering the two basins [(11)]:

<u>Reasons for a West Basin Water Replenishment District</u>:

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 was 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 relinquished by West Basin.
5. A district limited to West Basin could initiate proceedings to ensure financial replenishment from Central Basin.

"In other words," Ostrum 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." [(12)]

<u>Reasons for a replenishment district covering both basins</u>:

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 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. [(13)]

At the time, 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." [14]

A plan for a replenishment district limited to Central Basin was never advanced 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 WBWA. 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 fully aware that a combined district meant a single replenishment assessment for pumpers in both basins. Under the Water Replenishment District Act, any replenishment assessment adopted by a replenishment district board had to be uniform and based on groundwater production. (16)

5.5 The Underflow

Even in the face of whatever "disadvantages" Thomas had in mind, Central Basin pumpers supported formation of a single replenishment district 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 as they did 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]

The findings were ominous for Central Basin pumpers as well. An underflow number coming from a court-appointed state agency established a plausible right West Basin had to natural replenishment from Central Basin. As the volume of underflow diminished, as they soon realized it would, the risk of the potential Central Basin obligation to reduce pumping increased.

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 Board Chairman Joe Jensen put the formation of a single replenishment district covering both basins into a decidedly legal context. He said that "in his opinion, 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)

The implication of Jensen's message was not lost on Central Basin pumpers. 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)

Thomas made explicit in 1958 the legal concerns he and other Central Basin pumpers had with respect to West Basin pumpers since the *Report of Referee* in connection with the West Basin adjudication was published six years earlier.

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)]

Like their Central Basin counterparts, West Basin producers came to see the formation of a single replenishment district as an attractive alternative to litigation. "After their costly experience with litigation," Ostrum 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 Metropolitan Water District ("Metropolitan") would guarantee the delivery of sufficient water to meet the replenishment needs in either basin. 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 Alamitos 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 no authority to purchase replenishment water with property tax money and 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]

Ostrum 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 Ostrum 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*, Ostrum 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," Ostrum 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 halted with the completion of the Alamitos Barrier in 1964. Intrusion in West Basin was halted 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 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 is fully 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 Ostrum, *Public Entrepreneurship: a Case Study in Groundwater Basin Management* (Doctoral Dissertation, University of California, Los Angeles, 1965), pp. 414 - 460; Elinor Ostrum, *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.

Ostrum 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 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." Ostrum (1990), p. 29.

In her December 8, 2009 Nobel Prize Lecture, Ostrum 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 Ostrum, "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*.

(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; Ostrum (1965) pp. 414 – 460 and Ostrum (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) Ostrum (1990) p. 129.

(10) *Ibid.* p. 131.

(11) 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.

(12) Ostrum, *op. cit.,* p. 236.

(13) 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.

(14) WBWA, Minutes, November 17, 1955.

(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) Ostrum, *op. cit.,* p. 117.

(19) Carl Fossette, *West Basin Water News*, May 3, 1952.

(20) WBWA, Minutes, February 23, 195*6.*

(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. 2[nd] 137 (August 20, 1959).

(26) WBWA, Minutes, November 15, 1956.

(27) WBWA, Minutes, November 20, 1958.

(28) Fossette (1990), p. 222.

(29) Ostrum (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) Ostrum (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.

(36) CBWA, Minutes, August 7, 1958; WBWA, Minutes, August 28, 1958.

(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) Ostrum (1965), p. 455.

(39) Chapter 1514, Statutes of California, 1955. Procedures required for district formation are in Sections 60080 – 60125.

(40) Los Angeles County Registrar of Voters, “Certificate…as to the Sufficiency of a Petition to Incorporate a Water Replenishment District, to Be Designated ‘Central and West Basin Water Replenishment District’, Under and Pursuant to the Provisions of the Municipal Water Replenishment Act” (sic), June 2, 1959.

(41) *Ibid*. For a discussion of the petition campaign, see Water Replenishment District of Southern California Ad Hoc History Committee, “Essays on District Formation: Petition Campaign for Replenishment District Formation,” February 2009.

(42) California State Department of Water Resources, “In the Matter of Formation of Central and West Basin Water Replenishment District,” July 17, 1959.

(43) *Ibid*.

(44) Central and West Basin Water Replenishment District, Minutes, December 28, 1959.

(45) *California Water Code*, Sec. 60047. The Act references the “arid southern part of this State” because it was applicable “only to the replenishment of groundwater within that area in this State defined by the exterior boundaries of the Counties of Santa Barbara, Ventura, Los Angeles, San Diego, Riverside, San Bernardino, and Orange,” except for the areas of Orange included within the Orange County Water District.

(46) Ostrum (1990), p. 2.

(47) *Ibid*. p. 29.

(48) Ostrum (1965), p. 461.

(49) Bookman-Edmonston Engineering, Inc., “Comprehensive Review and Evaluation of the Los Angeles County Department of Public Works Seawater Barriers,” 1996, pp. 2-1 through 2-23. Some of the costs of the Dominguez Gap Barrier were paid with County general funds. The Flood Control District would continue to share in water purchase costs until 1971.

(50) Water Replenishment District of Southern California, “Engineering Survey and Report 2012,” p. A – 1.

(51) *California Water Service Co., et al v. City of Compton, et al*, LASC Case No. 506,806; *Central and West Basin Water Replenishment District v. Charles Adams, et al*, LASC Case No. C786656.

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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 California Department of Water Resources (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 abbreviated as CBWCB.

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. However, 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 an arbitrary 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, "*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*." (Declaration of Desi Alvarez, 2001, Pg. 2, Paragraph 4).

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

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: *"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."* (CDWR, 2012b, pg. 5).

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 CBWCB 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 CBWCB 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 CBWCB (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 CBWCB 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 CBWCB, 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 CBWCB 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 CBWCB 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 CBWCB 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 Angles, 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 CBWCB, 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 mergence 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 CBWCB 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 CBWCB 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 sewering 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 both 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 Central Basin and West Coast Basin, 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 2012

WRD and other agencies added nearly 6.9 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 2012 added to show the water level recovery. **Figure 6-15** is a groundwater elevation contour map for 2012 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 Central Basin and West Coast Basin 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 Central Basin and West Coast Basin 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 Central Basin and West Coast Basin 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 either direction based on the elevations of groundwater on either side. 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 Central Basin and the West Coast Basin 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 Central Basin and West Coast Basin. **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 (acft/yr)	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 water level 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 basins. 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 Central Basin and West Coast Basin 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, 2012b), in 2011/12 there were 66 parties to the Judgment, 25 active pumpers, and 47,124 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, is the case in the West Coast Basin, prepares an annual report of its activities. According to CDWR (2012a), in 2011/2012 there were 132 parties to the Judgment, 67 active pumpers, and 185,914 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 they would like, or they could go outside of the City 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 CBWCB, including California American Water Company, the City of Inglewood, GSWC, City of Los Angeles, CWS, 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 tap 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 nearly 7 million AF of imported and recycled water to the depleted Central Basin and West Coast Basin 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 – 2012/13

Recharge Method	Imported Water (acft)	Recycled Water (acft)	Makeup Water* (acft)	Total (acft)
Montebello Forebay Spreading Grounds (Rio Hondo and San Gabriel River)	2,467,377	1,815,017	215,121	4,497,515
Seawater Intrusion Barriers**	1,464,614	159,138	0	1,623,752
In-Lieu Replenishment	856,227	0	0	856,227
TOTAL (acft)	**4,788,218**	**1,964,155**	**215,121**	**6,977,494**
54-Year Average (acft/yr)	**88,671**	**36,373**	**3,984**	**129,028**

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 CBWCB as follows: "*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.*" (CDWR, 1963, pg. 4).

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, the anticipated price of untreated Tier 1 imported water to WRD next year for spreading will be $764 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 will be at an estimated melded rate of $60 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 Central Basin and West Coast Basin 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
2012/13 Imported Water Injection Amounts - (AF)	9,095	2,973	3,784
2012/13 Recycled Water Injection Amounts - (AF)	7,761	2,170	1,846

* 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 CBWCB 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. VanderLans 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, the anticipated price of potable Tier 1 imported water to WRD next year for the Dominguez Gap Barrier is expected to be $1,208 per AF (includes the MWD base rate plus surcharges by the WBMWD). Recycled water from the City of Los Angeles will be at an estimated rate of $881 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 this year. WRD has submitted a permit application to CDPH to expand from 50% to 100% recycled water use at the Alamitos Barrier which is expected to be adopted this year and the expansion of the Leo J. VanderLans plant will be completed 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 5 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 856,227 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. It was again offered for a limited time from May 2011 through September 2011, but has not been available since, allowing only a couple In-Lieu offerings since then. The future availability of the MWD and WRD In-Lieu program is uncertain.

6.6 Groundwater Quality

In addition to its groundwater replenishment responsibilities, 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 shared by the overlying users in the WRD Service Area.

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 groundwater basins and overlying users 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 over 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 two 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 groundwater quality in the Central Basin and West Coast Basin ("CBWCB"). 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. 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 CBWCB 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 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 administration cost necessary 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 replenishment assessment 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 well being of the basins.

The importance and technical details of makeup water can also be found in the ESR. Based upon technical analyses and historic groundwater levels, in 2002, the District adopted an Optimum Quantity for groundwater amounts in the Central Basin and West Coast Basin. 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; however, 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 ("RWQCB") 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 formerly used, thereby improving the reliability and quality of the water supply to the barrier. The plant has been producing 3 million gallons a day ("MGD") 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.

Construction is in progress to expand the capacity of the facility to 8 MGD so that it is capable of providing up to 100% of the barrier demand with advanced treated recycled water, thereby eliminating altogether the need for imported water. The anticipated completion date for the plant expansion is fall 2014. Expected operations costs for the coming year will involve operation and maintenance of the plant and groundwater monitoring at the barrier. Because the primary purpose of this project is to provide a more reliable means of replenishing the basin through injection, 100% of the costs are drawn from the Replenishment Fund. The capital costs for the expansion are funded by federal and state grants as well as the District's bond proceeds.

7.3 Robert W. Goldsworthy Desalter Project (Program 002)

The Robert W. Goldsworthy Desalter has been operating since 2002 to remove over 20,000 AF of brackish groundwater from a seawater intrusion plume (aka "saline plume") in the Torrance area that was stranded inland of the West Coast Basin Barrier after the barrier project was put into operation in the 1950s and 1960s. The production well and desalting facility are located within the City of Torrance 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. Expected costs for the coming year will involve operation and maintenance of the plant.

The District completed a feasibility study that evaluated several options for expanding the capacity of the treatment plant to 4,800 AFY. Work has begun on the final design of the treatment plant expansion along with two new source water wells and associated pipelines. Construction of these new facilities is expected to begin in late 2014. The purpose of the desalter expansion is directly related to remediating degraded groundwater quality and costs will be funded through WRD's Capital Improvement Program.

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 completing work on a groundwater master plan for the West Coast Basin to determine long-term solutions to this problem. The District continues to work with the City of Torrance Municipal Water Department, the pumpers' Technical Advisory Committee, and other West Coast Basin 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 successfully used for groundwater recharge by WRD since 1962. Recycled water provides a reliable source of high quality water for surface spreading in the Montebello Forebay and for injection at the seawater intrusion barriers. In view of the recurring drought conditions in California and uncertainties about future water availability and cost of imported water supplies, recycled water has become increasingly vital as a replenishment source.

In order to ensure that the use of recycled water for groundwater recharge remains a safe and reliable practice, WRD participates in various research and monitoring activities, proactively contributes to the regulatory and legislative development processes, and engages in information exchange and dialogue with regulatory agencies and other recycled water users. The District continues to closely coordinate with the County Sanitation Districts of Los Angeles County ("SDLAC"), which produces the recycled water used for surface spreading in the Montebello Forebay, on permit compliance activities, including groundwater monitoring, assessment, and reporting. Many monitoring and production wells are sampled frequently by WRD staff, and the results are reported to the regulatory agencies.

In addition to compliance monitoring and sampling associated with the spreading grounds, WRD is partnering with others to more fully investigate the effectiveness of soil aquifer treatment ("SAT") during groundwater recharge. Research is underway to more fully characterize the percolation process and to quantify the filtering and purifying properties of the underlying soil with respect to constituents of concern, such as nitrogen, total organic carbon, and chemicals of emerging concern ("CECs"). The District continues to be vigilant in monitoring research on the occurrence, significance, attenuation, and removal of CECs, including pharmaceuticals, endocrine disruptors, and personal care products.

Three separate groundwater tracer studies were performed in 2003-2005, 2005-2006, and 2010-2011 for the purpose of tracking and verifying the movement of recycled water from the spreading grounds by testing the monitoring wells and the production wells. Results showed that the depth rather than the horizontal distance from the recharge ponds is the key factor influencing arrival times of recycled 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 would only produce from the deeper aquifers. Tracer tests subsequent to well modification demonstrated an increased travel time compared to earlier results. These efforts, in addition to periodic studies assessing health effects and toxicological issues, are necessary to provide continued assurances that the use of recycled water for groundwater recharge remains safe and compliant with all regulatory standards.

In addition, WRD, in concert with other stakeholders, is working closely with the California Department of Public Health ("CDPH") to review, update, and help shape the regulations on groundwater recharge using recycled water. WRD contributed to the amendment of the Recycled Water Policy, adopted by the State Water Resources Control Board in January 2013 to assure that the required monitoring of groundwater recharge projects will be conducted using sound, scientifically credible methods.

Recycled water is also injected into the Los Angeles County Department of Public Works' three seawater intrusion barriers located along the coast of Los Angeles County (Alamitos, West Coast, and Dominguez Gap barriers). Highly purified recycled water used for injection at the Alamitos Barrier is produced at WRD's Leo J. Vander Lans Water Treatment Facility. The recycled water for the Dominguez Gap Barrier is generated at the City of Los Angeles' Terminal Island Water Reclamation Plant. And the recycled water for the West Coast Barrier is produced at the West Basin Municipal Water Districts' Edward C. Little Water Recycling Facility. Extensive recycled water monitoring and regular groundwater modeling are performed to ensure that the treatment plants are operating as intended and that the injected water is making a positive contribution to the groundwater basins. All three barrier projects are in various phases of expanding the recycled water produced for the barrier operations, with the ultimate goal of completely phasing out the potable water used at the barriers. Alamitos Barrier will reach the goal of 100% recycled water recharge in 2014, with the other two barriers following in the near future.

Projects under this program help improve the reliability and utilization of an available local resource, i.e. locally produced recycled water. This resource is used to improve replenishment capabilities and is thus funded 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 in the District's service area. Prior to moving forward with a prospective 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 capital projects are brought to the District's Technical Advisory Committee for review and recommendation. The culmination of this review and evaluation process is the adoption of the five - year Capital Improvement Program ("CIP") by the District's Board of Directors.

One of the main programs underway is the development of a Programmatic Environmental Impact Report ("PEIR") for the District's Groundwater Basins Master Plan. This effort will evaluate, at the programmatic level, the potential environmental impacts of future groundwater replenishment and extraction scenarios. This effort is expected to be completed in late 2014.

Also under this program, District staff will continue to monitor state and federal funding programs to determine applicability to the District's list of prospective projects. In the coming year, 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 was passed in November 2006. Grant applications for Proposition 84, Round 3 are expected to be submitted to the California Department of Water Resources in the upcoming year. The District anticipates submitting an application for the Groundwater Reliability Improvement Program ("GRIP") under this program.

