County Waterworks District No. 8
City of Simi Valley

Characterization and Groundwater Supply Assessment for Simi Valley Basin

Prepared for
County Waterworks District No. 8, City of Simi Valley

March 2016

TODD GROUNDWATER

Establishing the Foundation for Groundwater Sustainability

County Waterworks District No. 8
City of Simi Valley

Characterization and Groundwater Supply Assessment

For Simi Valley Basin

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Prepared for:

City of Simi Valley

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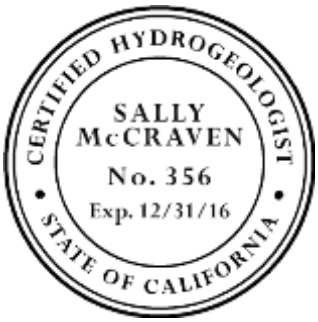

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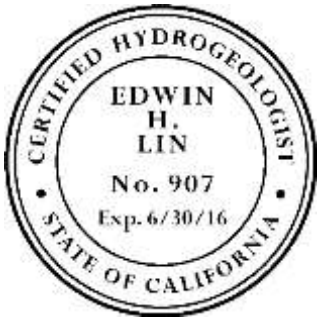

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List of Acronyms

AB3030	Assembly Bill 3030
AF	Acre-feet
AFY	Acre-feet per year

BSBPO	Basin-Specific Basin Plan Objective
BTEX	benzene, toluene, ethylbenzene, and xylenes
Calleguas	Calleguas Municipal Water District
CASGEM	California Statewide Groundwater Elevation Monitoring Program
CIMIS	California Irrigation Management Information System
CY	Calendar Year (January 1 to December 31)
DEM	Digital Elevation Model
DDW	State Water Resources Control Board Division of Drinking Water (formerly California Department of Public Health)
District	Ventura County Waterworks District No. 8
DTSC	California Department of Toxic Substances Control
DWR	California Department of Water Resources
ET	Evapotranspiration
ft-bgs	Feet below ground surface
ft^2/d	square feet per day
ft-msl	Feet mean sea level
gpcd	gallons per capita per day
gpd/ft	Gallons per day per foot
gpm/ft dd	Gallons per minute per foot of drawdown
GAMA	Groundwater Ambient Monitoring and Assessment Program
GIS	Geographic Information System
Golden State WC	Golden State Water Company
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
K_c	crop coefficient
LARWQCB	Los Angeles Regional Water Quality control Board
LID	Low Impact Development
LUST	leaking underground storage tank
MAR	Managed Aquifer Recharge
MCL	Maximum Contaminant Level
meq/L	milliequivalents per liter
Metropolitan	Metropolitan Water District of Southern California
MGD	millions of gallons per day
mg/L	milligrams per liter
MTBE	methyl-tertbutylether
N	Nitrogen
ND	Not Detected
NL	Notification Level
NO_3	Nitrate
NRCS	National Resources Conservation Service
PCE	perchloroethylene or tetrachloroethylene
PCi/liter	picocuries per liter
ppm	parts per million
PRISM	Parameter-elevation Regressions on Independent Slopes Model

RWMP	Recycled Water Master Plan
RWQCB	California Regional Water Quality Control Board, Los Angeles Region
Q	discharge rate
SC	specific capacity
SCS	Soil Conservation Service
SGMA	Sustainable Groundwater Management Act
SMCL	Secondary Maximum Contaminant Level
SVWQCP	Simi Valley Water Quality Control Plant
SWP	State Water Project
SWQO	Surface Water Quality Objectives
SWRCB	State Water Resources Control Board
S	(Aquifer) Storativity
TCE	trichloroethylene
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
T	(Aquifer) Transmissivity
µg/L	Micrograms per liter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USDA	United States Department of Agriculture
VOC	Volatile organic compound
WY	Water Year (October 1 to September 30)

Executive Summary

The Ventura County Waterworks District No. 8 (District), part of the City of Simi Valley (City), commissioned this hydrogeologic study to assess the potential for developing groundwater resources in the Simi Valley Basin. Groundwater across most of the Simi Valley Basin is of naturally poor quality, requiring treatment or blending with imported water to make it suitable for potable supply. The planned extension of the Calleguas Municipal Water District (Calleguas) Salinity Management Pipeline (Brine Line) to Simi Valley presents an important opportunity for the District and potentially other water purveyors to develop groundwater resources through treatment and export of residual brine.

The Simi Valley Basin is composed of unconsolidated alluvial deposits reaching thicknesses up to 800 feet in the central portion of the basin. In addition, fractured and porous formations under the alluvium yield some groundwater to wells. Unconfined aquifer conditions occur in the eastern and central portions of the basin, while semi-confined to confined aquifer conditions occur in the western portion of the basin with a shallower overlying water bearing zone. Current groundwater levels in the basin are stable, with general groundwater flow from east to west across the basin. Groundwater levels in the confined to semi-confined aquifer are above the ground surface in some portions of the western basin. The City operates a network of dewatering wells in the western portion of the basin to mitigate rising, nuisance groundwater conditions. Due to its poor quality, groundwater from dewatering wells is currently discharged to Arroyo Simi without beneficial use in the basin.

Current and historical water balances indicate that average annual Simi Valley Basin inflows (including rainfall recharge and septic, agricultural and municipal return flows) are as much as 9,000 acre-feet per year (AFY). Successful development of these inflows as a water supply is dependent on the locations and yields of new production wells, and the potential for undesired results. An average of 9,000 AFY can be considered as a potential perennial yield, recognizing that undesired results could occur with pumping at lower rates. Moreover, a single average perennial yield oversimplifies the flow into the basin; inflows vary with climatic conditions (among other factors) and depend on whether there is adequate available storage in the basin. This preliminary average perennial yield estimate should be refined as more data are collected and more sophisticated methods, such as groundwater modeling, can be applied to the analysis. The current water balance inflow estimate includes roughly 1,700 AFY of dewatering well water currently discharged to Arroyo Simi, which represents a potential source of water supply with treatment and brine disposal.

The Simi Valley Basin is capable of yielding sufficient groundwater to supply municipal wells. The recommended location for new production wells is the area south of Brea Canyon, bounded generally by the Arroyo Simi to the south and the drainage exiting Tapo Canyon to the east. Yields from properly designed, developed, and maintained wells in this area are expected to range between approximately 500 and 1,000 gpm; higher yields up to 1,600 gpm have been reported. New production wells should be designed and operated based on detailed geologic and geophysical logging and aquifer testing. The poor quality of groundwater in the Simi Valley Basin will necessitate routine maintenance and re-development to extend the service life of production wells.

Additional groundwater management plans/programs are recommended to support future development of groundwater resources. Activities should include development of a basin-wide groundwater level and water quality monitoring plan, completion of a synoptic stream gaging study of Arroyo Simi to assess surface water-groundwater interactions. As additional groundwater resources are developed, the District should consider construction and application of a groundwater flow model to evaluate impacts of future pumping and basin management strategies necessary to sustainably manage the basin. Available funding mechanisms to support these programs should be identified.

Development of a Groundwater Basin Management/Sustainability Plan is recommended to establish goals and objectives for monitoring, reporting, and sustainable development.

1 Introduction

The Ventura County Waterworks District No. 8 (District), part of the City of Simi Valley (City), currently relies almost entirely on imported water for water supply. With concerns over climate change, the recent drought, and increasing costs and uncertainty in imported water supplies, the City is looking to increase use of groundwater in the Simi Valley Basin. Groundwater across most of the Simi Valley Basin is of naturally poor quality, requiring treatment or blending with imported water to make it suitable for potable supply. The planned extension of the Calleguas Municipal Water District (Calleguas) Salinity Management Pipeline (Brine Line) to Simi Valley presents an important opportunity for the City to develop its Simi Valley groundwater resources, through treatment and export of residual brine.

Recognizing the need to develop this resource in a responsible and sustainable manner, the City commissioned this study to develop a comprehensive understanding of the groundwater basin. This is the first step toward management of the Simi Valley Basin for sustainable supply.

1.1 Purpose and Scope

The purpose of the report is to assess the hydrogeologic conditions of the Simi Valley Basin and determine its suitability for development of groundwater resources. By characterizing the perennial yield of the Simi Valley Basin (SVB), this report provides the foundation on which future basin planning and management decisions may be made.

The Simi Valley and nearby groundwater basins are shown on **Figure 1**. While focusing on the SVB, the Study Area includes the Simi Valley watershed shown on Figure 1. This report presents the hydrogeologic conceptual model of the SVB (Section 2), discusses groundwater quality (Section 3) and surface water quality (Section 4), estimates the Simi Valley watershed water balance (Section 5), provides an assessment of groundwater development potential and considerations (Section 6), and summarizes key findings, data gaps, and recommendations for future work to advance groundwater development and management of the SVB (Section 7). References considered in the study are provided in Section 8.

1.2 Acknowledgements

The authors would like to thank the staff of the City of Simi Valley, County Waterworks District 8, various Ventura County Departments, and Golden State Water Company (Golden State WC) for providing data and reports used to prepare this report. Unless otherwise noted, discussion of Golden State WC's water supply is based on data provided by Golden State WC.

2 Hydrogeologic Conceptual Model

2.1 Study Area Physiography

Figure 1 shows the Simi Valley and nearby groundwater basins; the Study Area includes the Simi Valley and Upper Calleguas Creek watersheds. The Simi Valley Basin, a broad, west-plunging valley located in southeastern Ventura County, California, is approximately eight miles long and two miles wide.

Simi Valley lies within the Transverse Ranges Geomorphic Province. The Transverse Ranges Province is geologically very complex and comprises chains of mountain ranges that extend east-west and are separated by valleys. Simi Valley is one of these valleys (Squires, 1997).

Figure 2 shows a preliminary geologic map of Simi Valley and the surrounding area (USGS, 1997). The Simi Valley Basin generally corresponds to the areas of younger alluvial deposits shown on the map.

Simi Valley is bounded on the north by the Simi Fault and Big Mountains and on the south and east by the Simi Hills that join the Santa Susana Mountains to form the eastern termination of the Simi Valley Basin.

The SVB is semi-closed; the Simi Fault crosses the western edge of the basin separating it from the downgradient South Las Posas Valley Basin. Only a small amount of subsurface flow discharges at the west end of the SVB. There is no hydraulic connection between the Simi Valley Basin and the Tierra Rejada Basin, located to the west (Figure 1).

A maximum surface relief of approximately 2,417 feet occurs between the highest peak along the drainage divide to the northeast (3,117 feet above mean sea level [ft-msl]) and the western end of the valley floor. The surface elevation of the basin floor slopes from east to west and ranges from approximately 700 ft-msl in the west to greater than 1,300 ft-msl at the apex of the alluvial fan deposited by the drainage systems of Chivo and Las Llajas Canyons.

The slopes of the mountainous terrain surrounding the valley floor are generally rugged, steep, and incised by rills and stream channels.

2.2 Land and Water Use History

Rancho Simi was created by a Mexican land grant to Don Jose de la Guerra Noriega in 1842. During the Civil War, the de la Guerra family moved to Tapo Canyon and built an irrigation system with aqueducts into the hills to water wine grapes (Leighton, 1985). The de la Guerra family members also were cattle ranchers, utilizing both surface water and groundwater for water supply (Evenson, 1997).

In the 1870s, the first farmers rented the valley floor from the Scott Syndicate of Pennsylvania, which owned a large part of Ventura County at the time. By the 1880s, fields were plowed and grain crops such as barley were grown without irrigation. Water for domestic use and livestock was obtained from shallow wells. In the west part of the Simi Valley Basin, water could be found within 20 feet of the surface. Some of the first wells for irrigation water were drilled in the 1890s, but most crops were watered only by rainfall until the dry years after 1910. Apricots

and walnuts were grown in the early 1900s. At that time, the population of the valley was estimated to be less than 200 (Miller, 1964).