Projects under the Groundwater Resources Planning Program serve to improve replenishment operations and general basin management. Accordingly, this program is also wholly funded through the Replenishment Fund.

7.6 Groundwater Quality Program (Program 006)

This program is 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 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.

Annually, the District offers a groundwater quality workshop to water purveyors. At the workshop, field experts and regulators provide information on the latest water quality regulations, state of the groundwater in the local basins, information on the cutting edge technology for contaminant removal or well rehabilitation, and other topics that are of key interest to the District's water purveyors. This annual workshop gives a comprehensive overview of the resources provided under the District's Groundwater Quality Program.

The District continually evaluates compliance with current and anticipated water quality regulations in production wells, monitoring wells, and spreading/injection waters of the basins. If noncompliance is suspected, WRD quickly investigates to confirm or 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. The program involves working with participating pumpers to comply with regulatory requirements for well water monitoring, including: (1) scheduling the collection and analysis of samples for Title 22 compliance required by CDPH and special sampling such as the Unregulated Contaminant Monitoring Rule ("UCMR") required by the United States Environmental Protection Agency ("EPA"); (2) coordinating the submittal of results to the CDPH; and 3) preparing the annual Consumer Confidence Reports for the pumpers. This program is available to pumpers who choose to participate and agree to reimburse the District the actual monitoring costs, including District staff time in administering the program. The District presently has 21 pumpers/participants in this program, which involves a total of 83 wells.

In recent years, new chemicals CECs have been identified nationwide as potentially impacting surface water and groundwater. 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 water resources. Their detection in the environment does not necessarily mean that they pose a health threat at their measured concentrations. WRD is actively monitoring surface spreading and injection activities for water quality constituents, including CECs, and based on its findings, advises the State Water Resources Control Board with regards to the development of policies related to water recycling, refinement of the anti-degradation policies, and technical reports concerning groundwater contamination. In addition, the District supports research evaluating CEC removals using innovative treatment technologies.

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 Basin and West Coast Basin Groundwater Contamination Forum: More than 10 years ago, WRD established this data-sharing and discussion forum with key stakeholders including the EPA, the California Department of Toxic Substances Control ("DTSC"), the RWQCB, the CDPH, the United States Geological Survey ("USGS"), and various cities and purveyors. Stakeholders drafted and signed a Memorandum of Understanding ("MOU") agreeing to meet regularly and share data on contaminated groundwater sites within the District. WRD acts 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 the Groundwater Contamination Forum, WRD developed a list of high-priority contaminated groundwater sites located 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 46 sites across the CBWCB. 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.

- Beginning in April 2010, WRD commenced work with the USGS on the Central Basin Groundwater Contamination Study. The purpose of this study is to characterize the threat of multiple contaminant plumes moving downward through potential 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 is expected to be completed by June 2014. WRD received AB303 grant funding to support this project.

- In 2012, WRD formed the Los Angeles Forebay Groundwater Task Force to coordinate and align regulators and water purveyors/agencies to collaboratively address groundwater contamination in the Los Angeles Forebay that is a threat to drinking water resources. The Task Force members currently include WRD, DTSC, EPA, RWQCB, CDPH, USGS, City of Vernon, City of Los Angeles and others. WRD and DTSC are investigating and collecting data to assess the extent of regional volatile organic compound and perchlorate plumes and find the source(s) of this contamination. This data will be utilized by the regulatory agencies to eventually facilitate remediation of the plumes.

WRD remains committed to projects seeking opportunities and innovative project concepts to enhance capture and recharge of local stormwater runoff in order to augment local groundwater resources, as follows:

- For many years, the District has participated on the Technical Advisory Committee ("TAC") for the Water Augmentation Study ("WAS") of the Los Angeles and San Gabriel Rivers Watershed Council. WAS is a multi-year investigation into the feasibility of capturing more local storm runoff, which would otherwise discharge into the storm drains, channels, and ultimately be lost to the ocean. Local stormwater captured from small-scale sites (e.g. neighborhoods, parks, ball fields, etc.) using various infiltration practices (e.g. bioswales, infiltration basins, and porous pavements) represents a potential source of new replenishment water, above and beyond the stormwater currently captured and used for percolation at the existing spreading grounds. As a TAC member, WRD helps to steer the study to examine and ensure that this new source of recharge water does not degrade groundwater quality if allowed to percolate at local sites. In 2012, with financial contributions from the District, two lysimeters were installed as part of the WAS investigation to evaluate the potential impacts of the locally captured stormwater on groundwater quantity and quality at the Elmer Avenue neighborhood BMP demonstration project constructed in 2009. Monitoring of the lysimeters began in early 2013. To date, the Elmer Ave project received only one storm of sufficient size for collecting stormwater samples from the lysimeters, in December 2013; however, the collected volumes were not sufficient to allow laboratory analysis. Therefore, the lysimeter monitoring program will be extended through 2014.

- The Stormwater Recharge Feasibility Study, which began mid-2011 and was completed in August 2012, investigated regional and distributed alternatives to capture more stormwater from parcels within the District service area for groundwater recharge. To identify and prioritize catchments or parcels with greatest potential to provide additional groundwater recharge and reduce pollutant loading to surface water bodies, an in-depth, regional assessment was conducted using spatial analysis and locally developed models, including the Structural Best management practices Prioritization and Analysis Tool ("SBPAT"), the Groundwater Augmentation Model ("GWAM"), and the WRD/USGS MODular three-dimensional finite-difference ground-water FLOW model ("MODFLOW"). The assessment considered a suite of factors important to siting groundwater recharge projects (e.g. surface flows, soil conditions, depth to water, and subsurface geologic conditions, preexisting contamination, and permanent dewatering activities) as well as local water quality objectives.

  The study identified 17 high priority catchments within the District service area where expected water supply benefits were estimated at 4,300 AFY if appropriate infiltration facilities are installed and maintained. A single 100 acre catchment was selected, and concept designs for a catchment-wide pilot stormwater capture and recharge facilities were completed. Results from the analyses and pilot project are scalable to inform future decisions about widespread implementation of distributed and regional stormwater capture projects. Findings of the study were presented to various audiences, including water purveyors, regulators, local environmental groups, and at regional and national stormwater conferences. The benefit cost analyses, which examined multiple factors including but not limited to water quality improvements, water supply benefits, and social benefits garnered wide interest from water quality agencies, water supply agencies, and policymakers.

In 2012, the District partnered with the City of Los Angeles Bureau of Sanitation (the lead applicant) to pursue Proposition 84 funding (Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006) to implement a portion of the concept design to increase stormwater infiltration and to assist the City of Los Angeles in its compliance with total maximum daily load (water quality-related) requirements. The proposed project area is located in the City of Los Angeles south of the 10 freeway and east of the 110 freeway. The combined watershed of all proposed stormwater infiltration projects is approximately 228 acres with mixed land uses. In 2013, the City was awarded $2,939,361 by the State Water Resources Control Board to construct and monitor the project. Known as the "Broadway Neighborhood Stormwater Greenway (Broadway) Project, this project is slated to be completed in 2016.

Much of the work for the coming year will involve additional investigations at well sites known to have contaminated water, continued tracking of water quality regulations and policies affecting production and replenishment operations, further characterization of contaminant migration into the deeper aquifers, and monitoring and expediting cleanup activities at contaminated sites. All work under this program is related to water quality and cleanup efforts and is funded from the Clean Water Fund.

7.7 Geographic Information System (GIS, Program 010)

The District maintains an extensive in-house database and Geographic Information System (GIS). The database includes water level and water quality data for WRD's 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. It 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. In the coming year, this information will be further integrated with readily available data from other state and federal agencies. Staff uses the system daily for project support and database management. Specific information is available upon request to any District pumper or stakeholder and can be delivered through the preparation of maps, tables, reports, or in other compatible formats. 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.

With the addition of a GIS Analyst in the upcoming year, 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 work closely with other District departments to evaluate and implement updates to the District's existing system to facilitate the seamless transfer of data and access to that data. 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 for the coming year. 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 CBWCB 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 over 300 WRD and USGS-installed monitoring wells at over 50 locations throughout the District, supplemented by the existing groundwater production wells operated by the water purveyors. 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 Basin and West Coast Basin. WRD hydrogeologists and engineers, provide 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 the Regional Groundwater Monitoring Report that documents groundwater level and groundwater quality conditions throughout the District. This report is distributed to the stakeholders in WRD and is also available on the District's website. In 2011, the National Groundwater Associated presented WRD with the "2011 Groundwater Protection Project Award" in recognition of the regional groundwater monitoring program.

WRD is also the designated groundwater monitoring entity for the CBWCB under the State of California's CASGEM program (California Statewide Groundwater Elevation Monitoring). WRD collects water level data from 28 of its nested monitoring wells and uploads it to the State's CASGEM website on a regular basis for seasonal and long-term water level trend tracking. Public access to the CASGEM website is at www.water.ca.gov/groundwater/casgem.

Most of the work during the ensuing year will involve equipping and sampling the three new monitoring wells installed by the USGS in 2013/2014, continuous field activities at the other wells including quarterly and semi-annual data collection, well and equipment maintenance, and annual reporting activities. Work associated with the Regional Groundwater Monitoring Program also supports activities relating to both replenishment and water quality projects. The program is funded equally by 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 removes contaminants from the underground supply and delivers the extracted water for potable purposes. Projects implemented through this program are accomplished in collaboration with well owners.

One component of the program focuses on the removal of VOCs and offers financial assistance for the design and equipment at the selected treatment facility. Another component offers zero-interest loans for secondary 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, the initial cost is generally prohibitive to most pumpers. Financial assistance through the District's SDWP makes project implementation much more feasible.

There are several projects in various stages of implementation and new candidates for participation are under evaluation. A total of 16 facilities have been completed and are online and one facility has successfully completed removal of the contamination and no longer needs to treat. While continued funding of this program is anticipated for next year, 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. Treatment projects for naturally-occurring constituents are classified as Priority B Projects and funded as 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 is completed.

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.

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 Public Works - Bureau of Sanitation ("BoS") Terminal Island Water Reclamation Plant/Advanced Water Treatment Facility ("AWTF") to the Dominguez Gap Barrier ("DGB"). Delivery of recycled water to the barrier, which commenced in late February 2006, was temporarily interrupted for about a year starting November 2011 when the AWTF shut down for plant upgrade and maintenance. Recycled water delivery to the DGB resumed in December 2012.

Prior to injection at the barrier, the recycled water produced at the AWTF undergoes advanced treatment processes including microfiltration, reverse osmosis, and chlorination. The DGB injection project was permitted by LARWQCB in conjunction with CDPH for up to 5 mgd of recycled water and 50% recycled water contribution (meaning recycled water may not exceed 50% of the total injected volume with the remainder consisting of potable water). Water quality requirements, including turbidity and modified fouling index ("MFI"), must also be satisfied to minimize potential fouling of DGB injection wells owned and operated by the County of Los Angeles Department of Public Works. WRD is working with BoS to expand the amount of recycled water produced for the DGB, with the ultimate goal of eliminating all potable water used for barrier injection.

While LADWP is responsible for the treatment and delivery of the recycled water and the water quality monitoring of the recycled water, WRD has responsibility for groundwater monitoring and compliance. As part of the DGB injection permit requirements, WRD conducts groundwater monitoring to measure and track water quality conditions, evaluate potential impact of recycled water on groundwater, and identify potential problems well before recycled water arrives at any downgradient drinking water wells. In addition, an extensive tracer study was conducted from the start of recycled water injection in February 2006 through fall 2010 to determine the extent of travel and movement of the recycled water blend through the aquifers. The tracer study confirmed that after injection, adequate mixing and further blending of recycled water with diluent water occurs in the ground and that groundwater samples collected were representative of the recycled water blend.

Recycled water use at the seawater intrusion barriers in Los Angeles County improves the reliability of a supply in continuous demand. Traditionally, water purchases for the barriers have been viewed as a replenishment function. Therefore, 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 19,900 AF of imported water for recharge; 16,000 AF for spreading and 3,900 AF for injection at the seawater barriers. By maximizing the use of recycled water and stormwater, the amount of imported water needed 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, barrier 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.

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. Working with the Army Corps of Engineers and LACDPW on additional improvements to the Whittier Narrows Conservation Pool will allow capture of more stormwater, as will development of Montebello Forebay projects to lower the water table through increased pumping and delivery downgradient to free up underground space to capture more storm water and/or recycled water.

The District plans to continue working with the LACDPW on several design projects for the Rio Hondo and San Gabriel Coastal Spreading Grounds with the goal of increasing the volume of recycled water conserved. The District is continually looking for opportunities to work with the LACDPW on improvement projects at the recharge facilities. Several potential projects have been identified and are being further evaluated to determine if they should be pursued. Two such projects are currently in the design and permitting stage. These projects consist of the construction of turnout structures along the San Gabriel River which will allow the delivery of increased recycled water to 1) the San Gabriel Coastal Spreading Grounds – Basin #2 & Interconnection Pipeline and 2) the portion of the unlined San Gabriel River south of Rubber Dam #4. Together these two turnout structures will help increase the spreading of recycled water at the San Gabriel Coastal and Rio Hondo Coastal Spreading Grounds and minimize the loss of recycled water to the ocean.

As its name implies, the Replenishment Operations Program deals primarily with replenishment issues and therefore its costs are borne by 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, changes 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. Much of this information is published in Technical Bulletins – easy to read two-page documents that summarize groundwater issues of importance in the District.

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. In 2013, WRD obtained extensive seismic reflection data which is being analyzed to help fill in gaps in the geologic structure. The ultimate goal of this project is to incorporate the 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 to fill project-related data requests.

The conceptual model updates are being incorporated into the USGS numerical model updates. The updates to the numerical model are being performed based on the new information gleaned from the additional aquifer-specific WRD monitoring wells installed since 2000 and the extensive groundwater monitoring that the District has performed since then to identify trends in groundwater levels. The upgrades will also include refining the model's resolution to 1/8-mile square cells versus the previous model's 1/2 - mile cells, and creating 11 vertical layers to simulate groundwater flow in the various aquifers versus the previous model's 4 layers. The model has also been converted to the newest version of Modflow known as Unstructured Grids (USG), which allows better simulation of groundwater flow in the complex geology of the Central and West Coast Basins. New seismic reflection data purchased by WRD will also be incorporated into the model. Time frames for model calculation will improve from annual measurements to quarterly. All of these upgrades will lead to a much improved groundwater modeling simulator for the District's future management efforts. 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 Basin and West Coast Basin.

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. WRD has initiated the process with other stakeholders and the Regional Water Quality Control Board, has completed a work plan and will make considerable progress on the Salt / Nutrient Management Plan in the ensuing year.

Modeling of groundwater flow and movement of injected recycled water at the Alamitos and Dominguez Gap seawater barriers are also included in this program. These efforts are required under permits for the recycled water injection.

In 2013, WRD received a grant from MWD through WBMWD to perform groundwater tracer tests using noble gasses at the three seawater barrier systems. Use of noble gasses instead of other compounds, if found effective, will provide a cost-effective means to reliably follow the movement of injected water through the aquifers.

The Hydrogeology Program addresses both groundwater replenishment objectives and groundwater quality matters. The cost of the program is evenly split between the Replenishment and Clean Water Funds.

7.13 Groundwater Reliability Improvement Program ("GRIP", Program 033)

The WRD continues to pursue projects through its Water Independence Now ("WIN") program to develop local and sustainable sources of water for use in groundwater replenishment activities. This has become increasingly important in light of persistent drought conditions in the state and environmental and regulatory issues that limit delivery of imported water to the Los Angeles area.

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 goal of GRIP is to offset the current use of imported water by providing up to 21,000 AFY of recharge using reliable alternative supply sources (e.g., recycled water, storm water) for replenishment via the Montebello Forebay. The primary goals of GRIP are to:

- Provide a sustainable and reliable supply for replenishing the Basins;
- Protect groundwater quality;
- Minimize the environmental/energy footprint of any option or options selected;
- Comply with pertinent regulatory requirements employing an institutionally feasible approach;
- Minimize cost to agencies using ground water; and
- Engage stakeholders in the decision making process.

The District is currently developing the 30% design for the Advanced Water Treatment facility and conveyance pipeline for providing 10,000 AFY of highly treated recycled water to the Montebello Forebay for groundwater recharge to better identify the design/operation parameters of GRIP. The additional 11,000 AFY of 21,000 AFY to be provided as part of the GRIP will come from tertiary treated recycled water from the SDLAC's San Jose Creek Water Reclamation Plant.

The District has recently completed the draft Environmental Impact Report ("EIR") for GRIP and is preparing to distribute the document for public review. Once public comments are incorporated in the document, the EIR will be presented to the WRD Board of Directors for adoption. Thereafter, full scale design and regulatory permitting efforts will commence to be followed by construction. Additional information related to GRIP may be found at www.wrd.org/grip.

GRIP efforts are part of WRD's capital improvement program and are funded primarily through bond proceeds.

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

This report has demonstrated that the groundwater occurring in and flowing through the WRD service area, although originating from differing regions, is interrelated and that actions in one basin affect available groundwater in the other. The groundwater resources are in a common underground pool that all groundwater pumpers in both the Central and West Coast Basins share. Consequently, it is equitable that the costs of replenishing and maintaining this resource as a safe source of water should be shared equally by all pumpers based on the amount of water pumped. Among other reasons, facts substantiating the use of a uniform rate for each acre-foot of water removed include the following:

- 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 replenishment assessment. They did so for a variety of policy, economic and scientific reasons, which are still applicable to today's circumstances.

- The Central Basin and West Coast Basin, although separately adjudicated, are, in fact, 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 Central Basin and West Coast Basin 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 groundwater moves 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 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).

- 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. 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.

- 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 permanent physical boundaries within the groundwater basins in WRD's Service Area to halt the movement of groundwater other than the bordering bedrock hills. There are temporary 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 Central and West Coast 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 a 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.

WRD replenishment activities benefit all groundwater pumpers in both basins directly or indirectly. Separate costs and benefits cannot be allocated to separate and distinct "service areas." 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).

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).

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.

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.

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 (PPA) & Water Costs

The Projects, Programs, 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 projects, programs, administration & water costs, totaling $53,959,000 for Fiscal Year 2014-15 (FY14-15). Water and water related costs make up $41,893,000 or 78 percent of operational expenses for budgetary purposes.

Table 9-1
Summary of FY14-15 Estimated Projects, Programs, Administration & Water Costs

Projects, Programs and Administration (PPA) & Water Costs	Estimated Amount
Water Supply Purchases	$36,558,000
Water Conservation	$791,000
Leo J. Vander Lans Water Treatment Facility Project	$4,544,000
Water and Water Related Costs	**$41,893,000**
Robert W. Goldsworthy Desalter Project	$1,189,000
Recycled Water Program	$654,000
Groundwater Resource Planning Program	$503,000
Water Quality Improvement Program	$775,000
Geographic Information Systems (GIS)	$362,000
Regional Groundwater Monitoring Program	$1,223,000
Safe Drinking Water Program	$155,000
Dominguez Gap Barrier Recycled Water Injection	$270,000
Replenishment Operations	$289,000
Hydrogeology Program	$977,000
Groundwater Reliability Improvement Program ("GRIP")	$329,000
Water Education	$638,000
Board of Directors	$358,000
General Manager	$407,000
Administration	$3,325,000
Retirement Fund Obligation (GASB 45)	$612,000
Projects, Programs and Administration (PPA) Costs	**$12,066,000**
Total (PPA and Water) Costs:	**$53,959,000**

9.2 Other Special Programs and Supportive Costs

In addition to the PPA & water costs, the FY14-15 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.

- Proportionality Study, Public Notices & Hearings. To ensure transparency, accountability, and fiscal responsibility, the District prepares a proportionality study, disseminates public notices, and conducts public hearings including the Budget Advisory Committee (BAC) per Senate Bill 620. Services in support of preparing the study, processing the notice, postage, and incidental expenses are included in this cost component.

- 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 FY14-15 expenditures.

Table 9-2
Summary of FY14-15 Other Special Projects and Supportive Costs

Other Special Programs and Supportive Costs	Estimated Amount
Litigation	$1,930,000
Cost of Service Study, Public Notices & Hearings, SB620	$100,000
Election Expense	$750,000
Total Costs:	**$2,780,000**

9.3 Capital Improvement Program/Plan (CIP)

The WRD's primary responsibilities are to protect the Basins by replenishing groundwater, deter sea water intrusion, and remove contaminants from the groundwater. Furthermore, 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 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:

- **Not** 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.
- Typically non-recurring, one-time expenditures.
- Expenditures spanning over two fiscal years or longer.
- Total project cost exceeding $20,000.

The District's recently adopted 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 replenishment assessment funds (non-capital funds). From a budgetary standpoint, the District's total FY14-15 estimated cost attributable to the CIP is approximately $11,186,000; of this amount, the breakdown and descriptions are provided below.

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 Certificates of Participations ("Certificates"), 2008 Certificates, and 2011 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 FY14-15, the estimated net debt service amount is $10,291,000.

CIP – Non-Capital Funds. The non-construction projects in the CIP are funded primarily by non-capital funds, which are pay-as-you-go funds to be collected annually through the replenishment assessment. For FY14-15, the estimated Non-Capital Fund amount is $895,000.

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 FY14-15, the estimated amount collected to replenish the reserve fund is $360,000.

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 FY 14-15 Budgetary Cost Estimates

FY 13-14 Budgetary Cost Components	Estimated Amount
Projects, Programs, Administration & Water	$53,959,000
Other Special Programs and Supportive Costs	$2,780,000
Capital Improvement Program/Debt Service	$11,186,000
Reserve Fund (replenishment)	$360,000
Total Revenue Requirements/Costs	**$68,285,000**

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 FY14-15 capital revenue from the two capital assets is approximately $3,435,000.

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 Metropolitan Water District's

(MWD) Local Resources Program (LRP). The estimated total revenue from this treatment facility is approximately $2,094,000 for FY14-15.

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 groundwater basin realizes 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 $1,341,000 for FY14-15.

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

Total Revenue Requirements (Cost):	$68,285,000
Less Capital Revenue:	$3,435,000
Estimated Cost of providing Service:	**$64,850,000**

10.0 COST ALLOCATION ANALYSIS

As discussed throughout the previous chapters of this report, the District has determined that its 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 242,000 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 FY14-15 is approximately **$64,850,000**; which is necessary to service the estimated 242,000 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:

Total Cost of Service ($)/Total Groundwater Pumped (AF) = Unit Cost ($/AF pumped)

For FY 14-15, the estimated unit cost, or Replenishment Assessment (RA), is as follows:

Replenishment Assessment ($/AF pumped) = $64,850,000/242,000 AF = $268/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 $268/AF of water pumped). For example, if an operator pumps a total of 1,000 AF, that operator will be charged a total of $268,000 (1,000 AF x $268/AF).

FIGURES

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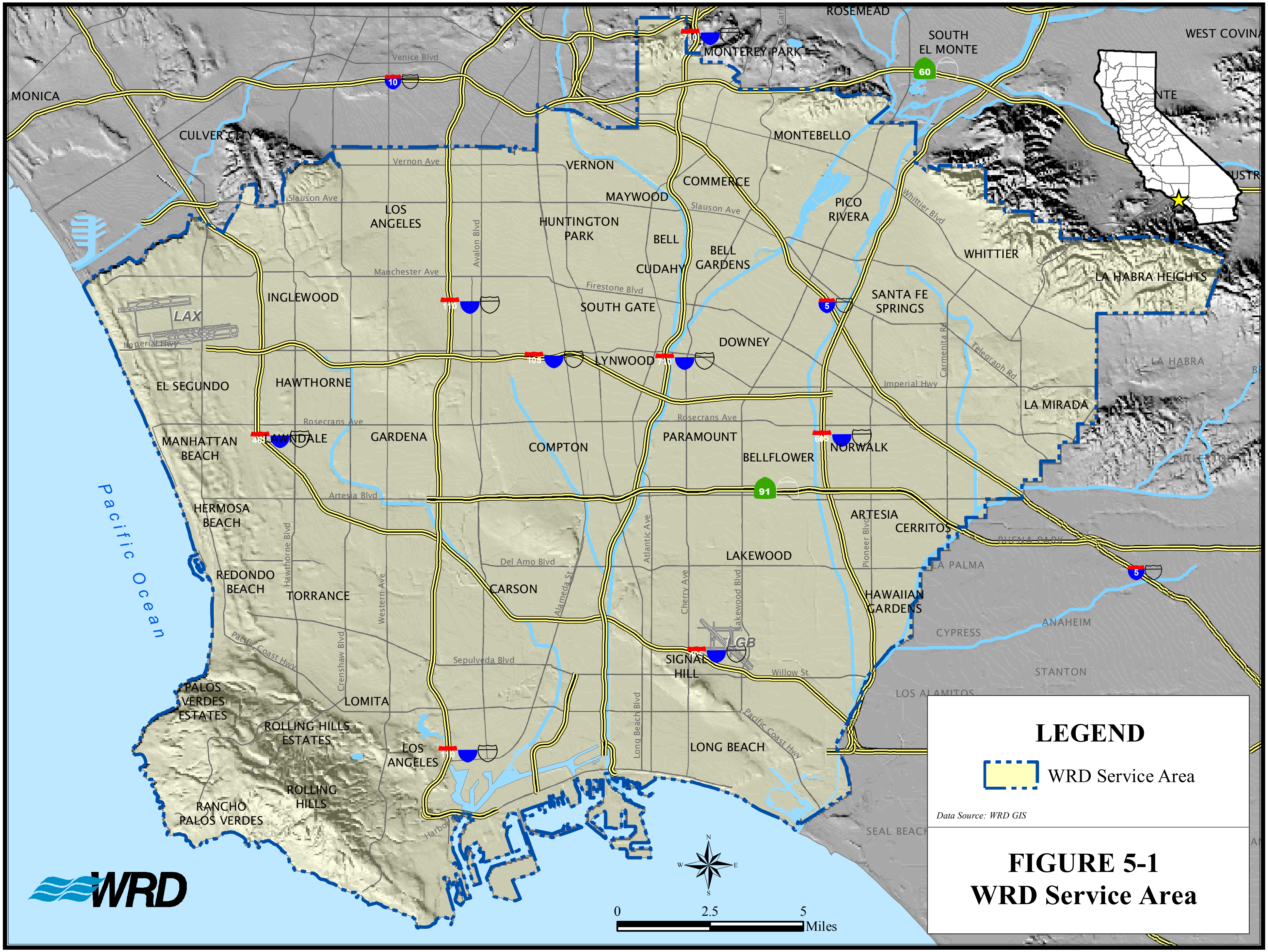