In the early 1900s, the first oil and gas wells were drilled in the vicinity of Simi Valley (Kew, 1918). As shown in **Figure 3**, the California Division of Oil, Gas & Geothermal Resources (DOGGR, 1992) has identified four main oil and gas fields in the vicinity of Simi Valley: the Old Area, Canada De La Brea Area, and Alamos Area located mostly in the hills north of the Simi Valley Basin, and the Strathearn Area located at the far west end of the basin. A number of dry holes have been drilled within the basin. Figure 3 shows very few new and currently active producing wells indicating that oil and gas development is not currently highly active in the Simi Valley area.

In 1911, two major subdivisions were created with five to fifteen-acre lots (ten acres being the rule). Citrus, walnuts and apricots were planted on the lots. A total of 480 acres were reserved at an unknown location for water development, including wells and reservoirs on creeks.

During the First World War, more walnut and citrus trees were planted. A series of dry years brought a water shortage, and new wells were drilled and old ones deepened to intercept the falling water table. After the war, planting of walnuts and citrus orchards continued, along with grapes and persimmons. Louis Robertson and Son developed the Canada Lolaho with a dam to impound water. Again the location is unknown. Walnuts had become a major crop, and in 1921, the Simi Valley Walnut Growers' Association built a walnut packing house in the valley. A total of 320 acres on Tapo Road were planted with figs in 1925 and irrigated by a well.

During the late 1920s and in the 1930s, tomato and vegetable culture was introduced to the valley, placing additional demands on the groundwater supply. At the same time, well drilling activity increased.

Groundwater levels continued to fall. Ventura County historian, Edwin Sheridan, reported that by 1940 water levels had fallen very low, and all existing wells had been deepened as far as possible. Troxell reported a 76 foot decline in groundwater levels in the basin well between 1929 and 1951 and only slight recovery of water levels during the 10-year wet period between 1934 and 1944, clearly indicating a condition of overdraft (USGS, 1957).

From the 1930s through the 1960s, more than a dozen local private water companies were formed and significant amounts of groundwater were pumped from all areas within the basin (Tabidian and others, 1996). Historical records maintained by private water agencies, the County of Ventura Public Works Agency, and other public entities document a continuous drop in groundwater levels during this period of groundwater exploitation.

Historical water quality information is very meager, but generally poor quality groundwater has been recognized since at least 1931 (Leighton, 1985).

Simi Valley was predominantly rural and agricultural in 1950 and the population was about 5,000. During the 1950s, high taxes and labor problems forced many orchards out of business, and the land was subdivided for residential development. By 1960 the population had grown to 8,110.

Review of Department of Water Resources (DWR) well driller's reports indicate that more than 700 wells have been drilled in Simi Valley. Because all well drillers do not provide driller's reports to DWR, the actual number of wells drilled is likely higher. The largest numbers of wells were drilled in the 1940s and 1950s and the dominant water well use was for agriculture. **Figure 34** shows the wells drilled by year, for which logs and drilling dates are available. Available logs indicated about 400 wells were drilled in the 1940s and 1950s. Note that driller's logs and the year the well was drilled is not available for all wells, so the documented 400 wells likely is an underestimate of the total wells drilled during that period.

Based on a 1961 agricultural crop map and estimated crop demand, approximately 14,000 AFY of water was being used for agricultural irrigation. In addition, assuming a valley population of 8,000 and a per capita daily water consumption of 80 gallons per person per day, approximately 700 AFY was being consumed for domestic use for a total estimated groundwater demand of 14,700 AFY in the early 1960s.

In 1963 the Calleguas Municipal Water District (Calleguas) completed a tunnel through the Santa Susana Mountains for imported water delivery to Simi Valley. Well drilling essentially ceased and residential development boomed. The population of Simi Valley swelled to 59,250 by 1970, an increase of 730 percent over 10 years. Many wells went out of operation during the 1960s and were sealed or abandoned as crop irrigation decreased and homes were connected to the municipal water system.

The Sinaloa Water Company quit-claimed some of its wells and well easements to property owners in 1959. In 1974 the Sinaloa Water Company turned over various interests to Ventura County Waterworks District No. 8 (District). The County of Ventura transferred control of the District to the City of Simi Valley in 1977, including wells and seven pump sites.

Many homes remained on individual septic systems, however. As late as 1968, approximately 40 percent of the homes in Simi Valley were not yet connected to a public sewage system.

The combination of decreased pumping, increasing use of imported water for landscape irrigation and increasing use of private sewage disposal systems resulted in a rapid recovery of pre-agriculture groundwater levels beginning in the early 1960s. By the early to mid-1970s, the early groundwater levels had been reestablished in the western part of basin. In 1978 a sharp recovery began from the long periods of below-average rainfall that occurred in the late 1940s and again in the 1960s. Several years of high rainfall contributed to the rise in groundwater levels. As remaining flowing wells were sealed or pumped wells ceased operating, the groundwater continued to rise.

By 1979 about 80 percent of the valley floor was developed, mainly by low- to medium-density single-family residences. The trend in future development appears to be continued development of the valley floor for higher overall residential densities and commercial and industrial uses.

2.2.1 Future Development

The City's General Plan encourages valley floor development while generally discouraging development of the outlying areas. The City's population as of 2011 was estimated to be

approximately 126,329 (RBF, 2011). The City projects that the population served will grow to 149,700 by 2035 with an ultimate water demand of 33,265 AFY (RBF, 2011). This estimate is based on current demand and does not account for the Water Conservation Act mandate to reduce water consumption by 20 percent by 2020. Average consumption over the past 10 years (2000 to 2010) is calculated to be 236 gallons per capita per day (gpcd).

2.3 Water Sources

2.3.1 Purveyors and Water Sources

The District serves approximately 68 percent of the customers in the City of Simi Valley (90,086 customers), while most of the remaining 32 percent are served by the Golden State Water Company (Golden State WC), an investor-owned public utility company. The District also serves unincorporated areas located southeast and north of the incorporated City boundary (RBF, 2011). There are also a small number of private groundwater wells in the Simi Valley Basin.

Currently, the District water supply is primarily imported water with as much as 3 percent of its supply being local. The District's local sources include groundwater and recycled water. Golden State WC's supply is typically less than 10 percent groundwater, with the remainder provided by imported water. Use of groundwater by Golden State WC can vary considerably from year to year.

The District and Golden State WC purchase imported water from Calleguas, who purchases it from Metropolitan Water District of Southern California (Metropolitan), whose primary source for water delivered to this portion of their service area is from the State Water Project (SWP). In the event service is disrupted or unavailable from the SWP, Metropolitan operates facilities to deliver water from the Colorado River Aqueduct (CRA) System water to this portion of their service area, although Calleguas' full demands cannot be met exclusively by CRA System water.

The District pumps groundwater from the adjacent Tapo/Gillibrand Basin via wells. Two wells were in operation through 2010, and a third well was added in early 2011. The wells supply groundwater to nearby customers in the Tapo/Gillibrand Basin for irrigation uses and feed water to the Tapo Canyon Water Treatment Plant for use in the Simi Valley Basin. The Plant currently (June 2015) produces about 140 AFY with the full plant capacity of 450 AFY, which the City hopes to produce later in 2016.

The District produces about 20 million gallons per year (60 acre-feet per year [AFY]) of recycled water, which is used predominantly for landscape irrigation. No recycled water supply is planned for the Golden State WC system.

Calleguas is currently planning to construct a Salinity Management Pipeline (Brine Line), which is planned to reach the western boundary of Simi Valley. Once constructed, the Brine Line will enable the District and Golden State WC to pursue additional groundwater pumping projects, which require treatment to reduce salts. Treatment is currently infeasible given the cost and difficulty of brine disposal.

2.3.2 Surface Water/Stormwater

Surface water is not used for water supply in the Simi Valley.

2.3.3 Imported Water

Table 1 shows the imported water use by the District and Golden State WC between 2006 and 2015 as provided by Calleguas. Over that time period, the District purchased an average of about 22,300 AFY and Golden State WC purchased about 6,700 AFY for an average total imported water delivery to the valley of 29,000 AFY.

Table 1 Imported Water Use

Year	Imported Water (AFY)		
	District	Golden State WC	Total
2006	24,185	7,585	31,770
2007	25,733	7,931	33,663
2008	24,851	7,686	32,537
2009	22,363	6,757	29,119
2010	19,735	5,690	25,425
2011	20,335	5,955	26,289
2012	21,613	6,875	28,488
2013	23,221	6,584	29,804
2014	22,421	6,373	28,794
2015	17,869	5,315	23,184
Average	**22,232**	**6,675**	**28,907**

AFY – acre-feet per year
District – Ventura County Waterworks District No. 8
Golden State WC – Golden State Water Company
Data provided by Calleguas Municipal Water District

2.3.4 Groundwater

The District and predecessors have used groundwater for decades (RBF, 2005); the District currently operates three groundwater production wells located in the Tapo/Gillibrand Basin north of the Simi Valley Basin. In early 2011, Well 31B was replaced by Well 31C, and, at the same time, a new well was added to improve reliability, Well 31D. The Tapo/Gillibrand Basin is not adjudicated; however, a Groundwater Management Plan has been developed (Geoscience, 2007) and the District and the P.W. Gillibrand Company, have agreed to abide by the estimated sustainable yield of 1,450 AFY evaluated as part of the plan (RBF, 2011). The Management Plan also established a monitoring and re-evaluation process to calibrate and refine the yield estimate. Pumping and groundwater elevation data in the Tapo/Gillibrand Basin are collected and recorded monthly.

Figure 5 shows locations of active production wells in the Simi Valley Basin and Tapo/Gillibrand Basin, including the three District wells (31C, 31D and 32) labeled respectively on the map with

ending state well numbers: 24H6, 24H7, and 24C7. The individual well pumping rates documented on the drillers' logs during initial testing were:

- Well 31C: 1,400 gpm
- Well 31D: 1,400 gpm
- Well 32: 900 gpm

The wells are operated to supply untreated groundwater for irrigation to Lost Canyons Golf Course, American Wholesale Nursery, and Spragues Redimix, all located in the Tapo/Gillibrand Basin. In addition, the wells feed the Tapo Canyon Water Treatment Plant. The Plant has a treatment capacity of one million gallons per day (MGD). The annual plant productivity, however, is constrained by seasonal operational need and discharge concerns, and Basin Management limitations. The plant currently produces about 140 AFY, but is planned to produce 450 AFY of potable water for distribution in the District-wide system in 2016 (Wong, 2015).

Table 2 shows the historic groundwater production from the Tapo/Gillibrand Basin by the District and P.W. Gillibrand Company. The District does not currently pump any groundwater from the Simi Valley Basin for water supply. As shown in the table, groundwater production by the District can vary from year to year and averaged about 650 AFY from 2006 to 2015. Incomplete data for the P.W. Gillibrand Company for the period between 2008 and 2015 indicate average groundwater production of about 560 AFY.

Table 2 Tapo/Gillibrand Basin Groundwater Production

Year	City of Simi Valley	P.W. Gillibrand Co.
	AFY	
2006	792	
2007	804	
2008	775	692
2009	777	536
2010	453	434
2011	623	
2012	691	
2013	629	558
2014	501	546
2015	394	572
Average	**644**	**556**

AFY – acre-feet per year
Data provided by Ventura County Waterworks District No. 8

Currently, groundwater from the Simi Valley Basin is pumped by Golden State WC from two active groundwater wells. Historically, groundwater typically has provided less than 10 percent of Golden State WC's total water supply, with the remainder composed of imported water. The groundwater has elevated salts and is blended with imported water to lower the overall salts in water delivered to customers.