LEGEND

WRD Service Area

Data Source: WRD GIS

FIGURE 5-1
WRD Service Area

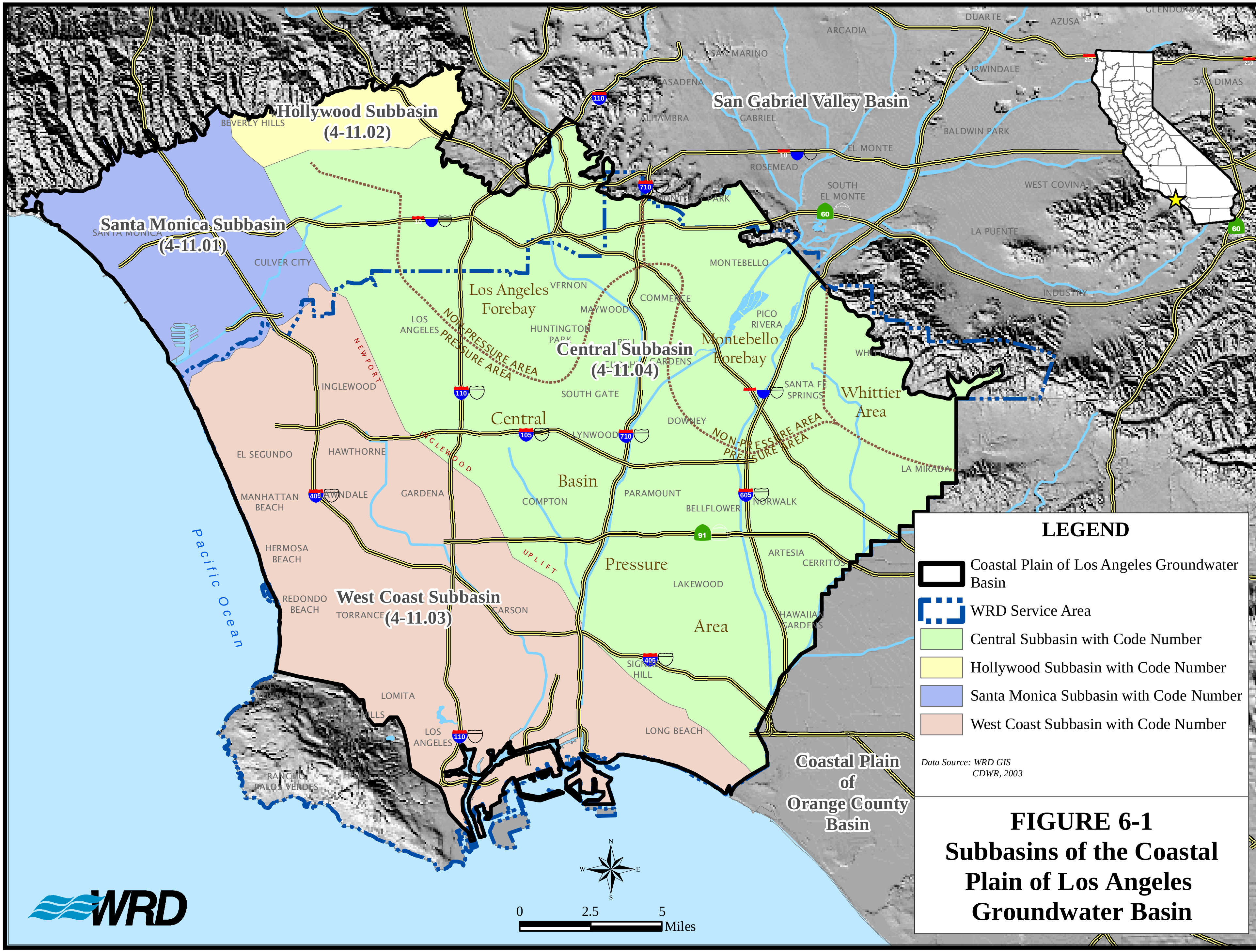


FIGURE 6-1
Subbasins of the Coastal Plain of Los Angeles Groundwater Basin

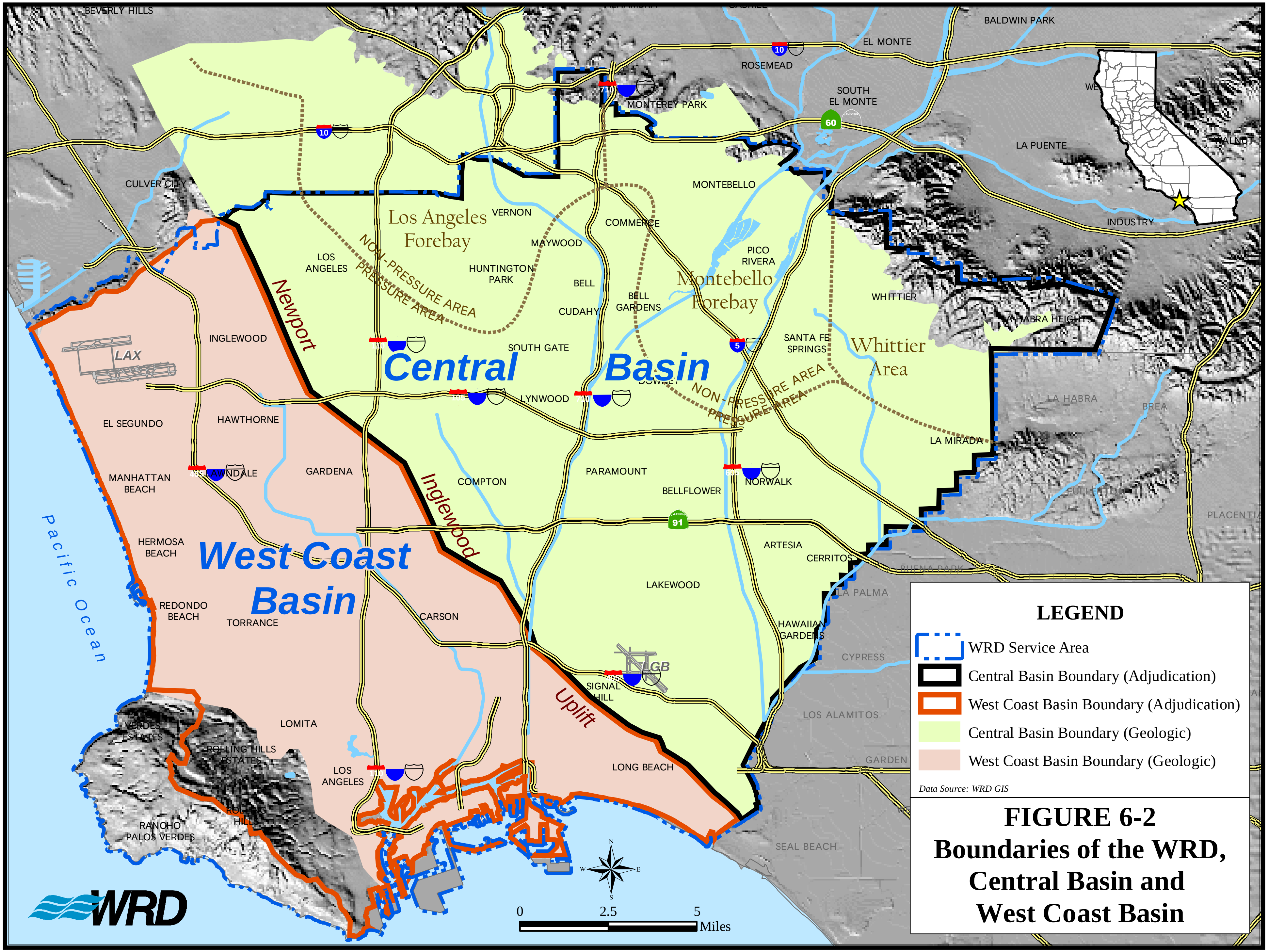
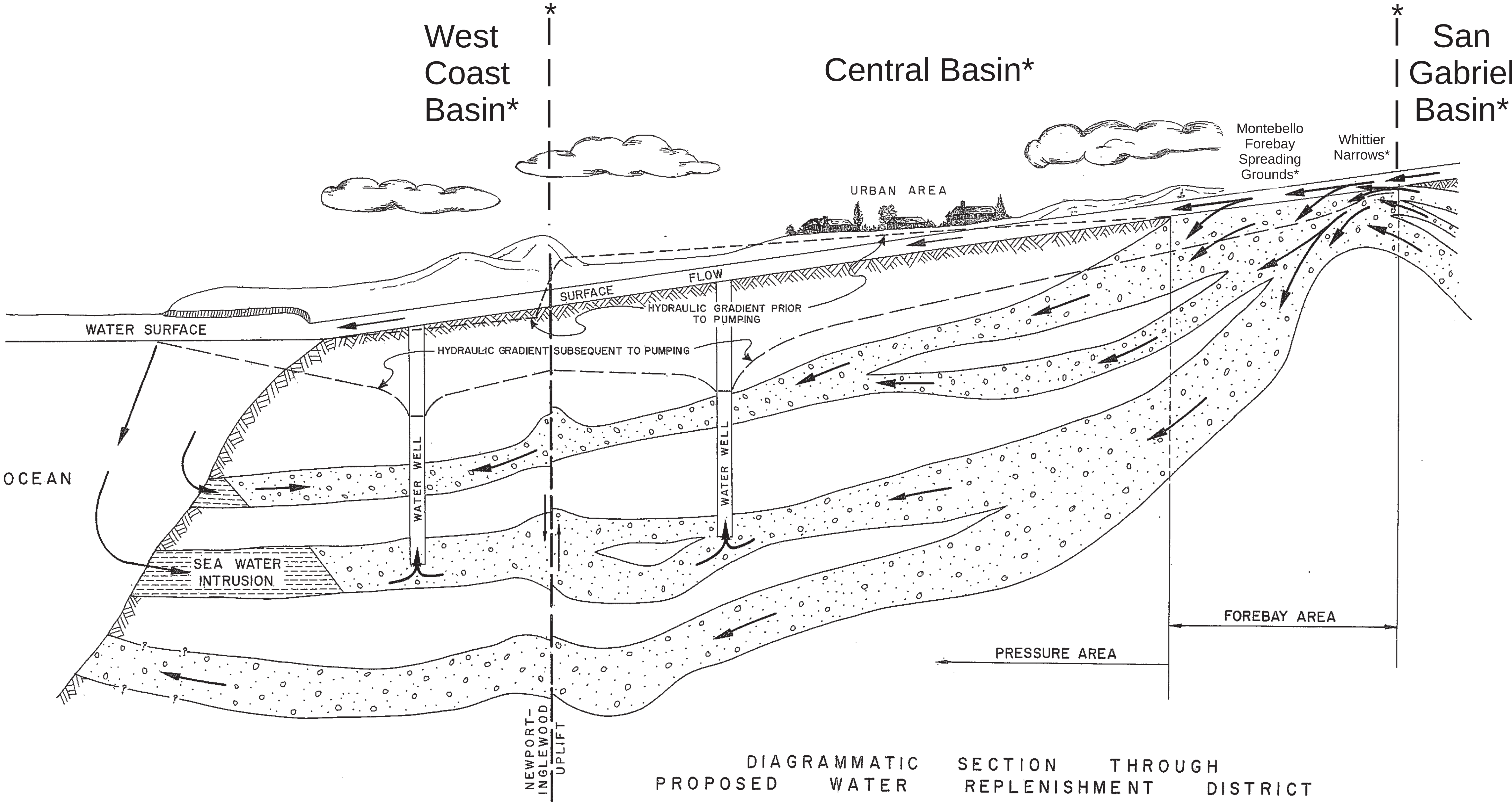


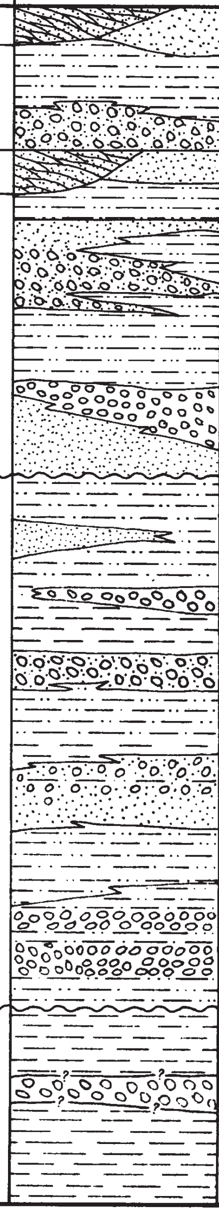
FIGURE 6-2
Boundaries of the WRD, Central Basin and West Coast Basin



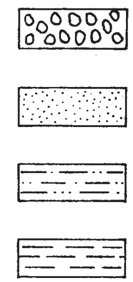
Data Source: CDWR, 1959
* Text and Lines added by WRD for Clarity

Figure 6-3

Generalized Cross-Section

System	Series	Formation	Lithology	Aquifer and Aquiclude	Max. Thickness (Feet)	Previous Formation Names✱	Previous Aquifer Names✱
Quaternary	Recent	Active Dune Sand		Semiperched	60	Alluvium	Semiperched†
Quaternary	Recent	Alluvium		Bellflower Aquiclude	140	Alluvium	
Quaternary	Recent	Alluvium		Gaspur	120	Alluvium	Gaspur†
Quaternary				Ballona	40		"50 Foot Gravel"
Quaternary	Upper Pleistocene	Older Dune Sand		Semiperched	200	Terrace Cover	
Quaternary	Upper Pleistocene	Lakewood Formation		Bellflower Aquiclude	200	Palos Verdes Sand	Semiperched†
Quaternary	Upper Pleistocene	Lakewood Formation		Exposition Artesia	140	Unnamed Upper Pleistocene	
Quaternary	Upper Pleistocene	Lakewood Formation		Gardena	160	Unnamed Upper Pleistocene	Gardena†
Quaternary	Upper Pleistocene	Lakewood Formation		Gage	160	Unnamed Upper Pleistocene	"200 Foot Sand"
		Unconformity				Local Unconformity	
Quaternary	Lower Pleistocene	San Pedro Formation		Hollydale	100	San Pedro Formation	
Quaternary	Lower Pleistocene	San Pedro Formation		Jefferson	140	San Pedro Formation	
Quaternary	Lower Pleistocene	San Pedro Formation		Lynwood	200	San Pedro Formation	"400 Foot Gravel"†
Quaternary	Lower Pleistocene	San Pedro Formation		Silverado	500	San Pedro Formation	Silverado†
Quaternary	Lower Pleistocene	San Pedro Formation		Sunnyside	500	San Pedro Formation	
		Local Unconformity					
Tertiary	Upper Pliocene	Pico Formation		Undifferentiated		Pico Formation	

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

GENERALIZED STRATIGRAPHIC COLUMN
COASTAL PLAIN OF LOS ANGELES COUNTY

Figure 6-4

Data Source: CDWR, 1961 - Plate 5

DEPARTMENT OF WATER RESOURCES 1961

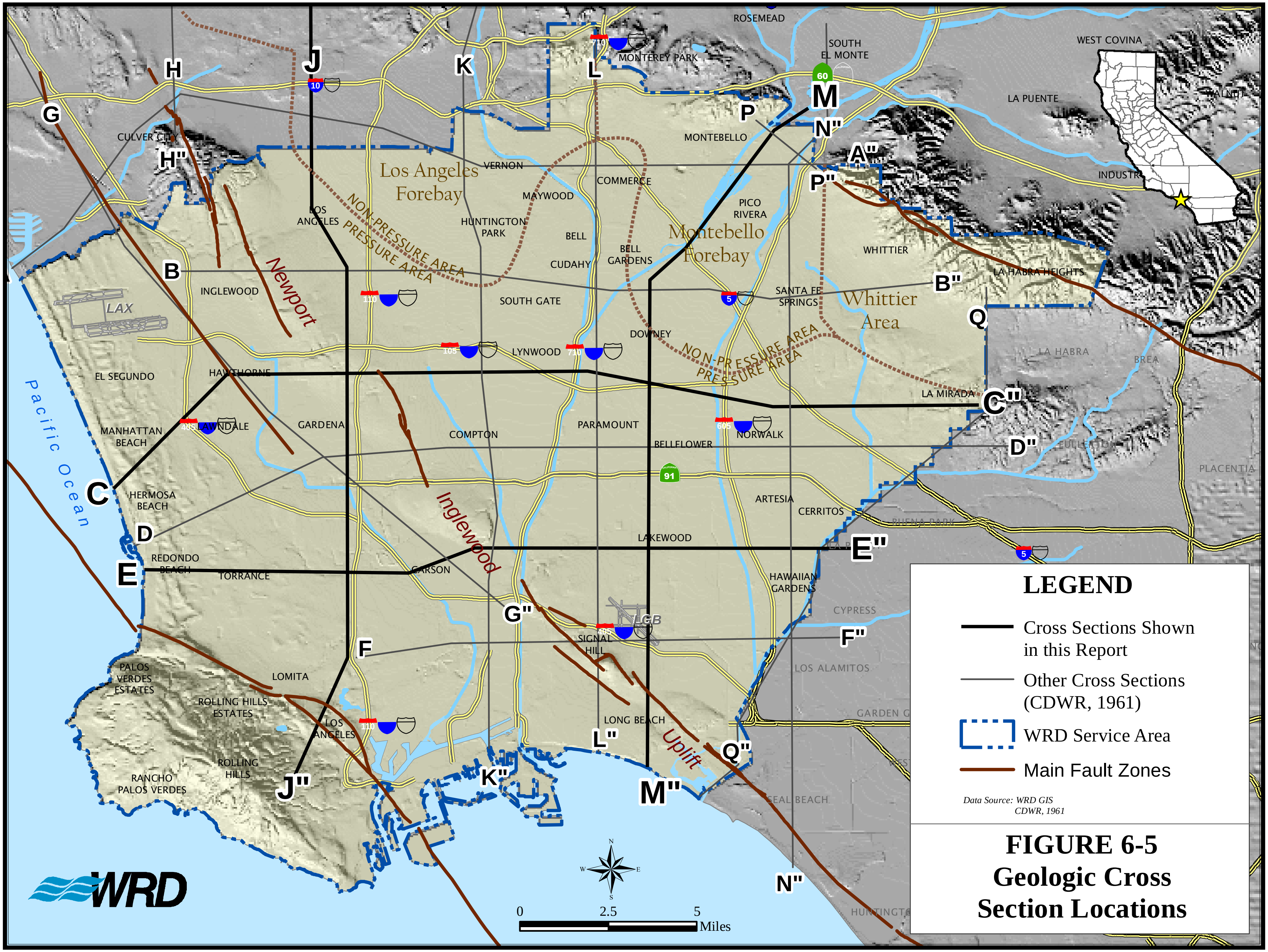
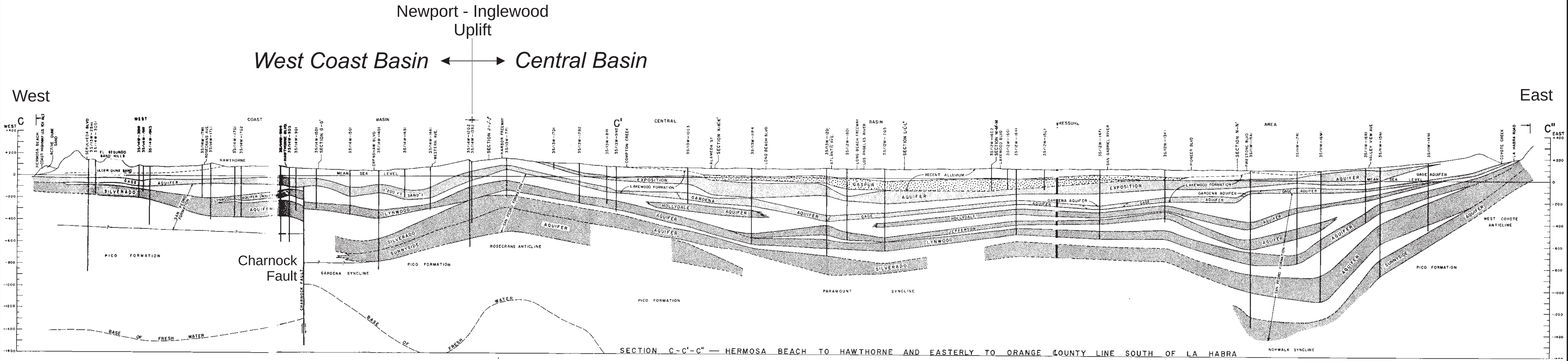
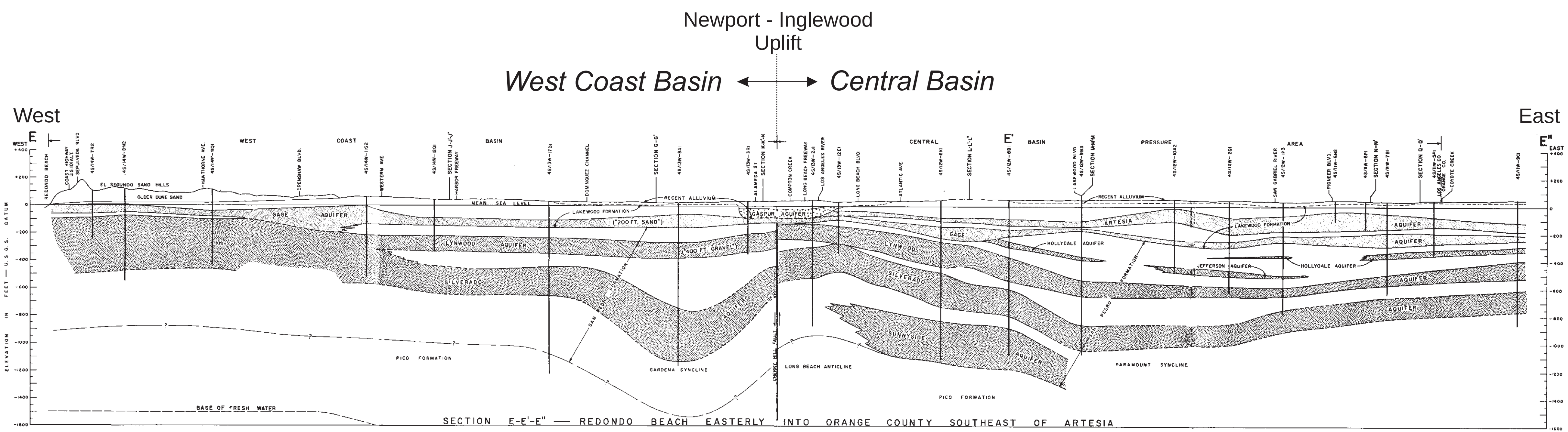