As shown in **Table 3**, groundwater production by Golden State WC varied considerably from year to year and averaged about 750 AFY from 2006 to 2015.

There are a few other private domestic and agricultural wells in the basin. As shown on Figure 5, in addition to the District's dewatering wells discussed in Section 2.5 and the Golden State WC's two municipal wells, there are about 34 other active production wells in the valley identified by Ventura County. Of these, 26 are agricultural, 7 are domestic and one has unknown use. The wells are not metered, so the volume of groundwater pumped is not known, but is presumed to be relatively small compared with municipal pumping and dewatering.

Table 3 Golden State Water Company Groundwater Production

Year	AFY
2006	1,272
2007	861
2008	670
2009	584
2010	831
2011	644
2012	151
2013	892
2014	813
2015	97[1]
Average	746[2]

AFY – acre-feet per year
Data provided by Golden State Water Company
1 – Below normal production due to maintenance issues
2 – Average of 2006 to 2014

2.3.5 Wastewater and Recycled Water

The City of Simi Valley's recycled water system, originally built and owned by the Calleguas, delivers recycled water to the Public Services Center, Simi Valley Landfill and Recycling Center (Ventura County Star, 2011). According to Calleguas' 2010 UWMP, total current recycled water use from the Simi Valley Water Quality Control Plant (SVWQCP) is approximately 60 AFY (B&V,

2011). Recent flows from the SVWQCP are shown in **Table 4** and average about 9,500 AFY. Treated effluent from the SVWQCP is discharged to Arroyo Simi near the western end of the Simi Valley Basin

Table 4 District Wastewater Flows

Year	Wastewater Flow (AFY)
2008	9,822
2009	9,756
2010	9,970
2011	9,980
2012	9,579
2013	9,523
2014	9,051
2015	8,532
Average	**9,527**

AFY – acre-feet per year
Data provided by City of Simi Valley

The City of Simi Valley's Sanitation Division completed its Wastewater Reclamation Facilities Plan in 1992. The plan outlined a water reclamation program (Simi Valley Regional Recycled Water System), which would involve the construction of new reclaimed water distribution facilities including pipelines and two new reservoirs that would serve users within the District's service area. The City completed an update to the 1992 Plan in 2008 which outlines expansion of their existing recycled water supply and distribution system.

The 2008 Recycled Water Master Plan (RWMP) identifies potential users of recycled water, which could have a cumulative ultimate recycled water demand of more than 9,000 AFY (K/J, 2008). The District is proceeding with the West Simi Valley Water Recycling Project (Project), based on the recommended projects in the RWMP, to extend the existing system to deliver recycled water to as many as 70 additional customers for their irrigation and other non-potable water uses.

The Project, at an estimated cost of $23 million, would include upgrading an existing recycled water pump station at the SVWQCP and constructing another small pump station, a reservoir and underground pipelines. When completed and fully implemented, the upgraded system could potentially deliver an additional 1,200 AFY of recycled water to local customers including several golf courses, parks, schools, and cemeteries.

In approving the Project, the council authorized the City to initiate negotiations with Calleguas to have the District purchase the existing recycled water system. As with the development of groundwater resources in the Simi Valley Basin, increased use of recycled water reduces the City's reliance on increasingly unreliable imported water supplies.

2.4 Salinity Management Plan

As part of the Salinity Management Plan for the Calleguas Creek Watershed, Calleguas is constructing the Regional Salinity Management Pipeline (Brine Line), extending from an outfall in Port Hueneme to Simi Valley. Currently, groundwater is not heavily developed in Simi Valley because of its poor quality. When the facilities for brine disposal become available in Simi Valley, the use of Simi Valley Basin groundwater for potable water supply could significantly increase by the District. The Simi Valley Basin groundwater supply is critical to the District as its 2010 Urban Water Management Plan (RBF, 2011) projects that water usage (28,152 AFY) is anticipated to exceed supply in 2020. Simi Valley Basin groundwater can expand the City's water supply portfolio in a time of uncertain imported water deliveries. In addition, the Brine Line will improve groundwater quality by moving salts out of the watershed.

The third and final phase of the project will extend the Brine Line to Simi Valley. The alignment of the pipeline has not yet been determined (Padre, 2014). The goal for pipeline completion is the year 2022 in accordance with the salt Total Maximum Daily Loads (TMDL) compliance schedule. The Brine Line would allow the District and possibly Golden State WC to treat Simi Valley Basin groundwater with higher mineral content and dispose of the concentrated brine via the pipeline with ultimate discharge to the ocean.

2.5 Dewatering Operations

Following delivery of imported water supplies to Simi Valley in the 1960s, use of groundwater declined and problematic high groundwater conditions worsened in the west end of the valley affecting more and more acreage as groundwater levels gradually recovered to pre-development levels. **Figure 6** shows the estimated area of artesian conditions in 1972, 1985 and projected for 1995, which was estimated to be expanding at a rate of five to ten acres per year (Leighton, 1985). Subsequently, Leighton (1988) estimated that the area of artesian conditions had increased to an area of 1,341 acres by 1987.

As described in Section 2.8.1, the west end of the Simi Valley Basin comprises a shallower unconfined water bearing zone, a zone of confining deposits, and an underlying deeper confined to semi-confined aquifer. Upward leakage of groundwater occurs from the lower confined/semiconfined aquifer to the shallow water-bearing zone along both natural and manmade pathways; manmade conduits include poorly sealed or improperly abandoned wells.

In 1987, the District began installing and operating a network of dewatering wells screened in the deeper aquifer to mitigate problematic high groundwater conditions (Leighton, 1988). The dewatering facilities currently include six extraction wells: Ward (08B4), Chain (08D4), Pacific (08K7), Sinaloa 2 (08L7), Sinaloa 3 (08L8), and First Street (09E1) (see Figure 5). A seventh dewatering well, Madera (08M1), is idle and has not pumped since 2006. To monitor the effectiveness of the dewatering facilities, the District regularly collects groundwater levels from six paired shallow/deep aquifer observation wells, Los Angeles East (07J3), Los Angeles West (07J4), Cochran West (08A1), Cochran East (08A2), Shasta South (08C3), Shasta North (08C4), Bonita West (08N1), Bonita East (08N2), Sinaloa South (08Q4), Sinaloa North (08Q5), First Street South (09N2), and First Street North (09N3) (see Figure 5). The area of artesian

conditions was reported to have decreased to 707 acres by 1988 following initiation of dewatering and below normal rainfall (Leighton, 1988).

Groundwater quality in the western Simi Valley Basin is poor and not suitable for potable or irrigation purposes without treatment. Accordingly, the dewatering water is discharged to the storm drain system and ultimately to the Arroyo Simi.

Table 5 shows the total dewatering pumping from 2007 to 2015, which averaged 1,700 AFY over that time period.

Table 5 Dewatering Pumping

Year	Dewatering Pumping (AFY)
2007	1,949
2008	1,882
2009	1,867
2010	1,782
2011	1,828
2012	1,522
2013	1,569
2014	1,523
2015	1,428
Average	**1,675**

AFY – acre-feet per year
Data provided by City of Simi Valley

2.6 Climate

The climate of Simi Valley is mild with average temperatures in the 70s in the summer and 50s in the winter, although temperatures on the valley floor can fall below freezing in the winter. The weather is influenced by the continental air mass most of the time and by the ocean climate a small percentage of the time. Most precipitation occurs during the months of December through March. Precipitation is less frequent in the summer months and dry periods can often last several months. The average annual precipitation was about 14.5 inches between 1927 and 2015. But precipitation varies considerably from year to year. Multiple years of below normal rainfall constitute drought periods.

2.7 Geology

Simi Valley and its watershed are located in the Transverse Ranges geomorphic province. A surface geologic map of the valley and surrounding areas is shown on Figure 2 (USGS, 1997). This province consists of a series of east-west trending mountain ranges which extend from eastern San Bernardino County to the Channel Islands. Simi Valley is bounded on the north by

Big Mountain and on the south and east by the Simi Hills. The valley is the result of a broad synclinal depression that plunges to the west.

The Simi Valley Basin is underlain and surrounded by bedrock composed of alternating layers of conglomerate, sandstone, siltstone, shale and minor amounts of volcanic rocks. The sedimentary rocks are both marine and non-marine in origin. As a result of a gentle westward inclination of the strata, the oldest rocks are exposed at the eastern end of the basin. These rocks consist of well cemented sandstones that are resistant to weathering and dominate the local skyline.

The major part of the valley is underlain by Pleistocene and Recent Alluvial deposits composed of unconsolidated sands, silts, gravels, clays and minor amounts of peat that reach a thickness of about 800 feet in the central part of the valley. Isolated patches of terrace deposits are located along the lower foothills of the valley. These deposits are older than the youngest valley floor deposits. They are composed of sands, silts, clays and minor amounts of gravels. The predominant structural feature controlling the valley is a west-plunging syncline (trough-like fold).

2.7.1 Faults and Barriers

The Simi Fault is a reverse fault located along the north edge of the valley (see Figure 2). This fault trends toward the southwest. At the west end of the valley, Arroyo Simi crosses the buried trace of the fault. The Simi Fault is of Tertiary age with up to 1,600 meters vertical separation (Oligocene Sespe) and continued Quaternary activity (USGS, 2000).

The fault is classified by the California Division of Mines and Geology as being "active" (as far east as Las Llajas Canyon), which means that it has experienced surface rupture during the last 10,000-11,000 years. Recent work on the fault in the area (just north of the site of the former Simi Valley Drive-in Theater) has led to the conclusion that the fault has experienced surface rupture during the last 1,500 to 6,000 years.

The Simi Fault crosses the northwestern end of the Simi Valley Basin at the southeast end of the South Las Posas Basin. The fault may be a partial barrier to groundwater flow between the two basins.

2.8 Hydrogeology

2.8.1 Aquifer Systems

Within the Simi Valley Basin, the primary water-bearing units are within the recent alluvium. Groundwater also occurs in interstices and fractures of the older formations underlying the alluvium and in the adjacent formations in the Tapo/Gillibrand Basin (SWRCB, 1956). In particular, permeable sand and gravel members of the Santa Barbara Formation are the source of groundwater in the Tapo/Gillibrand Basin. In addition, drillers' logs indicate that many wells in the Simi Groundwater Basin have well screens that extend below the alluvium.

The two main water-bearing zones in the western portion of the basin, a lower confined or semi-confined aquifer and an overlying unconfined water-bearing zone separated by a zone of predominantly fine grained materials (SWRCB, 1953; DWR, 1968). The upper zone is considered

a water-bearing zone rather than an aquifer because yields from the zone are insufficient to supply a well. The lower aquifer in the western portion of the basin has areas that are semi-confined or "leaky" providing recharge to the overlying thick section of silt, clay, and poorly sorted sand. As such, the two water-bearing zones are separated by a leaky aquitard that consists primarily of clay or sandy clay. In addition, lost and improperly abandoned wells are believed to provide conduits for leakage of water from the lower aquifer to the upper water-bearing zone (Leighton, 1985). The upper water-bearing zone ranges in depth from 35 to 80 feet.

The central and eastern portions of the basin are composed of one unconfined aquifer. Water supply wells in the basin are screened at various depths in the eastern portion of the basin and in the deeper confined to unconfined aquifer of the western basin. The upper aquifer in the western portion of the basin does not produce significant volumes of water.

2.8.2 Hydrogeologic Cross Sections

Seven hydrogeologic cross sections (A-A' through G-G') were prepared for this study and are presented on **Figures 7** through **11**. Inset maps provided on each figure show the cross section locations, which were selected to maximize the amount of hydrogeologic data presented. Three cross sections, A-A' through C-C', are oriented in the direction of groundwater flow in the valley (east-west), while four cross-sections (D-D' through G-G') are oriented perpendicular to groundwater flow in the valley (north-south). Cross section G-G' depicts hydrogeologic conditions in both the Tapo/Gillibrand and Simi Valley Basins.

Cross sections were developed using geologic maps, well construction, lithologic, and aquifer pumping test information contained in DWR well completion reports. For each well, lithologic information is symbolized to show the distribution of fine, coarse-grained, and consolidated deposits encountered. Available borehole geophysical (electric) logs are also provided on the sections for comparison. Additionally, aquifer pumping test information contained in the DWR well completion report is presented above the well name, including the pumping test discharge rate (Q) in gpm and calculated well specific capacity (SC) in gpm per foot of water level drawdown (gpm/ft dd).

The interpreted depth to the base of unconsolidated sediments is also shown on each cross section, with semi-consolidated/consolidated sediments labeled as bedrock on the cross sections. Groundwater levels depicted on each cross section reflect average 1990 conditions. Ground surface elevations on the cross sections are estimated from the 30-meter digital elevation model.

Key features shown on the cross sections are described below:

<u>Cross Section A-A':</u> Cross section A-A' (Figure 7) is an eight-mile, west-to-east cross section generally oriented along Highway 118. The section begins at the western margin of the Simi Valley Basin, crosses the buried Simi Fault and the northern portion of the artesian/dewatering zone, and terminates in semi-consolidated deposits along the eastern margin of the Simi Valley Basin. The base of unconsolidated sediments along the section coincides primarily with the top of shale deposits composing the Sespe Formation and varies from approximately 200 feet

below ground surface (ft-bgs) in the western and eastern portions of the section up to 800 ft-bgs in the central portion of the valley.

Sand and gravel deposits identified on the cross section are highly permeable in two main areas: 1) between the District's Ward dewatering well (2N/18W-8B4; third well east of D-D' on the section) and 2N/18W-3L2 (well closest to and west of F-F'); and 2) between 2N/18W-11A7 and 2N/18W-1K1 (at and just west of G-G'). Well specific capacities in these areas generally exceed 10 gpm/ft dd for relatively high pumping rates (ranging from 800 to 1,100 gpm). From 2N/18W-3R2 to 2N/18W-11B4 (east of F-F'), lower specific capacities (less than 5 gpm/ft dd) appear to be the result of less permeable sand deposits and increased clay content in this area. Alluvial deposits east of G-G' gradually thin to the east and appear to be less permeable; thus, this area is considered less favorable for future groundwater development.

Cross Section B-B': Cross section B-B' (Figure 8) is a nine-mile, west-to-east cross section oriented parallel with and about 0.75 miles south of cross section A-A'. The section begins in the western portion of the Simi Valley Basin, crosses the southern portion of the artesian/dewatering zone, and terminates in semi-consolidated deposits along the southeastern boundary of the Simi Valley Basin. Similar to cross section A-A', the base of unconsolidated sediments along the section coincides with the top of shale deposits of the Sespe Formation. Depths vary from less than 100 ft-bgs along the western and eastern margins of the basin up to 600 ft-bgs in the central portion of the valley. The eastern half of the basin along this section is generally thinner (200 to 250 feet) and more clay-rich compared to the western half of the basin (300 to 600 feet). With the exception of a few wells (including the District's Ward dewatering well and Golden State WC Niles #1), well specific capacities along this section are relatively low (typically less than 3 gpm/ft dd). Well yields are low to moderate, ranging from less than 100 up to 500 gpm along the section.

Cross Section C-C': Cross section C-C' (Figure 9) is a six-mile, west-to-east cross section oriented along the southern portion of the valley, about 0.5 miles south of cross section B-B'. The section begins in the southwestern portion of the Simi Valley Basin and terminates where the Arroyo Simi and outcropping bedrock meet at northern end of Runkle Canyon (see Figure 2). As shown on the cross section, the depth to the base of unconsolidated sediments varies considerably along this section, with relatively shallow depths (less than 200 feet) in the western half of the basin, increasing to approximately 500 feet in the central portion of the basin, before shallowing considerably east of 2N/18W-15H3 (near F-F'), where sandstone and shale occur just below the ground surface. It is noted that alluvial sediments encountered in 2N/18W-12P5 are projected onto the cross section, representing conditions slightly to the north of the section. Localized pockets of permeable sand and gravel exist, but similar to wells on cross section B-B', well specific capacities are relatively low (ranging from 0.2 to 4.0 gpm/ft of drawdown) for low to moderate pumping rates (between 45 and 460 gpm).

Cross Section D-D': Cross section D-D' (Figure 10) is a three-mile, north-to-south cross section that crosses the Simi Fault through the western portion of the artesian/dewatering zone and into the southwestern portion of the Simi Valley Basin. Depth to the base of unconsolidated sediments south of the Simi Fault is approximately 600 ft-bgs and gradually decreases to about 300 ft-bgs in the south/southwest on average. Alluvial deposits are predominantly clay. Thin

sand and gravel deposits are tapped by existing wells, but well specific capacities are relatively low (less than 5.0 gpm/ft dd) for well pumping rates between about 400 gpm in the artesian/dewatering zone to 125 gpm in the south/southwest.

Cross Section E-E': Cross section E-E' (Figure 10) is a three-mile, north-to-south cross section that originates at the southern end of Brea Canyon (see Figure 2) east of the artesian/dewatering zone, crosses the Simi Fault, and terminates in the Simi Hills to the south. South of the Simi Fault, the depth to the base of unconsolidated sediments is about 500 ft-bgs in the northern half of the valley gradually decreasing to less than 50 ft-bgs at the southern margin of the basin. Sand and gravel deposits within a 0.5-mile stretch near cross section A-A' are highly permeable. Well specific capacities for two wells (2N/18W-9A1 and -9A2) are 11 and 40 gpm/ft dd, respectively. Well specific capacity is unknown for the three wells on the cross section near B-B' (2N/18W-9H2, -9J1, and -10N1). Given the significant sand and gravel deposits encountered in these wells, specific capacities are likely moderate to high in these wells (5 to greater than 10 gpm/ft dd). Specific capacities of wells to the south (near cross section C-C') range from 3 to 4 gpm/ft dd.

Cross Section F-F': Cross section F-F' (Figure 11) is a three-mile, north-to-south cross section that begins in the hills near Dry Canyon and terminates in the Simi Hills to the south. As shown on the section, consolidated sediments (sandstone and shale) occur just below the ground surface near the Simi Fault south to 2N/18W-3J1. The basin deepens considerably to between 600 and 800 ft-bgs (between cross sections A-A' and B-B'), shallowing gradually to the south. Three wells in the central portion of the basin (near cross section B-B'), including the Golden State WC's two wells, have relatively high well specific capacities (10 to 23.0 gpm/ft dd). In contrast, other well specific capacities along the section are fairly low (ranging from 2 to 3 gpm/ft dd).

Cross Section G-G': Cross section G-G' (Figure 11) is a six-mile, north-to-south cross section that begins in the Tapo Gillibrand Basin, traverses through the Simi Valley Basin, and terminates in semi-consolidated deposits along the southern boundary of the Simi Valley Basin. Note that cross section G-G' has a different vertical scale. Existing District wells in the Tapo-Gillibrand Basin (Well 32, 31C, and 31D on the section) tap highly permeable sand and gravel deposits of the Saugus Formation from about 200 to 700 ft-bgs. Well specific capacities range from 12 to 35 gpm/ft dd for pumping rates between 1,400 and 2,100 gpm. The depth to base of unconsolidated deposits in the Simi Valley Basin reaches up to 500 ft-bgs in the middle of the basin and gradually declines to the south. As shown on the section, one well (2N/18W-1K1) has a high well specific capacity (14.3 gpm/ft dd) with a well yield of 1,000 gpm. While data are limited, well yields and specific capacities likely decline south of B-B'.

2.8.3 Recharge Areas

During 1951 and 1952, the Soil Conservation Service (SCS) conducted an investigation of possible spreading areas in Simi Valley (1953). This investigation included studies of infiltration rates and soil profiles to determine the suitability of various areas for spreading for local stormwater.

The SCS estimated that there were about 725 acres of land overlying Simi Basin suitable for water spreading purposes. Of this area, it was concluded that about 590 acres would have a continuous infiltration capacity of about one foot of water per day, and that about 135 acres would have a continuous capacity of about two feet of water per day.

Studies by SCS indicate the most suitable locations for major spreading works on alluvium are situated near the mouth of Tapo Canyon and Dry Canyon, along Chivo Creek, and along Arroyo Simi just west of Santa Susana (see Figure 2 for canyon and creek locations).

Figure 12 shows the distribution of soil infiltration potential based on the most recent SCS survey. The figure reveals that the Simi Valley Basin has a broad distribution of soil infiltration capacity. **Figure 13** isolates areas with moderate and high infiltration rate soils, corresponding to high recharge potential. As delineated on Figure 13, confined aquifer conditions likely limit the groundwater recharge potential of permeable soils in the western portion of the Simi Valley Basin. In contrast, unconfined conditions in the central and eastern portions of the basin generally allow for more efficient groundwater recharge.

As shown in the aerial photograph that provides the background for the Figure 13 infiltration potential map, much of the area with high to moderate recharge potential is urban and has been built on and paved, which limits natural recharge of precipitation and runoff as well as the potential of managed recharge. Protecting recharge areas is important for maximizing natural replenishment of the basin. Accordingly, managing land use in these areas and encouraging Low Impact Development (LID) measures (e.g., stormwater detention/recharge systems, contoured unlined swales, and permeable pavement) is recommended if groundwater development is pursued. Larger, undeveloped areas with moderate to high infiltrating soils may be suitable for potential future managed aquifer recharge (MAR) facilities.

2.8.4 Aquifer Properties

Two key parameters, transmissivity (T) and storativity (S), are used to quantify the potential productivity and storage characteristics of water-bearing units. Transmissivity is an indication of the productivity of an aquifer and can be estimated by performing a constant rate, long-term pumping test. If an aquifer has a transmissivity less than about 150 square feet per day (ft^2/d) or 1,000 gallons per day per foot (gpd/ft), it can supply only enough water for domestic wells or other low-yield uses. With a transmissivity of about 1,500 ft^2/d or 10,000 gpd/ft or more, well yields are adequate for industrial and municipal purposes (Driscoll, 1986).

Storativity can be defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in the component of head normal to the surface (Todd and Mays, 2005). Generally, storativity (a unit-less value) indicates whether the water bearing zone is unconfined (0.01 to 0.3) or confined (0.005 to 0.00005).

One constant rate long-term pumping test was conducted in the Sinaloa dewatering well in the western portion of the basin, which included monitoring at the pumping well and two observation wells (Leighton, 1985). Analysis of the data, using the Hantush-Jacob method (1955) developed for a pumping test in a leaky aquifer, yields a transmissivity of 2,304 ft^2/d and a storativity of 0.03. These values indicate a relatively productive aquifer capable of providing

yields adequate for municipal supply wells with a storativity representative of a semiconfined aquifer. The pumping test analysis is included in Appendix A.

While a constant rate, long-term pumping test is the best method of determining transmissivity, it can also be calculated empirically based on the initial pumping rate of the well and the observed drawdown. These initial measurements are often recorded on well drillers' logs. The specific capacity of a well is equivalent to the discharge (Q) of the pumping well in gpm divided by the drawdown in feet in the pumping well at a specified time interval. The specific capacity can be used to estimate T values. As a general rule of thumb, developed from an empirical calculation (Driscoll, 1986), the transmissivity (in gpd/ft) approximately equals the specific capacity (in gpm/ft dd) times a coefficient of 2,000 for confined aquifers and 1,500 for unconfined aquifers. Because this empirical method is impacted by well efficiency (which is commonly less than 100 percent), the T value is considered a conservative (low) estimate of the actual transmissivity of the aquifer.