FIGURE 6-5
Geologic Cross Section Locations





LEGEND

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

0 — 6,000
Horizontal Scale (feet)

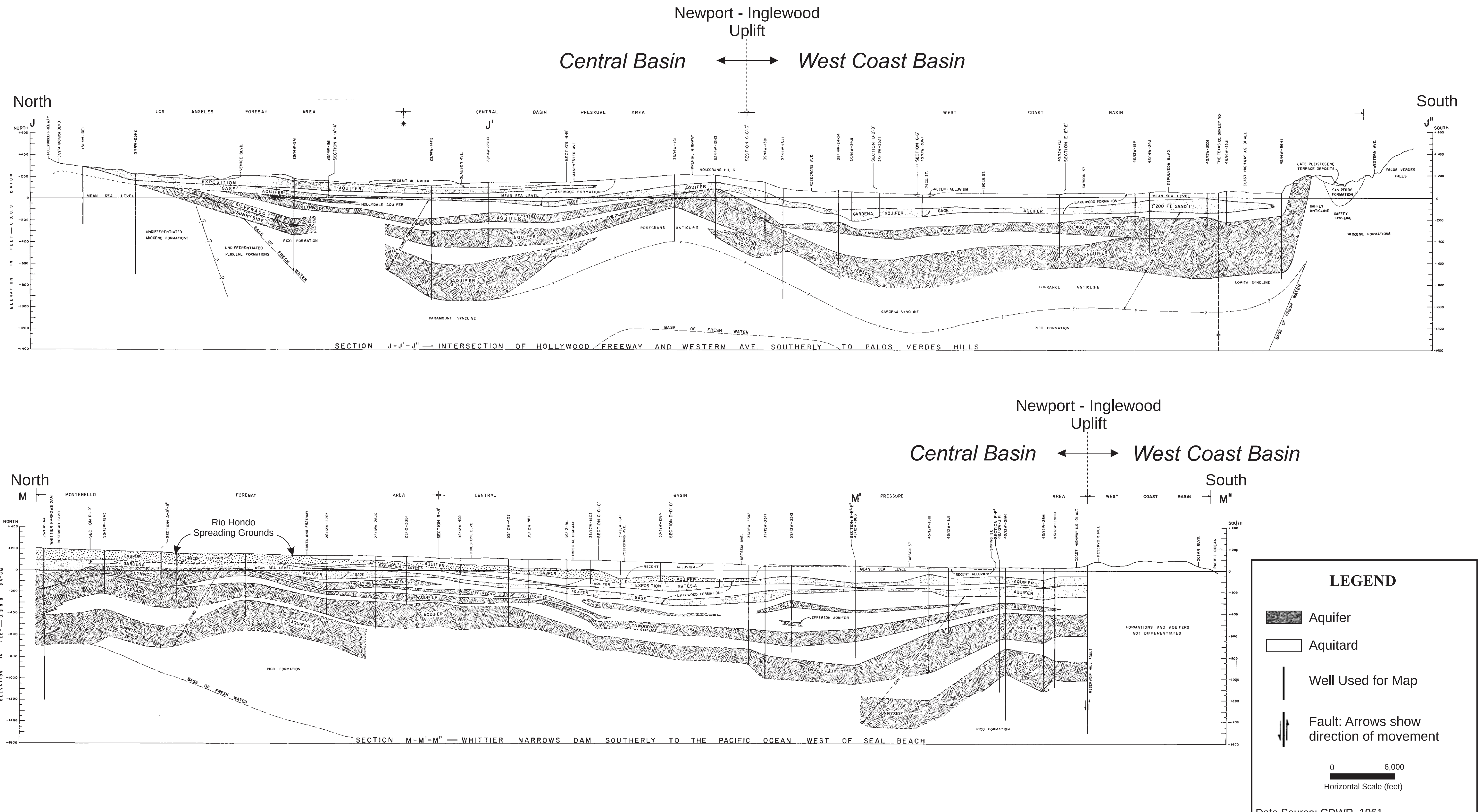
Data Source: CDWR, 1961

Text added by WRD for Clarity: West Coast Basin, Central Basin, Newport-Inglewood Uplift, East and West, Charnock 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

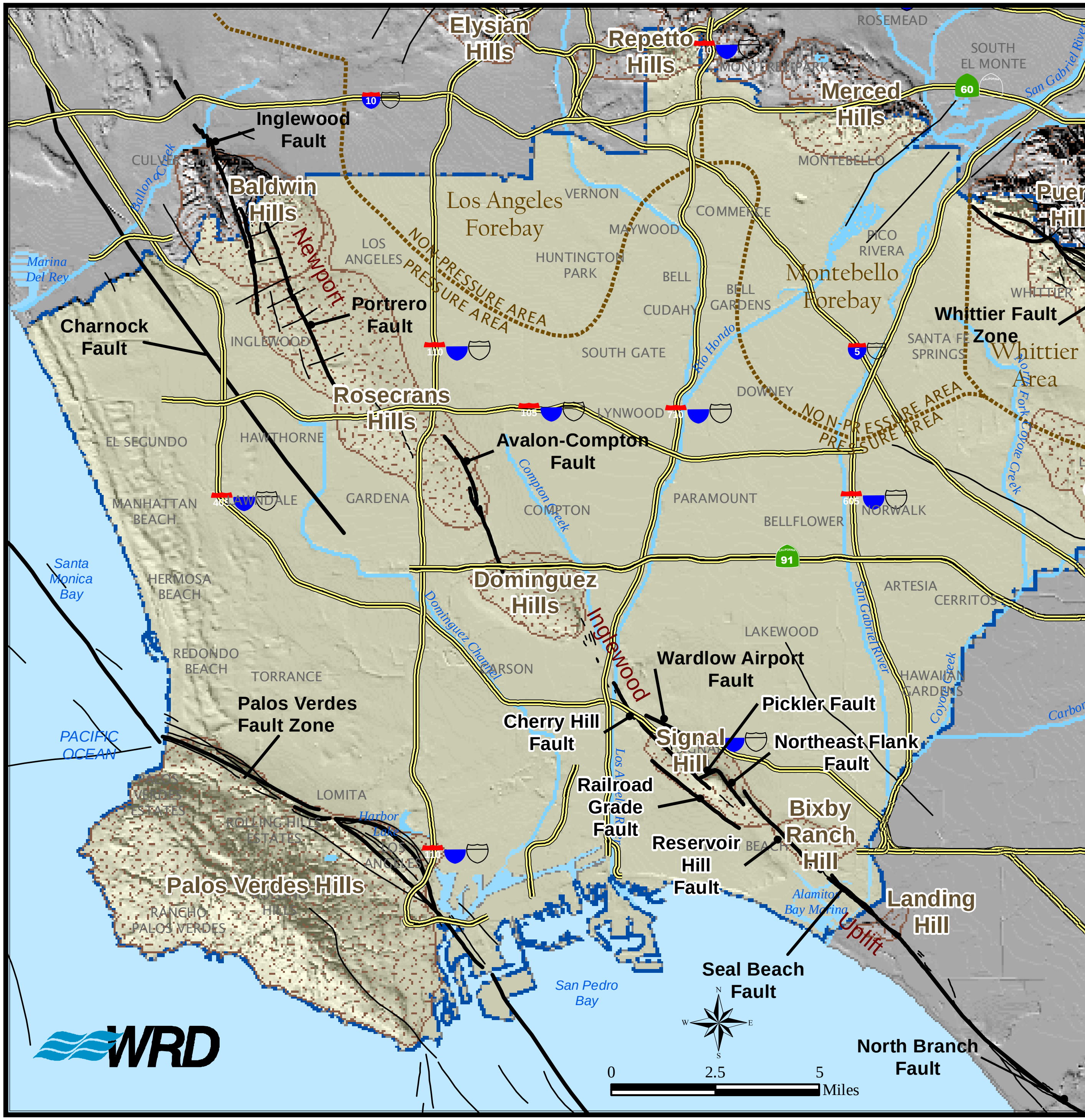


Text added by WRD for Clarity: West Coast Basin, Central Basin, Newport-Inglewood Uplift, South and North, J J" M M", Rio Hondo Spreading Grounds, and arrow lines.

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.