Figure 14 illustrates the spatial distribution of T values for 72 wells derived from hydraulic information contained in well driller's reports. Reported well yields, as represented by the pumping rate (in gpm) at the time of initial testing after well completion, are shown in the text labels next to each well. As indicated, T values range from less than 100 gpd/ft up to 160,000 gpd/ft. The large range and geographic distribution of values indicate the importance of location within the basin in predicting potential well yield.

As shown on the figure, the distribution of T values shows a distinctive spatial pattern. Within the Simi Valley Basin, higher T values occur in the area south of Brea Canyon, generally bounded by the Arroyo Simi to the south and drainage from Tapo Canyon to the east. Estimated aquifer T values in this area are generally above 10,000 gpd/ft and commonly exceed 50,000 gpd/ft. Elsewhere, T values are lower ranging from less than 1,000 up to 10,000 gpd/ft. A small pocket of higher T values exists in the most southeastern portion of the Simi Valley Basin.

In the Tapo/Gillibrand Basin, T values of the Saugus Formation tapped by the three active District wells (Wells 31C, 31D, and 32) are relatively high (greater than 20,000 gpd/ft).

Based on the pumping test values and distribution of empirically-derived T values, development of municipal supply wells in the study area is feasible.

2.8.5 Well Yields

Well yields depend on the aquifer properties as well as the diameter and design of the well and well efficiency, among other factors. Review of driller's reports indicates a range of pumping rates from 4 to 1,600 gpm with an average of about 400 gpm. It is noted that the pumping rates reported in the driller's reports provide a general indication of typical well yield, but may not reflect the maximum sustainable pumping rate of a particular well. Review of dewater well pumping presented in Table 5 indicates a declining trend in recent years. Leighton (1988) noted that wells located in the western portion of the basin have a short lifespan due to corrosive water and have problems with calcium carbonate cementation and iron bacteria encrustation. Accordingly new dewatering wells were installed with stainless steel screens and acidation

pipes to facilitate cleaning and pump columns and bowl assemblies were covered with epoxy to limit encrustation.

Yields in the shallow water-bearing zone in the western portion of the basin are very low, and two exploratory wells reportedly pumped dry in a matter of minutes (Leighton, 1972).

As shown on Figure 14, the spatial distribution of well yields is similar to those observed for T values. High yields (1,000 to 1,600 gpm) are observed in the area south of Brea Canyon bounded by the Arroyo Simi to the south and drainage from Tapo Canyon to the east. Some high well yields are also observed east of the Tapo Canyon drainage. Well yields south of Arroyo Simi are lower, generally ranging from less than 50 gpm up to about 500 gpm.

In the Tapo/Gillibrand Basin, well yields of the three active District wells (Wells 31C, 31D, and 32) are high, generally ranging from 1,400 to 2,100 gpm.

2.9 Groundwater Occurrence and Flow

The predominant direction of groundwater flow within the Simi Valley Basin is east to west. Unconfined conditions occur in the eastern and central portion the basin transitioning to an upper unconfined and lower confined or semiconfined aquifer in the western portion of the basin. **Figure 15** shows groundwater elevation contours in the fall of 1951 as mapped by the SWRCB (1956). Elevations range from about 1,050 ft-msl in the eastern end of the basin to 650 ft-msl in the western end of the basin. A pumping depression is shown in the western end of the basin. Average groundwater elevation contours in 1980 and 1990 are shown on **Figures 16** and **17**, respectively. Groundwater elevations are higher in the more recent maps compared with Fall 1951 and generally higher in 1990 compared with 1980. Elevation contours represent the unconfined water table aquifer in the eastern and central portions of the basin and the deeper semi-confined to confined aquifer in the western portion of the basin. The approximate area of artesian conditions where groundwater levels in the lower aquifer are above the ground surface are also shown.

2.9.1 Groundwater Levels and Trends

Groundwater level data are available from the California Statewide Groundwater Elevation Monitoring (CASGEM) program, the City dewatering observation wells, and from Golden State WC for their two production wells. The CASGEM program was initiated by the State Legislature in an amendment to the Water Code in late 2009. This program mandates statewide groundwater elevation monitoring to track seasonal and long-term trends in groundwater elevations in California's designated groundwater basins. To achieve that goal, the amendment requires DWR to seek out voluntary participation by local monitoring entities to collect and publish groundwater elevation data (DWR, 2010). The intent of the CASGEM program is to establish a permanent, locally-managed program of regular and systematic monitoring that builds on established local groundwater monitoring and management programs. DWR has prioritized basins based on various factors, but the ranking is primarily based on degree of reliance on groundwater. Because the Simi Valley Basin is not currently highly reliant on groundwater for water supply, it has been designated as a low priority basin. The Ventura

County Flood Control District is the designated monitoring entity that reports groundwater level data to the CASGEM program.

Before the extensive agricultural development and subsequent over-pumping in the 1940s and 1950s, steady-state groundwater conditions existed within the basin. Historically shallow groundwater conditions in the western portion of the basin were evident in mapped marshy areas and peat deposits. During the period of extensive over-pumping in the 1940s and 1950s's, significant overdraft was observed within the basin. Average water levels during this period dropped at a rate of over 7 feet per year until the early 1960s when the delivery of imported water began in the basin.

The upper chart on **Figure 18** shows a histogram of three wells with long records of water level measurements. Well 08C2 (blue) is located in the western portion of the basin and Well 10A2 (red) is located in the central portion of the basin as shown on Figure 5. Well 12L3 (now destroyed) was located in the central portion of the basin. Well 10A2 is the Key Water Level Well used by the County to monitor long-term-water levels in the basin. Significant groundwater elevation declines began in the 1930s (in Well 12L3) and continued through the early 1960s (in 08C2). Groundwater levels recovered to at or above the ground surface beginning in the mid-1970s in Well 08C2. Well 10A2 shows a similar recovery trend from the 1960s through 1990s. Relatively stable conditions in Well 10A2 are observed following the 1990s, with groundwater levels between about 62 and 70 ft-bgs.

Annual precipitation in the basin (shown on the bottom of the upper chart) reveals the response of groundwater levels to significant wet and dry periods. Groundwater levels in 12L3 show a significant recovery in the Fall of 1941 following the wet 1941 Water Year (WY). (A Water Year runs from October 1 to September 30 and is designated by the year in which it ends.) A drop in groundwater levels are observed in 08C2 and 10A2 in the late 1970s following an extended drought period. A jump in groundwater levels of about 10 feet is observed in 10A2 following the winter El Nino storms in WY 1998.

The bottom chart on Figure 18 illustrates relatively stable groundwater levels between 1972 and 2014 in two wells. One is located in the eastern portion (09N5) of the basin and the other in the northwestern portion of the basin (04R2) (well locations are shown on Figure 5).

Figure 19 shows the relationship between shallow and deep groundwater levels in the western portion of the basin in selected District paired observation wells. The location of the observation wells are shown on Figure 5. Typically groundwater elevations are higher in the deeper confined to semi-confined aquifer compared with the shallow water-bearing zone. Note that depths to groundwater plotted at zero may actually be above the ground surface representing artesian conditions in the deep aquifer.

As described in Section 2.5, artesian conditions, leakage through the aquitard from the deep confined to semi-confined aquifer to the shallow water-bearing zone, and problematic high groundwater exist in the western portion of the basin. While dewatering wells operated by the District have mitigated the problem, artesian conditions still exist in the western portion of the basin. The approximate areas of artesian conditions are shown on Figures 16 and 17.

Leighton (1972) noted that problematic shallow groundwater also exists in the eastern portion of the basin as well. Water levels in the eastern portion of the basin measured for the 1972 investigation ranged from 5 to 21 ft-bgs. Groundwater seepage through the construction joints of the lined flood control channel in the vicinity of the investigation was observed at various locations.

2.10 Groundwater Storage

The volume of groundwater in storage within the Simi Valley Basin has been previously estimated at about 180,000 acre-feet (AF) (SWRCB, 1956). While the methodology used to derive this estimate is not well documented, the estimate is consistent with an area of about 12,100 acres, an average thickness of 175 feet, and an average specific yield of about 8.6 percent (DWR, 2004).

The base of unconsolidated sediments and 1990 water levels were used to estimate the variable saturated thickness across that Simi Valley Basin. As shown on **Figure 20**, the saturated aquifer thickness ranges from less than 100 up to about 600 feet. The average saturated thickness across the main portion of the Simi Valley Basin (highlighted areas covering 9,868 acres) is 256 feet. Assuming an average specific yield of 5 percent, the estimated groundwater in storage in the Simi Valley Basin in 1990 is about 126,000 AF. It is noted that while this is a large volume, only a small portion of this total volume can be pumped without causing undesirable results as discussed in Section 6.4.

3 Groundwater Quality

Groundwater quality data are available from several sources including the SWRCB Division of Drinking Water (DDW, formerly California Department of Public Health) for purveyors having more than 15 connections, the DWR from special studies, Ventura County from regular monitoring from selected wells, and the online GeoTracker Groundwater Ambient Monitoring and Assessment (GAMA) program. The GeoTracker GAMA groundwater information system integrates and displays water quality data on an interactive, searchable map (http://geotracker.waterboards.ca.gov/gama/). The system contains data records from different sources such as cleanup sites, well logs, DDW, DWR, California Department of Pesticide Regulation, the GAMA Priority Basin Project, the GAMA Domestic Well Project, and the GAMA Special Studies Project. The USGS has collected groundwater samples in the Simi Valley Basin as part of the California GAMA Priority Basin Project (2011).

The water quality discussion presented herein describes water quality in the main production zones in the basin. Therefore data available for environmental contamination sites, which typically monitor shallow groundwater, are not considered.

Water quality objectives or standards have been developed for many constituents that occur in groundwater. The DDW establishes primary and secondary maximum contaminant levels (MCLs and SMCLs). The U.S. Environmental Protection Agency (USEPA) also adopts MCLs under the federal Safe Drinking Water Act. The primary MCL is the highest level of a contaminant that is allowed in drinking water and is protective of human health. Primary MCLs reflect not only the chemicals' health risks but also factors such as their detectability and treatability, as well as the cost of treatment. SMCLs are derived based on aesthetic considerations such taste, odor, and laundry staining. Notification levels (NLs) are published for chemicals for which there is no drinking water MCL. Notification levels are based mainly on health effects. NLs are advisory to water suppliers. If the Threshold 1 NL is exceeded, local government notification is required and customer notification is recommended. At the Threshold 2 NL is exceeded, the drinking water source is recommended to be taken out of service.

The Los Angeles Regional Water Quality Control Board (LARWQCB) has established Basin-Specific Basin Plan Objectives (BSBPOs) for the confined aquifers of the Simi Valley Basin for TDS, sulfate, chloride, and boron (LARWQCB, 2011). BSBPOs have not been established by the LARWQCB for the unconfined aquifers in the Simi Valley Basin. MCLs, BSBPOs and NLs for selected constituents are provided in **Table 6**.