Figure 6-7
Geologic Cross
Sections J & M



LEGEND

- Main Fault Lines
- Minor Faults
- WRD Service Area

Data Source: WRD GIS

FIGURE 6-8
Faults and Hills in WRD Service Area

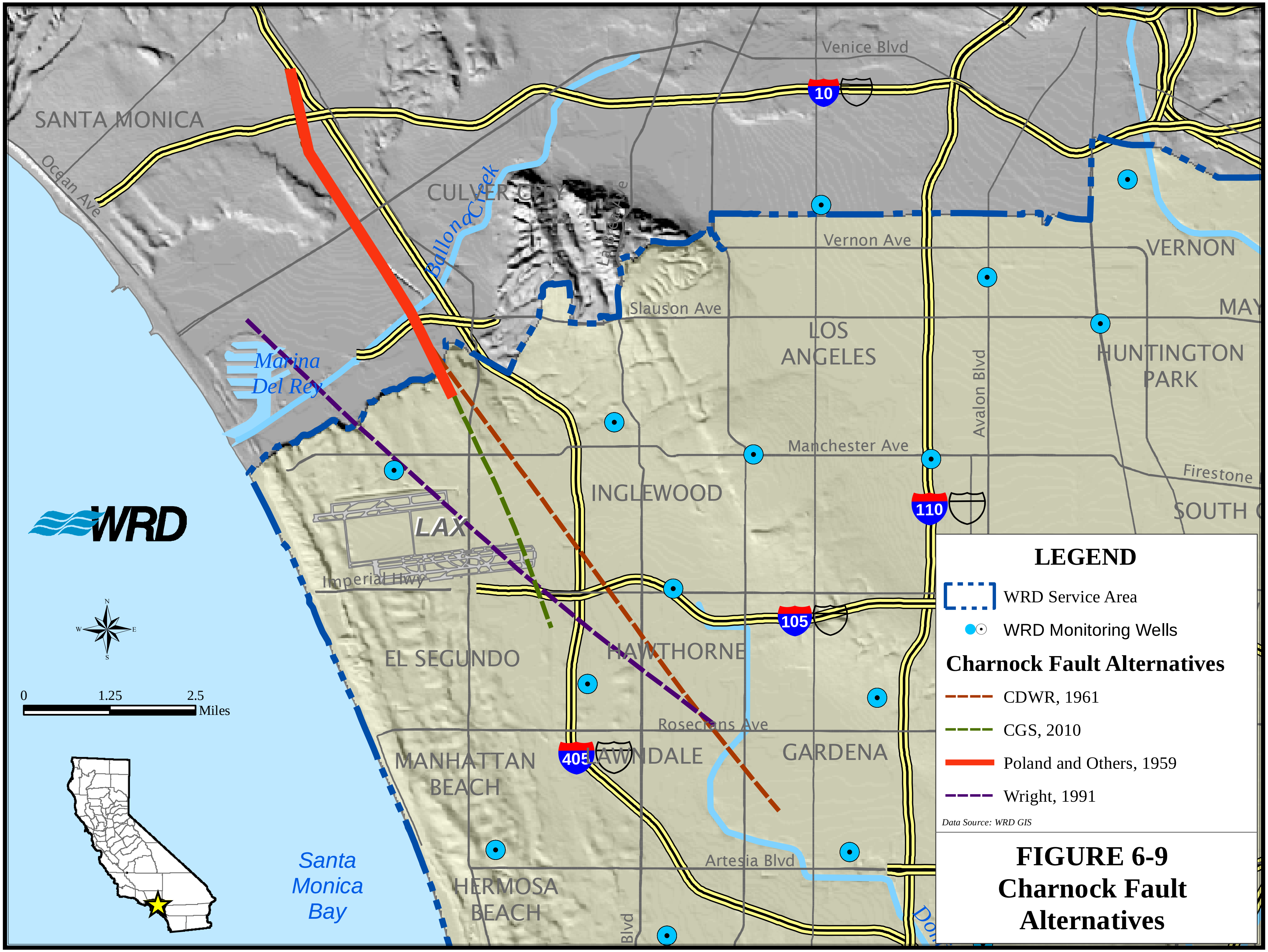


FIGURE 6-9
Charnock Fault Alternatives

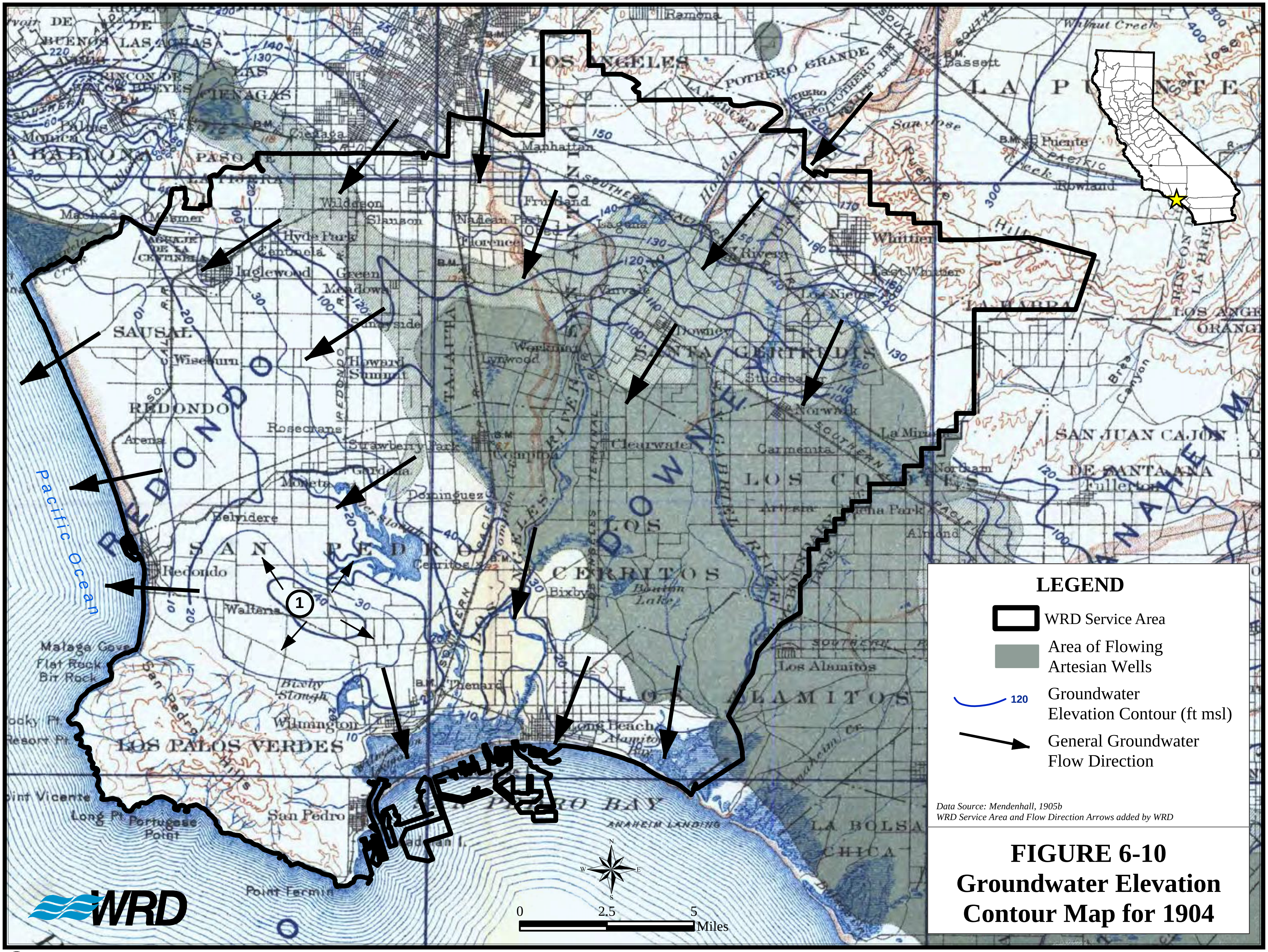


FIGURE 6-10
Groundwater Elevation Contour Map for 1904

(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.

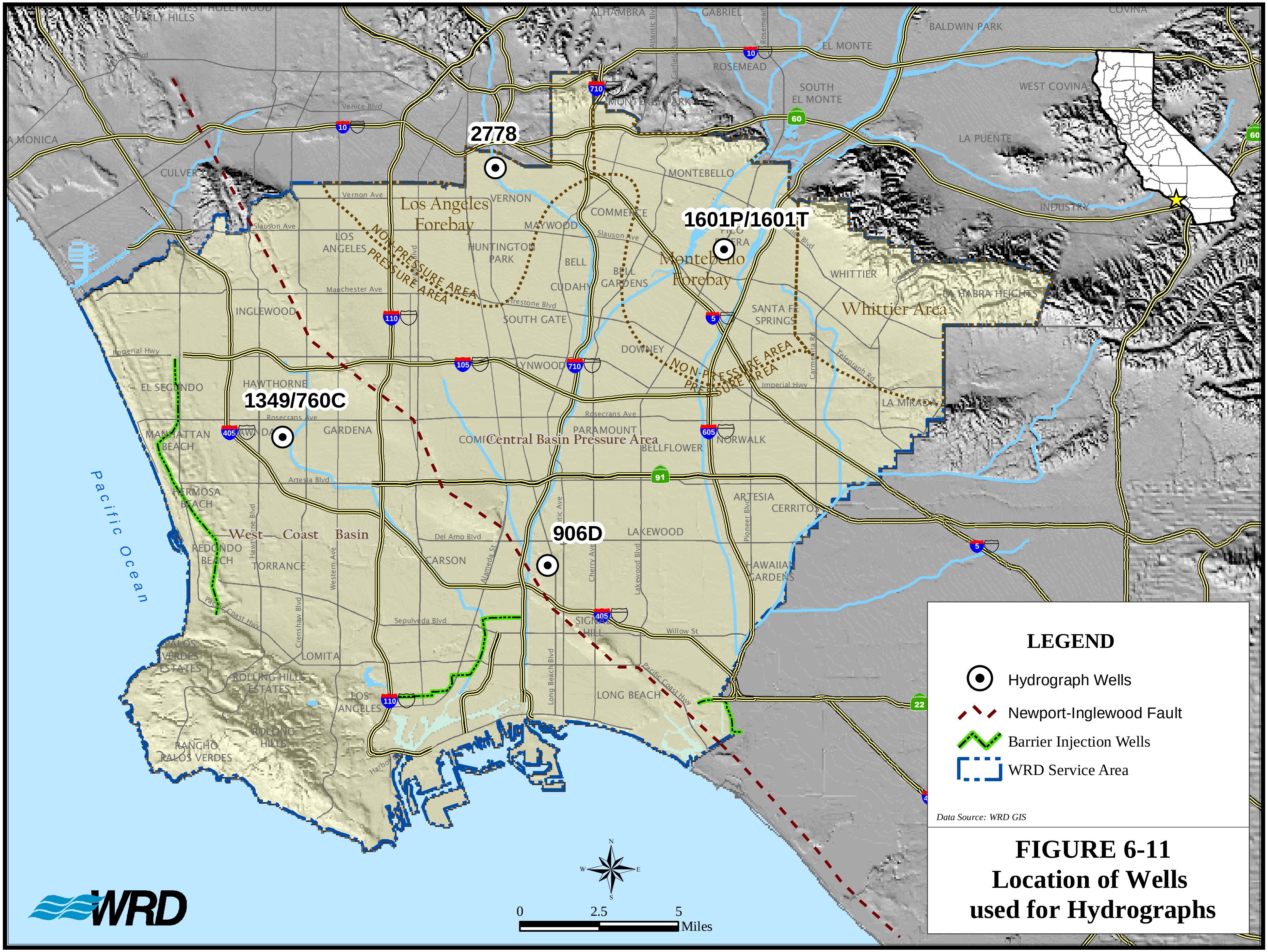
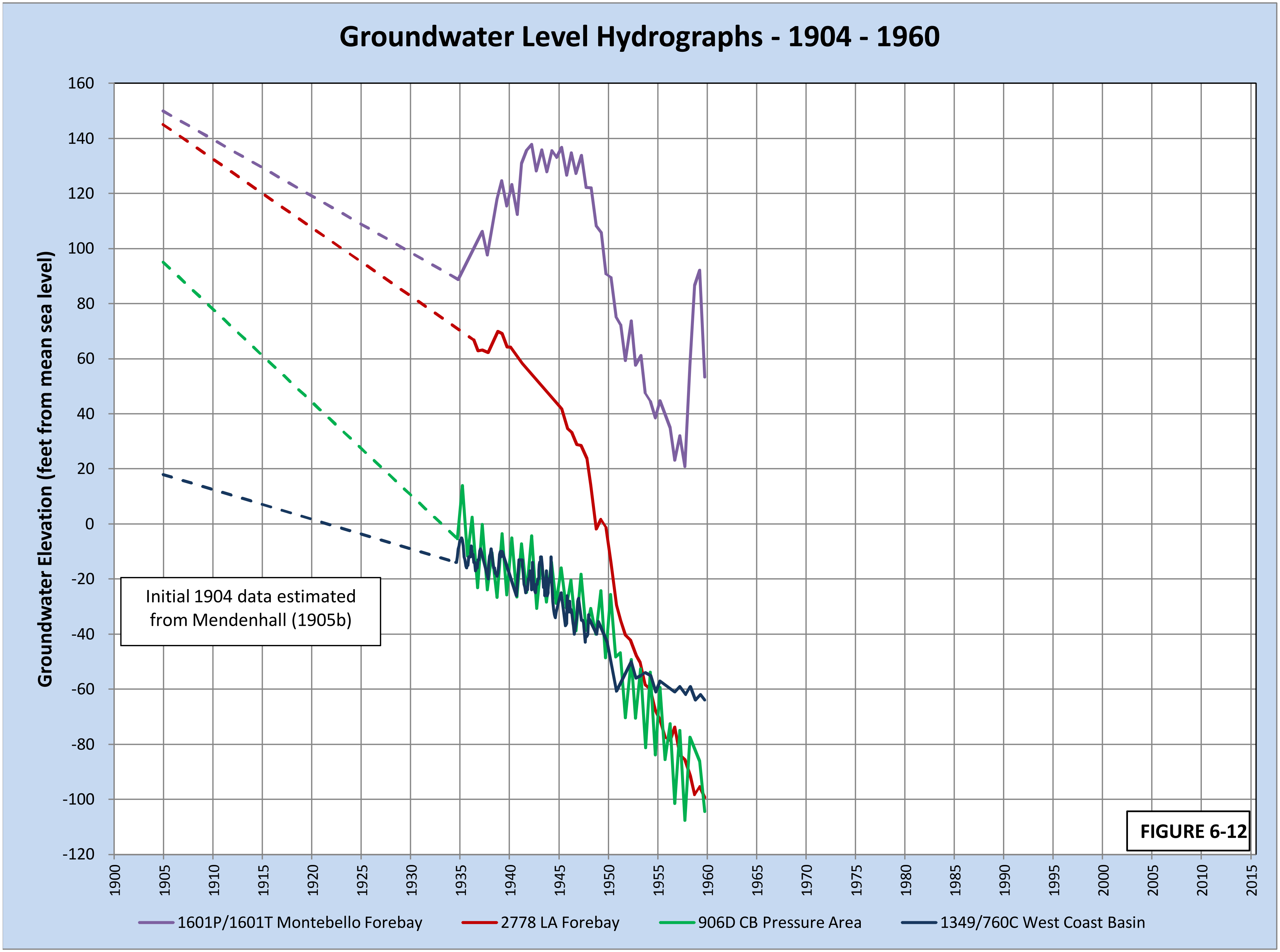


FIGURE 6-11
Location of Wells used for Hydrographs



Groundwater Level Hydrographs - 1904 - 1960
Groundwater Elevation (feet from mean sea level)
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Initial 1904 data estimated from Mendenhall (1905b)
1601P/1601T Montebello Forebay
2778 LA Forebay
906D CB Pressure Area
1349/760C West Coast Basin