Table 6 Regulatory Limits for Potential Constituents of Concern in Groundwater in Simi Valley

Constituent	Primary MCL (mg/L)	SMCL (mg/L)	BSBPO Simi Valley Basin Confined Aquifers (mg/L)	Notification Level (mg/L)	
				Threshold 1	Threshold 2
TDS	NA	500/1,000/1,500	1,200	NA	NA
Sulfate	NA	250	600	NA	NA
Chloride	NA	250/500/600	150	NA	NA
Iron	NA	0.3	NA	NA	NA
Manganese	NA	0.05	NA	NA	NA
Boron	NA	NA	1.0	1.0	10
Nitrate as Nitrate (NO_3)	45	NA	45	NA	NA
Perchlorate	0.006	NA	0.006	NA	NA
Gross Alpha Radioactivity[1]	15	NA	15	NA	NA

MCL – Maximum Contaminant Level
SMCL – Secondary Maximum Contaminant Level
1 – in units of picocuries per liter
mg/L – milligrams per liter
NA – not applicable
BSBPO – basin-specific basin plan objective

3.1 General Groundwater Quality

Stiff and trilinear (or Piper) diagrams are commonly used to describe and illustrate groundwater quality and to compare groundwater quality from different aquifers or basins. **Figure 21** shows a trilinear diagram of groundwater quality in the Simi Valley (eastern, central and western areas) and Gillibrand Basins. In the diagram, cations, expressed as percentages of total cations in milliequivalents (meq/L), plot as a single point on the left triangle; anions, similarly expressed as percentages of total anions, appear as a point in the right triangle. These two points are then projected into the central diamond-shaped area parallel to the upper edges of the central area. While samples from the eastern portion of the basin plot over a fairly wide area, groundwater samples from the central and western portion of the Simi Valley Basin plot more tightly.

Stiff diagrams of the sampling results are plotted next to each well in **Figure 22**. In Stiff diagrams, concentrations of cations are plotted to the left of the vertical zero axis and anions to the right; all values are in meq/L. Waters of similar quality show distinctive shapes. The figure illustrates that water in the central and western Simi Valley Basin is similar in quality and different from the groundwater quality in the eastern Simi Valley Basin and Gillibrand Basin. Groundwater from the eastern portion of the Basin is neutral to sodium-bicarbonate in character and groundwater from the central and western portions of the basin is calcium-sulfate in character and very hard. **Table 7** provides the general groundwater quality in mg/L and meq/L.

Table 7 General Mineral Concentrations

Well Name	Date Sampled	Chemical																
		Cations								Anions								
		Sodium		Potassium		Calcium		Magnesium		Chloride		Bicarbonate		Carbonate		Sulfate		TDS
		mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L
Eastern Basin																		
15E4	10/27/09	106	4.611	5	0.1279	99	4.9401	46	3.7853	70	1.9747	430	7.048	0	0	209	4.3514	965
16A10	10/11/11	139	6.047	4	0.1023	49	2.4451	28	2.3041	47	1.3259	370	6.064	0	0	155	3.2271	793
Central Basin																		
10A2	10/11/11	121	5.264	8	0.2046	267	13.323	92	7.5707	180	5.0778	330	5.409	0	0	1030	21.445	2,090
10H3	10/27/09	163	7.091	4	0.1023	206	10.279	70	5.7603	140	3.9494	310	5.081	0	0	690	14.366	1,630
Western Basin																		
08D4	10/22/14	206	8.961	6	0.1535	238	11.876	85	6.9947	180	5.0778	370	6.064	0	0	810	16.864	1,910
09E1	10/22/14	163	7.091	5	0.1279	230	11.477	78	6.4186	130	3.6673	300	4.917	0	0	770	16.031	1,700
08K7	10/22/14	187	8.135	5	0.1279	294	14.671	87	7.1592	170	4.7957	310	5.081	0	0	960	19.987	2,070
Gillibrand Basin																		
24C7	10/22/14	43	1.871	3	0.0767	156	7.7844	32	2.6333	28	0.7899	280	4.589	0	0	320	6.6624	811

Data provided by Ventura County Watershed Protection District, Water and Environmental Resources Division.
TDS = Total Dissolved Solids
mg/L = milligrams per liter
meq/L = milliequivalents per liter

Previous studies indicate a gradual increase in salt content in the groundwater from east to west due to reuse as groundwater flows through the basin from east to west (DWR, 1959). Shallow aquifer groundwater in the western portion of the basin is of poorer quality than deep aquifer groundwater. Testing of groundwater indicates it is very hard (greater than 200 milligrams per liter [mg/L] of calcium carbonate) (Leighton, 1972).

3.2 Total Dissolved Solids (TDS)

Total salinity is commonly expressed in terms of total dissolved solids (TDS) as mg/L or parts per million (ppm). As established by the DDW, the SMCL for TDS is 500 mg/L, with an upper limit of 1,000 mg/L, and a short-term limit of 1,500 mg/L. While TDS can be an indicator of anthropogenic impacts, there are also natural background TDS levels in groundwater. The background TDS concentrations in groundwater can vary considerably based on purity and crystal size of the minerals, rock texture and porosity, the regional structure, origin of sediments, the age of the groundwater, and many other factors (Hem, 1989).

Elevated TDS concentrations are undesirable for aesthetic reasons related to taste, odor, or appearance of the water and not for health reasons; however, elevated TDS concentrations in water can damage crops, affect plant growth, and damage municipal and industrial equipment. Reduced salinity (lower TDS concentrations) increases the life of plumbing systems and appliances, increases equipment service life, decreases industrial costs for water treatment, increases agricultural yields, reduces the amount of water used for leaching, reduces brine disposal costs and improves the usability of recycled water (MWD and USBOR, 1999).

Figure 23 shows average TDS concentrations in groundwater with colored circles representing different ranges of concentrations for three selected time periods including 1950 to 1969, 1970 to 1989, and 1990 to present. The most comprehensive groundwater monitoring was conducted in the 1950 to 1969 time period because a large number of wells still existed in the basin and DWR performed significant monitoring.

As shown in the figure representing the 1950 to 1969 time period, TDS concentrations frequently exceeded the upper SMCL of 1,000 mg/L and the short-term limit of 1,500 mg/L. TDS concentrations were significantly lower in the eastern portion of the basin with concentrations progressively increasing toward the west, where concentrations could exceed 3,000 mg/L. The figure also shows a pattern of slightly higher TDS concentrations in the northern portion of the basin compared with the southern portion of the basin.

For the 1970 to 1989 and 1990 to present time periods, there are significantly fewer data points and it is difficult to discern any patterns or changes in groundwater quality given the limited data; however, for the available data, concentrations appear similar in recent data compared with historical data.

Only a few water supply wells in the basin have been sampled repeatedly over time. The top portion of **Figure 24** shows TDS concentrations in two wells located in the eastern portion of the basin and three wells located in the western portion of the basin. As shown in the figure, the wells show relatively stable concentrations over time. Concentrations in eastern portion of the basin are lower than in the western portion of the basin. The bottom chart on the figure

shows TDS concentrations in two wells located in the central portion of the basin. These wells show an increasing TDS trend. Because TDS is conservative and because the basin is semi-closed, i.e., little groundwater flows out of the basin as subsurface flow, an increasing TDS trend would be expected due to continued salt loading.

The elevated TDS concentrations in the Simi Valley Basin may be associated with both natural and anthropogenic factors. Because the Simi Valley Basin is surrounded and underlain by marine sediments, it is likely that these sediments have contributed to elevated salts in the basin. In addition, the basin is relatively closed so a significant amount of groundwater and salts do not exit the basin as subsurface flow. In addition, high groundwater conditions in the west end of the basin have resulted in naturally-occurring marshy conditions where evaporation concentrates salts. The major anthropogenic factors contributing to elevated TDS would include historical agricultural irrigation return flows and septic system discharges.

The widespread elevated TDS concentrations above the upper SMCL (1,000 mg/L) and short-term limit (1,500 mg/L) indicate that groundwater used for water supply would need to be either blended with better quality water or treated to reduce salts with subsequent export of salts. The planned Brine Line extension to Simi Valley would provide a mechanism to improve groundwater quality in the basin over time.

3.3 Sulfate

Sulfate occurs naturally in drinking water, but also has anthropogenic sources. Health concerns regarding sulfate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate. Of particular concern are groups within the general population that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations. Sulfate in drinking water currently has a SMCL of 250 mg/L, based on aesthetic effects (i.e., taste and odor). The BSBPO for sulfate is 600 mg/L.

Sulfate in Simi Valley Basin groundwater typically exceeds both the SMCL and the BSBPO. Sources of elevated sulfate include irrigation return flows and oxidation of reduced sulfur in sulfide minerals in the marine sediments of the surrounding hills and aquifer matrix as well as organic matter in sediments (USGS, 2011). Due to elevated sulfate, groundwater would need to be blended or treated to reduce sulfate concentrations for domestic uses.

3.4 Nitrate

Nitrate is a colorless, odorless, and tasteless ion that is often present in groundwater. Nitrate is a health concern due to methemoglobinemia, or “blue baby syndrome,” which affects infants. Elevated levels may also be unhealthy for pregnant women (SWRCB, 2010). The BSBPO and primary MCL for nitrate is 45 mg/L.

High levels of nitrate in groundwater are associated with agricultural activities, septic systems, confined animal facilities, landscape fertilization, and wastewater treatment and disposal facilities. Additionally, airborne nitrogen compounds discharged from industry and

automobiles are deposited on the land in precipitation and as dry particles, referred to as dry deposition. These sources also contribute to nitrate loading to groundwater. Nitrate can occur naturally in groundwater, but levels are generally very low, typically less than 10 mg/L.

The fate and transport of nitrogen compounds in the environment is very complex. Nitrate is the primary form of nitrogen detected in groundwater. It is soluble in water and can easily pass through soil to the groundwater table. It can also be added to percolating water through dissolution of formation media. Nitrate can persist in groundwater for decades and accumulate to high levels as more nitrogen is applied to the land surface every year in basins with significant sources of nitrate loading and limited outflow. The history of agricultural activity in the Simi Valley Basin along with the use of onsite septic systems has provided significant nitrogen loading to the basin. Nonetheless, unlike TDS, nitrate can be removed naturally from water through denitrification.

Figure 25 shows nitrate concentrations for similar time periods as discussed for TDS. For the 1950 to 1969 time period, only two wells in the eastern portion of the basin showed nitrate concentrations above the 45 mg/L primary MCL. The 1970 to 1989 time period shows one well in the western basin with nitrate exceeding the primary MCL. In the 1990 to present time period, nitrate in two wells exceeded the MCL. As with TDS, it is difficult to assess trends, due to the relatively limited recent period data.

The top chart in **Figure 26** shows nitrate concentrations in two wells located in the eastern portion of the basin and three wells located in the western portion of the basin. As shown in the figure, the wells show relatively stable concentrations over time. The wells in the eastern portion of the basin show no detectable level of nitrate. One well in the western basin indicates nitrate consistently above the primary MCL of 45 mg/L. The bottom chart on the figure shows nitrate concentrations in two wells in the central basin. These wells show an increasing nitrate trend; however, Well 10A2 shows a significant drop in nitrate in 2009. Nonetheless concentrations in these wells are above the primary MCL.

Based on the available data, it appears possible that water supply wells developed in the Simi Valley Basin could contain nitrate at concentrations above the primary MCL. Water from such wells would require either blending with better quality water or treatment to reduce concentrations below the primary MCL.

3.5 Chloride

Chloride occurs naturally in groundwater, but concentrations can be increased by human activities. As established by the DDW, the recommended SMCL for chloride is 250 mg/L, with an upper limit of 500 mg/L and a short-term limit of 600 mg/L. The BSBPO for chloride is 150 mg/L.

Similar to TDS, elevated chloride concentrations are undesirable for aesthetic reasons related to taste, odor, or appearance of the water and not for health reasons; however, elevated chloride concentrations in water can damage crops, affect plant growth, and damage municipal and industrial equipment. Chloride is mobile in the environment and conservative (meaning that it does not readily interact with subsurface media (vadose zone and saturated zone) and is

not readily attenuated in the subsurface). Accordingly, chloride is an ideal indicator of groundwater quality trends.

Chloride is typically detected at concentrations below the SMCL of 250 mg/L in the Simi Valley Basin.

3.6 Boron

Boron is a naturally-occurring element in soil and groundwater and concentrations depend mostly on the local geology. Anthropogenic boron sources include industrial waste discharges and municipal sewage because boron is found in household detergents. Most human exposure to boron comes from either boric acid or borax. Boric acid is the form of boron most likely to be encountered in drinking water, and can be lethal at high concentrations. Other symptoms of boric acid ingestion include gastrointestinal tract distress, vomiting, abdominal pain, diarrhea, and nausea. Animal studies have observed reproductive and developmental effects when boron was ingested at high levels (SWRCB, 2010).

Boron is typically detected in Simi Valley Basin groundwater at concentrations near or above the Notification Level (NL). Groundwater with concentrations above the NL would require blending or treatment to reduce concentrations.

3.7 Iron

Sources for iron in groundwater are both natural and anthropogenic. Iron is leached from sediments in subsurface aquifers and, under corrosive conditions, from steel pipes used for construction of water wells and distribution systems. Sufficient concentrations of iron in water can affect the water's suitability for domestic or industrial purposes. For example, some industrial processes cannot tolerate more than 0.1 mg/L of iron. The SMCL for iron in drinking water is 0.3 mg/L; high concentrations of iron in water can stain plumbing fixtures and clothing, encrust well screens, clog pipes, and may impart a salty taste. While these problems are recognized, iron also is an essential nutrient for human health, and does not pose significant health effects except in special cases.

Iron is typically detected in Simi Valley Basin groundwater below the SMCL.

3.8 Manganese

Manganese is naturally-occurring and is objectionable in water in the same general way as iron. Stains caused by manganese are black and are more unsightly and harder to remove than those caused by iron. While manganese is considered an essential nutrient for human health at low levels, a SMCL of 0.05 mg/L is established for manganese due to its undesirable aesthetic qualities.

Manganese in Simi Valley Basin groundwater is typically detected below the SMCL.

3.9 Gross Alpha Radioactivity

Radionuclides often are naturally occurring in rocks and sediments and emit ionizing radiation – alpha particles, beta particles, and gamma rays – when they decay. Alpha-emitting substances

in natural water are mainly isotopes of radium and radon. Gross alpha radioactivity in groundwater is typically reported in picocuries per liter (pCi/L).

The health effects of alpha particles depend primarily upon how exposure takes place. External exposure (external to the body) is of far less concern than internal exposure, because alpha particles lack the energy to penetrate the outer dead layer of skin. However, if alpha emitters have been inhaled, ingested (swallowed), or absorbed into the blood stream, sensitive living tissue can be exposed to alpha radiation. The resulting biological damage increases the risk of cancer; in particular, alpha radiation is known to cause lung cancer in humans when alpha emitters are inhaled. The primary MCL for gross alpha radioactivity is 15 pCi/L.

While typically detected below 15 pCi/L, alpha radioactivity has been occasionally detected in Simi Valley Basin groundwater at concentrations above the primary MCL.

3.10 Perchlorate

Perchlorate is both a naturally-occurring and anthropogenic chemical. Perchlorate is widespread in the environment at low concentrations (NRC, 2005; USEPA, 2008; and OEHHA, 2008). Natural sources with relatively high concentrations include Chilean nitrate deposits used as fertilizers and other deposits in arid areas. Chilean fertilizer has been widely used in the U.S., particularly for citrus.

Perchlorate is also found in a number of anthropogenic products including rocket propellant, road flares, fireworks, blasting agents and explosives (Motzer, 2001). Perchlorate has been detected in soil and groundwater at the Boeing (former Rocketdyne) Santa Susana Field Laboratory located in the Simi Hills south of Simi Valley (CH2MHILL, 2007).

Perchlorate may interfere with or inhibit the body's iodide uptake by the thyroid gland; this can decrease the production of thyroid hormones, which are needed for prenatal and postnatal growth and development, as well as normal body metabolism. Because of the important role of the thyroid gland in fetal development, pregnant women and their developing fetuses have a higher risk from perchlorate exposure compared with other populations. The primary MCL for perchlorate is 0.006 mg/L or 6 micrograms per liter (ug/L).

Perchlorate has very high aqueous solubility and does not sorb to soil particles or readily biodegrade once released to the environment; thus it is persistent and highly mobile in well-oxygenated groundwater (Nzengung et al., 1999). However, perchlorate will diffuse into fine-grained materials.

In 1999, perchlorate was found in shallow, non-drinking water wells (environmental release site monitoring wells such as gasoline stations) in Simi Valley (DTSC, 2003). Following these detections, the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) and the LARWQCB conducted an extensive program to sample soil, wells, springs, and surface water drainages throughout Simi Valley. Perchlorate was detected in 15 out of 66 wells sampled. Most detections were scattered within the valley at depths of less than 20 feet at environmental release site monitoring wells. Concentrations of perchlorate ranged from 4 to 19 ug/L. Review of the DDW water quality data for municipal supply wells indicates sporadic detection of perchlorate in two water supply wells at concentrations between not

detected and 5.6 ug/L. These wells are screened to depths of 450 and 534 feet. In addition, sampling by the USGS (2011) showed a detection of 4.2 ug/L in a water supply well screened to a depth of 290 feet.

Perchlorate was not detected in any surface water samples from Arroyo Simi sampled by DTSC, but it was detected in two surface water seeps in the area of high groundwater in the southwestern portion of the valley (CH2MHILL, 2007).

Figure 27 shows the DTSC sampling results in Simi Valley along with results at the Rocketdyne site south of the valley. Perchlorate is detected in soil, surface water and groundwater at the Rocketdyne facility. Concentrations in groundwater at the Rocketdyne site are found at concentrations up to 1,600 ug/L (CH2M HILL, 2007). Perchlorate has also been detected in an offsite well (Brandeis Well, see Figure 27) although detections have shown significant variability when sent to different laboratories for confirmation sampling (DTSC, 2003). Other contaminants are also detected in groundwater at the Rocketdyne facility, predominantly volatile organic compounds (VOCs) (Boeing, 2015).

The source or sources of perchlorate detections in the Simi Valley have not been determined. Chilean fertilizer used for citrus irrigation is a possible source. Given the distribution of perchlorate detections, new groundwater supplies developed in the valley may contain low levels of perchlorate. However, based on the reported detections and well depths, detections in new deeper water supply wells may be below the primary MCL.

3.11 Environmental Contamination Sites

The online GeoTracker site (http://geotracker.waterboards.ca.gov) was accessed to identify environmental release sites that could potentially impact new water supply wells in the valley. **Figure 28** shows active and inactive leaking underground storage tank (LUST) sites and other cleanup sites. Inactive sites are sites that have been closed by the relevant regulatory agency following investigation and possible remediation.

As shown in the figure, there are a large number of closed LUST sites in the valley. Chemicals associated with gasoline stations include petroleum hydrocarbons and gasoline additives such as methy-tertbutyether (MTBE). It has been well documented in the literature and through experience at individual LUST release sites that petroleum fuels naturally attenuate in the environment through adsorption, dispersion, dilution, volatilization, and biological degradation. This natural attenuation slows and limits the migration of dissolved petroleum plumes in groundwater. The biodegradation of petroleum, in particular, distinguishes petroleum products from other hazardous substances commonly found at commercial and industrial sites (SWRCB, 2012). Unlike petroleum fuels, MTBE, an additive historically used in gasoline, is more mobile and less attenuated.

Only two active LUST sites have been identified on GeoTracker as shown on Figure 28. The Texaco SS site has been undergoing remediation and is currently undergoing verification monitoring to assess remedial effectiveness (WaynePerry, 2015). The Exxon #7-0462 site underwent a period of remediation and is currently being monitored (Cardno ERI, 2015).

Two active Spills, Leaks, Investigations and Cleanup (SLIC) are identified on GeoTracker. An active dry cleaner site (Joe's Cleaners) is identified where perchloroethylene ([PCE], also called tetrachloroethylene) has impacted groundwater to depths of about 100 ft-bgs. The site is located in the unconfined portion of the basin. A groundwater remediation plan was proposed for the site in 2015 (Converse, 2015). **Figure 29** shows the location of the site on the recent groundwater elevation contour map with a local scale map showing the extent of groundwater contamination. The plume is about 250 feet in length; although, the downgradient extent is not well defined. The reported site groundwater flow direction is also shown.

The Moving Solutions site, used historically for textile-dying operations, also is an active remedial site. The site overlies a portion of the basin that is confined to semi-confined. Shallow groundwater near the site shows detections of VOCs including primarily PCE and trichloroethylene (TCE). The site is currently undergoing remediation via groundwater and vapor extraction (Leymaster, 2015). TCE and PCE both have a primary MCL of 5 ug/L). Figure 29 shows the extent of total VOCs (about 800 feet in length); however, the downgradient extent is not fully characterized. The reported groundwater flow direction at the site is also shown.

In assessing potential production well locations, contamination release sites should be considered. A water supply well should not be sited near the dry cleaner site, where PCE is detected at significant depth, until groundwater remediation has been completed. In general the western portion of the valley affords more protection from shallow environmental releases due to the confining units and the upward vertical gradient from the deep aquifer to the shallow water-bearing zone. However, it is noted that because there is a hydraulic connection between the deep aquifer and the shallow water-bearing zone, pumping at depth could lead to a reversal in the vertical groundwater gradient and could induce the downward migration of shallow contamination. Contaminants released in the central and eastern portion of the basin are more likely to impact the regional unconfined aquifer, particularly if pumping from production wells creates a downward gradient.

As noted in Section 2.2, there has been oil and gas exploration and production in and near the Simi Valley Basin. Naturally occurring surface seeps or outcrops of oil stained sands occur in the vicinity of Simi Valley (Kew, 1918) and have the potential to contaminate groundwater. In addition, while oil and gas drilling and production is highly regulated, there is potential for associated groundwater contamination from surface spills of chemicals associated with drilling or the historical disposal of produced water, which is high in salts and petroleum hydrocarbons.

4 Surface Water Hydrology

Figure 30 shows surface water features in Simi Valley and the surrounding area. Arroyo Simi is the main surface water feature in Simi Valley. Arroyo Simi is mostly unlined; however a portion from about Los Angeles Avenue to Stearns Avenue is reported to be lined (Leighton, 1972). The arroyo reportedly has flow year round likely due to groundwater discharge into the arroyo and urban runoff as well as natural storm runoff after precipitation events. The arroyo likely has both gaining and losing stretches. Shallow groundwater in the east and west of the basin likely recharges the arroyo. In the central portion of the basin, Arroyo Simi likely provides recharge to groundwater, because groundwater levels are below the base of the creek.

A number of mostly unnamed smaller streams and arroyos are tributary to Arroyo Simi as shown on Figure 30.

4.1 Surface Water Quality

Arroyo Simi and other tributaries of Calleguas Creek are identified on the 2002 Clean Water Act Section 303(d) list as impaired due to elevated levels of boron, chloride, sulfate, and TDS. Accordingly, the LARWQCB has amended its Basin Plan to incorporate Total Maximum Daily Loads (TMDLs) for boron, chloride, sulfate, and TDS for the Calleguas Creek Watershed (2007). The amendment establishes Surface Water Quality Objectives (SWQOs) for the Calleguas Creek Watershed upstream of Potrero Road including Arroyo Simi. SWQOs are listed in **Table 8**.

Table 8 Surface Water Quality Objectives for Calleguas Watershed

Constituent	SWQOs Upstream of Potrero Road (mg/L)
TDS	850
Sulfate	250
Chloride	150
Boron	1.0

mg/L – milligrams per liter
SWQO – surface water quality objective

Arroyo Simi is monitored under the Calleguas Creek Watershed TMDL Monitoring Program (LWA, 2013). As part of that program, station G-1 is gaged for flow and monitored for water quality. G-1 is located just downstream of the SVGWPCP effluent discharge location to Arroyo Simi (see Figure 30). Sampling at this gage in 2012 showed TDS at 1,020 mg/L, sulfate at 430 mg/L, chloride at 164 mg/L, and boron at 0.7 mg/L.