FIGURE 6-12

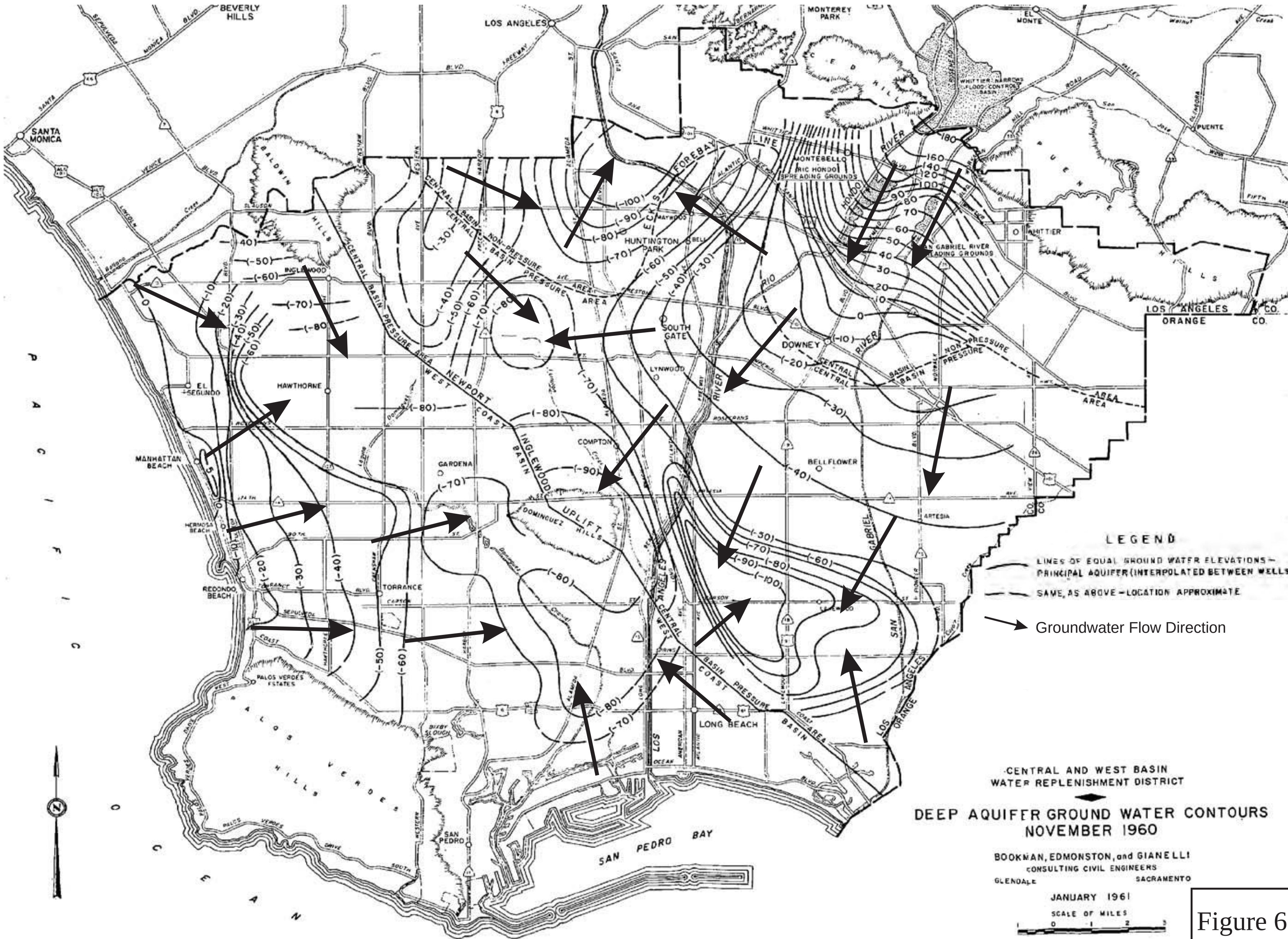
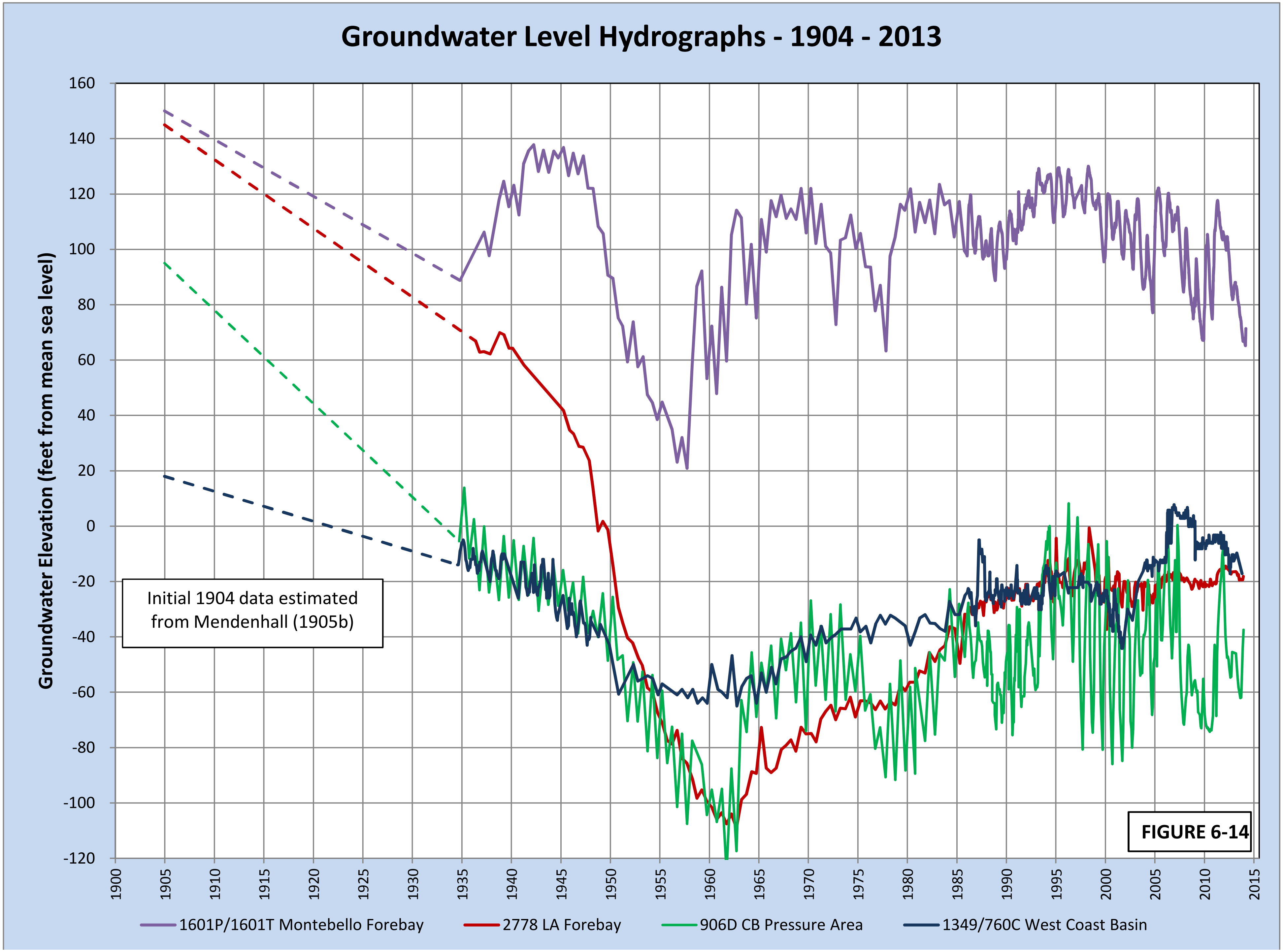


Figure 6-13

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


Groundwater Level Hydrographs - 1904 - 2013
Groundwater Elevation (feet from mean sea level)
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Initial 1904 data estimated from Mendenhall (1905b)
FIGURE 6-14
1601P/1601T Montebello Forebay
2778 LA Forebay
906D CB Pressure Area
1349/760C West Coast Basin

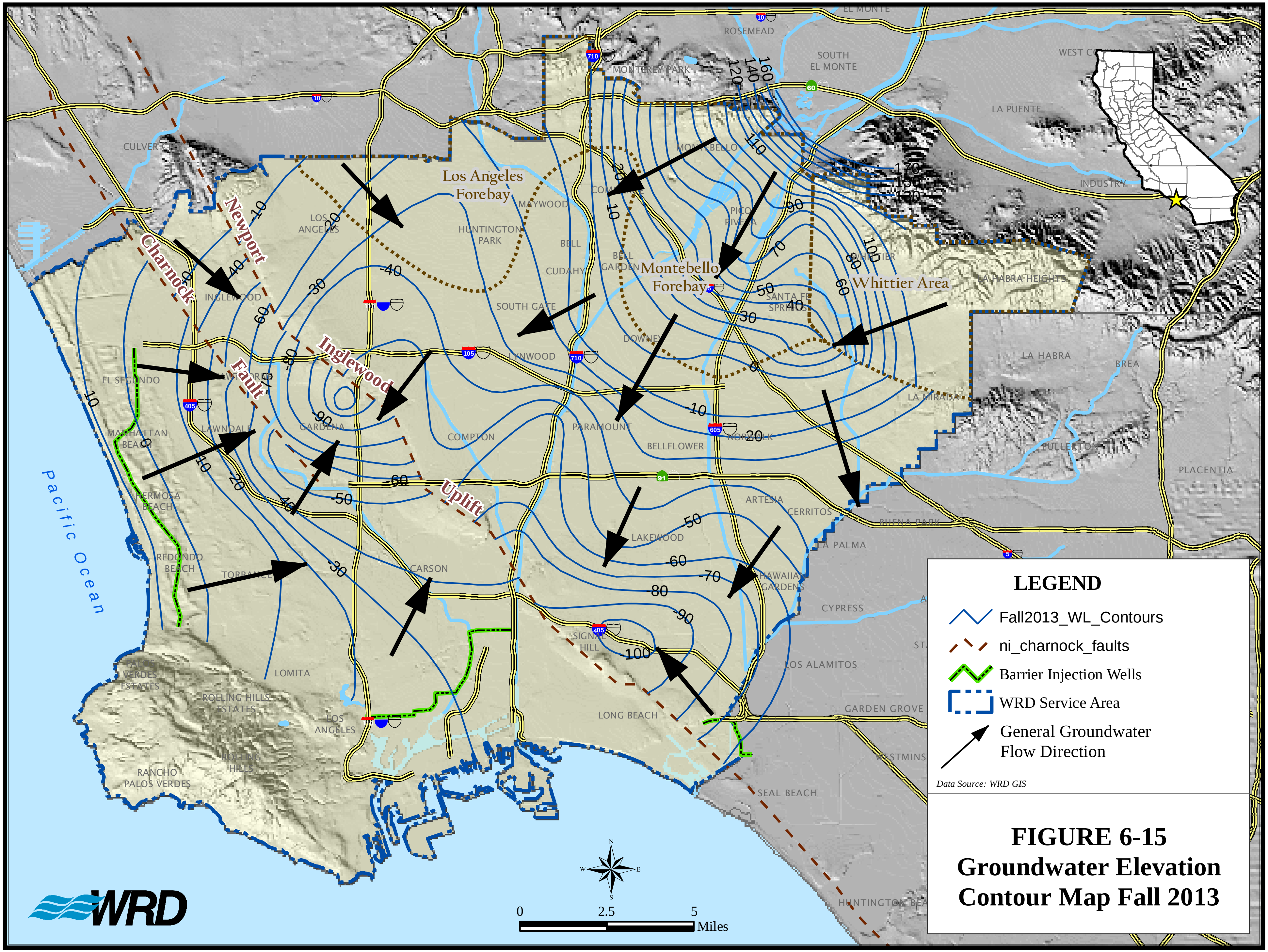


FIGURE 6-15
Groundwater Elevation Contour Map Fall 2013

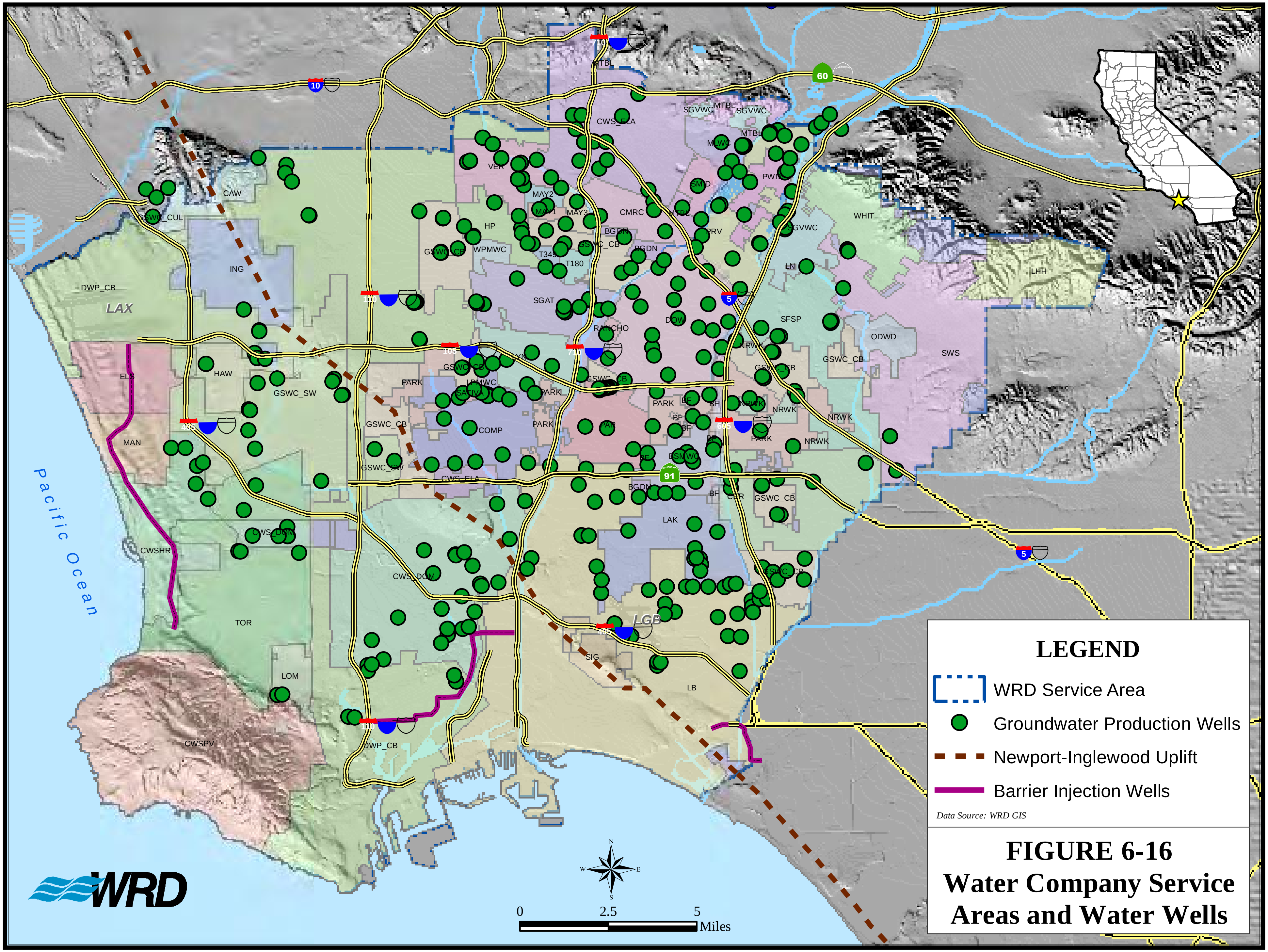


FIGURE 6-16
Water Company Service Areas and Water Wells

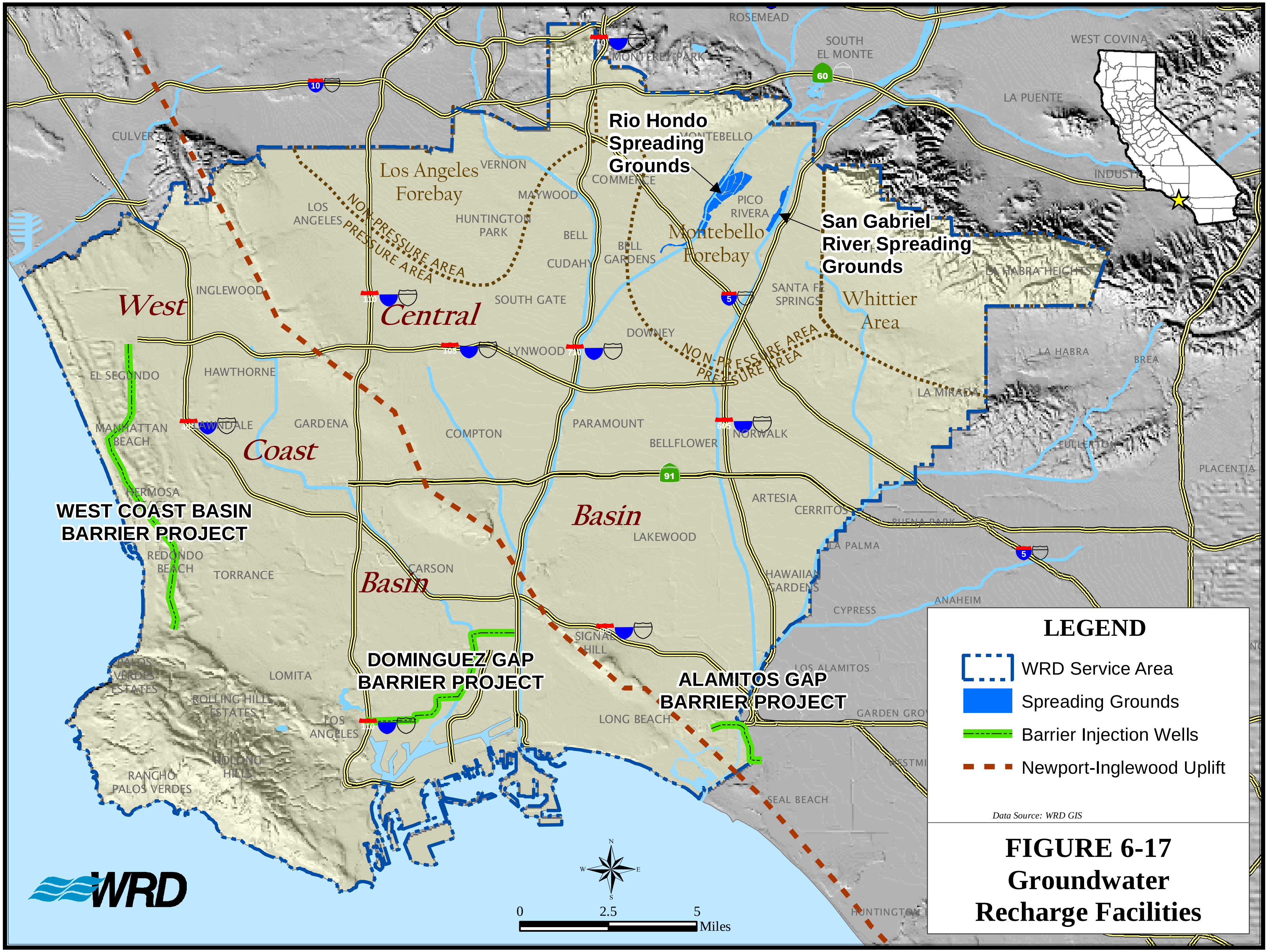
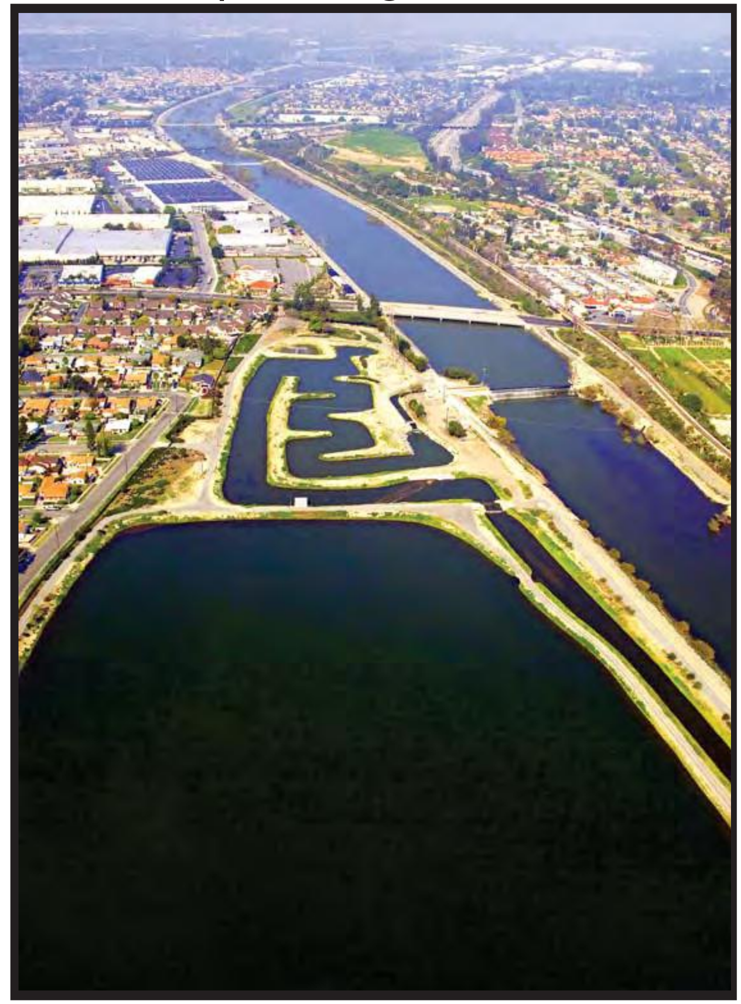


FIGURE 6-17
Groundwater Recharge Facilities

San Gabriel Coastal
Spreading Grounds

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.

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

Photo Source: WRD

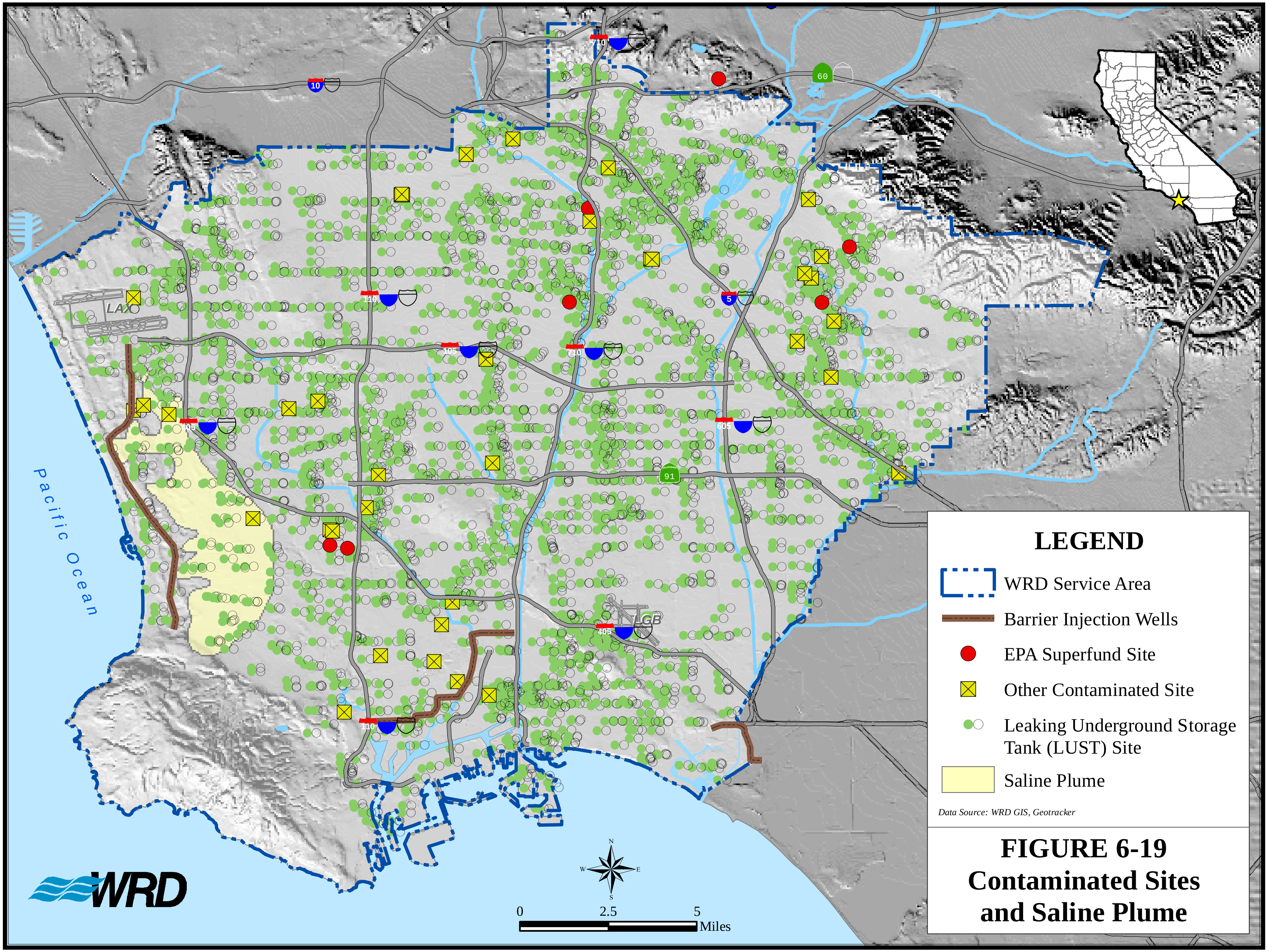


FIGURE 6-19 Contaminated Sites and Saline Plume

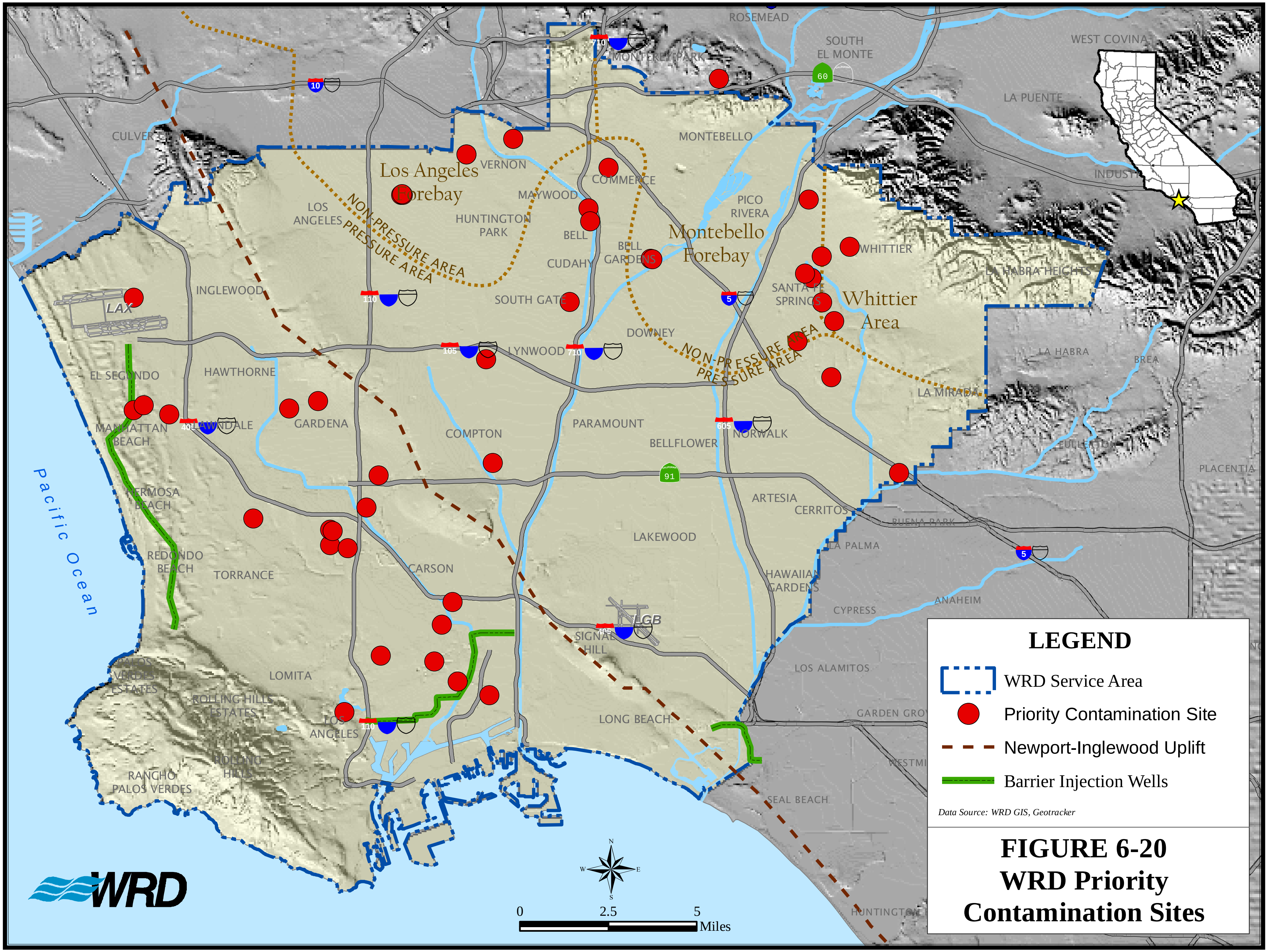


FIGURE 6-20
WRD Priority Contamination Sites

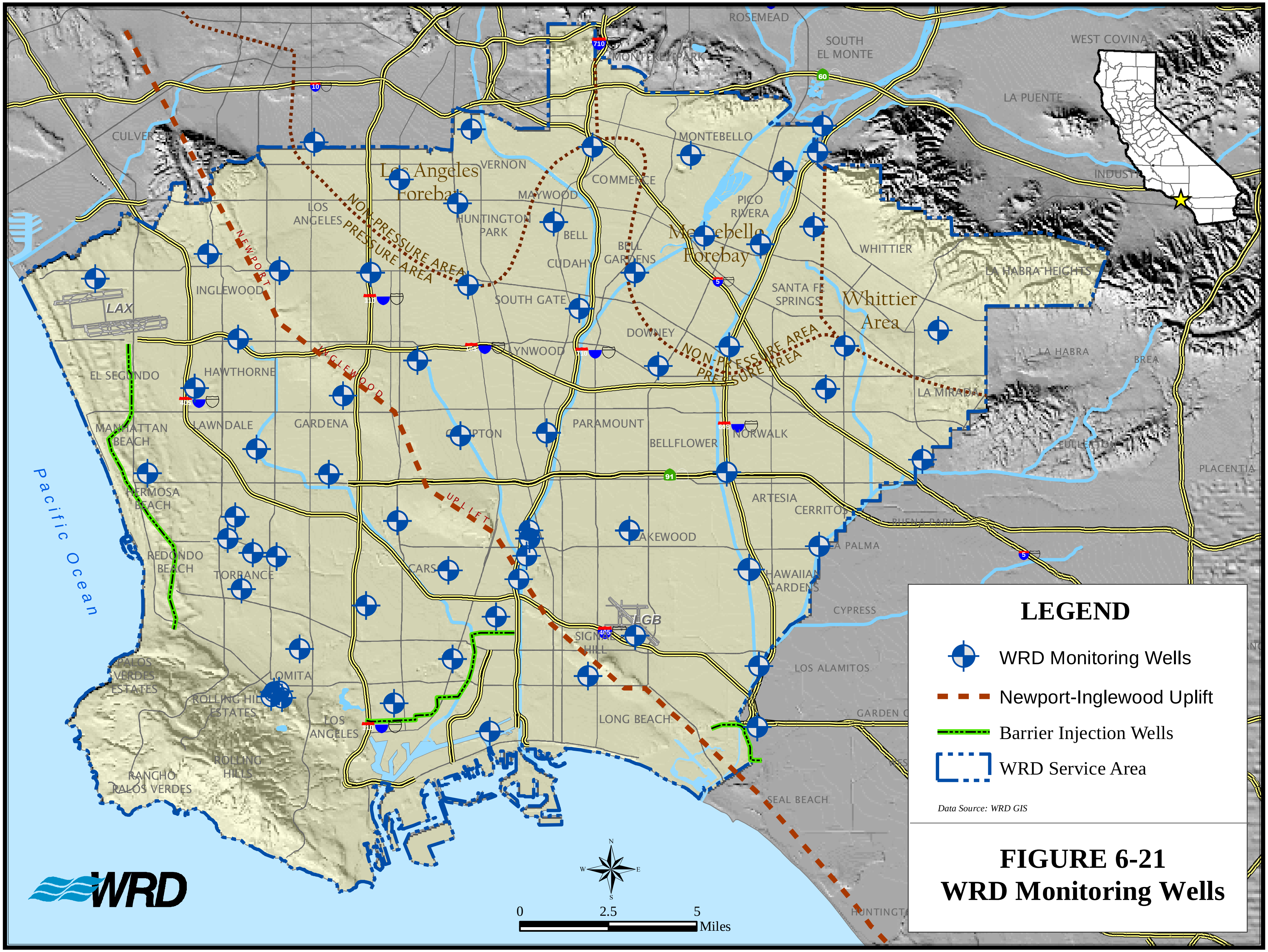


FIGURE 6-21
WRD Monitoring Wells

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WATER REPLENISHMENT DISTRICT
OF SOUTHERN CALIFORNIA

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