5 Upper Calleguas Creek (Simi Valley) Watershed Water Balance

A major objective of the water balance is to estimate the quantity of groundwater that can be sustainably developed from the Simi Valley Basin. This involves evaluation of the significant inflows and outflows of water as part of the water balance equation:

$$\Delta Storage = \Sigma Inflows - \Sigma Outflows$$

In many cases, the water balance involves individual estimation of each of inflows and outflows, followed with computation of change in storage as the residual of the equation. Change in groundwater storage also can be evaluated independently using groundwater level data and storativity estimates.

A water balance for Simi Valley presents particular challenges. The Simi Valley groundwater basin is relatively small and oriented along Arroyo Simi, and groundwater is connected closely and dynamically with surface water flow in Arroyo Simi. Moreover, recent groundwater levels (especially in the west) are near the ground surface, allowing little available storage for potential recharge. These factors combine to create a change in storage that is zero and rejected recharge, such that more potential inflow could occur to the basin than actually happens.

Because much of the potential recharge flows out of the basin through the creek, and surface water data are limited (relative to the variable and dynamic nature of the creek), the water balance could not be tested against an independent evaluation of storage change. Nonetheless, a water balance for existing, high-groundwater conditions can illuminate the relative contributions of various inflows/recharge sources. The first portion of this water balance addresses inflows and outflows for current (1994 to 2014) conditions, and provides a relatively low-end estimate of inflows.

Another objective of this water balance is to consider how the basin may respond when groundwater development is increased. Additional pumping (represent an increased outflow) would reduce groundwater storage—thereby creating additional storage space—and could induce additional inflows. Accordingly, this study includes consideration of a historical water balance for a period of time when pumping in the basin was significant. For this historical period, 1941 to 1961, groundwater storage change was estimated by evaluating the decreasing water levels in the basin, and pumping was estimated based on the agricultural land use at the time. This allowed an independent assessment of how much recharge could be induced through groundwater pumping. Given that groundwater levels fell precipitously during this time period, the pumping rate of that time may serve as a high-end limit for potential future development (with the understanding that the overall water balance has changed significantly with water importation and with urbanization).

5.1 Current (1994 to 2014) Water Balance

The current water balance was developed for the Upper Calleguas Creek Watershed including the Simi Valley Basin, Tapo/Gillibrand Groundwater Basin, and the surrounding hills that drain into the Simi Valley Basin. The Upper Calleguas Creek Watershed (Study Area) used for the analysis is shown on Figure 1.

For a given groundwater basin under pre-development conditions, a long-term balance typically exists between the quantity of water recharged to the basin and the quantity of water leaving the basin.

The major components of groundwater recharge (inflow) in the Simi Valley Basin are:

- Direct percolation of precipitation
- Agricultural and major municipal landscape irrigation return flows
- Residential landscape return flows
- Septic system losses
- Water system losses
- Stream recharge
- Mountain front and subsurface groundwater inflow

The major components of groundwater discharge (outflow) from the Simi Valley Basin are:

- Groundwater pumping and consumptive use
- Groundwater discharge to Arroyo Simi
- Subsurface outflow to the South Las Posas Groundwater Basin
- Evapotranspiration directly from high groundwater

When discharge or outflow exceeds recharge or inflow, groundwater levels fall and there is a decrease in groundwater in storage. This occurred in the first half of the twentieth century when groundwater levels declined steadily. When recharge exceeds discharge, groundwater levels rise and there is an increase in storage. This occurred in the basin between the 1960s and the 1990s (see Figure 19).

The study period of the water balance was January 1994 through December 2014. The study period represents an average precipitation of 14.3 inches, similar to the long-term average of 14.5 inches (1941-2014 for the Ventura County Precipitation Stations 193 and 193A). In addition, the period begins and ends in a dry period. Beginning and ending the study period in dry times allows us to eliminate potential lag times in percolation and ensure that the long-term change in storage reflects similar hydrologic conditions.

Table 9 summarizes the water balance inflows and outflows over the study period; evaluation of each inflow and outflow component is described in the following sections.[1] The methodologies used to develop the components of inflow and outflow are described below. In this groundwater basin, more inflow may be available to recharge the basin but due to high water levels, this potential groundwater recharge results in runoff or creek flow. The water balance and possible changes due to future conditions are discussed further in Section 5.4. In all cases, when annual (or more frequent) data were not available, the long-term average was used. While many of these components could have trends over time, without the observed data these assumptions cannot be confirmed.

5.1.1 Groundwater Recharge (Inflows)

5.1.1.1 Deep Percolation of Precipitation

Deep percolation of precipitation is the portion of precipitation (rainfall) that falls on the ground, infiltrates through the root zone, and recharges underlying groundwater. Deep percolation of precipitation can contribute a significant portion of inflow to a basin.

The portion of precipitation available for deep percolation is influenced by several factors, including: 1) the amount and intensity of precipitation, 2) soil type, 3) topography, 4) vegetative evapotranspiration potential, 5) hydrogeology of the vadose zone and aquifer, and 6) area of impervious cover. Deep percolation of precipitation was calculated over the watershed area through a soil moisture balance and runoff analysis on a monthly time step and summarized here as annual totals. The groundwater basins (Simi Valley and Tapo/Gillibrand) and surrounding area were subdivided into “elements,” areas that share specific attributes including location within or outside the groundwater basin, land use type, soil type, and precipitation amount. The deep percolation on a monthly time step for each element was calculated using the following equation:

Deep Percolation = Effective Precipitation - Evapotranspiration - Soil Moisture Storage

[1] In this evaluation, climatic and hydrologic values may be shown to the tenth or hundredth place. As a result, numbers may appear to be accurate to four or five digits, which is not the case. Values for data that are measured (e.g., areas) are probably accurate to two or three significant digits. Estimated values (e.g., groundwater recharge) are probably accurate to one or two significant digits. In the text and tables, digits are retained to minimize rounding errors, preserve correct totals in tables, and to maintain as much accuracy as possible in subsequent computations.

Table 9 Annual Water Balance

	Inflows									Outflows							
	Deep Percolation of Precipitation			Agricultural Irrigation Return Flow		Municipal Retun Flows	Septic System Losses	Water System Losses		Pumping							
Water Year	Simi Valley	Tapo/ Gillibrand	Maximum Subsurface/ Mountain Front Recharge [1]	Simi Valley	Tapo/ Gillibrand	Simi Valley	Simi Valley	Simi Valley	TOTAL INFLOW	GSWC (Simi)	Dewatering (Simi)	Tapo/ Gillibrand [2]	PW Gillibrand [3]	Subsurface Outflow	Net Discharge to Creek [4]	TOTAL OUTFLOW	POSSIBLE REJECTED RECHARGE
1994	150	638	3,202	224	88	1,600	75	1,080	7,057	524	1,740	672	553	100	1,596	5,185	1,872
1995	1,992	1,469	3,202	229	90	1,608	75	1,046	9,713	633	1,740	672	553	100	1,596	5,294	4,419
1996	347	1,406	3,202	240	94	1,559	75	1,132	8,054	604	1,740	672	553	100	1,596	5,265	2,789
1997	528	1,448	3,202	236	92	1,686	75	1,208	8,476	639	1,740	672	553	100	1,596	5,300	3,176
1998	3,890	2,098	3,202	182	72	1,799	75	1,097	12,414	564	1,740	672	553	100	1,596	5,225	7,189
1999	141	339	3,202	227	90	1,633	75	1,318	7,025	962	1,740	672	553	100	1,596	5,623	1,402
2000	232	713	3,202	225	88	1,963	75	1,382	7,881	481	1,740	672	553	100	1,596	5,142	2,739
2001	1,341	1,720	3,202	220	87	2,058	75	1,313	10,016	544	1,740	672	553	100	1,596	5,205	4,811
2002	144	579	3,202	217	85	1,956	75	1,435	7,693	531	1,740	672	553	100	1,596	5,192	2,501
2003	333	887	3,202	212	84	2,138	75	1,386	8,317	1,019	1,740	672	553	100	1,596	5,680	2,637
2004	260	1,265	3,202	207	82	2,064	75	1,477	8,633	830	1,740	672	553	100	1,596	5,491	3,142
2005	5,567	2,335	3,202	176	69	2,200	75	1,414	15,038	985	1,740	672	553	100	1,596	5,646	9,392
2006	329	1,075	3,202	189	75	2,106	75	1,493	8,543	1,272	1,740	792	553	100	575	5,032	3,511
2007	101	205	3,202	204	81	2,224	75	1,582	7,674	861	1,949	804	553	100	1,566	5,832	1,841
2008	341	992	3,202	223	88	2,356	75	1,529	8,807	670	1,882	775	692	100	1,641	5,760	3,047
2009	172	816	3,202	212	84	2,278	75	1,369	8,208	584	1,867	777	536	100	1,090	4,954	3,254
2010	1,080	2,052	3,202	183	72	2,038	75	1,195	9,898	831	1,782	453	434	100	2,141	5,741	4,157
2011	383	851	3,202	220	86	1,780	75	1,236	7,833	644	1,828	623	553	100	2,564	6,312	1,521
2012	164	662	3,202	222	87	1,840	75	1,339	7,591	151	1,522	691	553	100	1,596	4,613	2,979
2013	100	133	3,202	227	89	1,994	75	1,401	7,222	892	1,569	629	558	100	1,596	5,344	1,878
2014	158	1,005	3,202	233	91	2,086	75	1,310	8,161	813	1,523	501	546	100	1,596	5,079	3,082
AVERAGE	**845**	**1,080**	**3,202**	**215**	**85**	**1,951**	**75**	**1,321**	**8,774**	**716**	**1,740**	**672**	**553**	**100**	**1,596**	**5,377**	**3,397**

all values in acre-feet

GSWC - Golden State Water Company

1 - Maximum represents long term average potential water for recharge, actual recharge would vary based on local water elevations.

2 - 1994 to 2005 values are average of 2006 to 2014

3 - Average values are used from 1994-2007 and 2011-2012

4 - 1994 to 2005 and 2012 to 2014 values are average of 2006 to 2011

Effective precipitation is the portion of precipitation that does not run off and that infiltrates into the ground. The amount of initial runoff and effective precipitation was estimated using the Soil Conservation Service (SCS) curve method. The method is described in the U.S. Department of Agriculture *Technical Release 55* (USDA, 1986). Data used in the SCS curve method include precipitation, land use cover, and soil type. Precipitation gage data from the Ventura County Precipitation Station 193 and regional isohyetal maps from the PRISM Climate Group (http://www.prism.oregonstate.edu/) were used to estimate average annual rainfall across the Study Area. **Figure 31** shows the isohyetal map for the Upper Calleguas Creek Watershed. The monthly precipitation at higher elevations was scaled based on the ratio of the average annual precipitation at a given elevation to the average annual precipitation at Ventura County Precipitation Station 193. Effective precipitation is available for consumption by plants via evapotranspiration (ET), is temporarily stored in the soil root zone, and may percolate and recharge groundwater.

ET is the water demand of the vegetation or crops that overlie the watershed or groundwater basins. Each element was assigned a land use classification based on the 2000 DWR land use map, **Figure 32**. Land use in this area has not significantly change since the DWR land use map of 1980. The four basic categories are agriculture (avocadoes and strawberries), large urban landscape (parks, cemeteries, and other open areas), native, and urban. The water use of vegetation in each land use classification was assigned a monthly crop coefficient (Kc) to scale the reference ET data and determine the elements potential ET. Reference ET is based on data from the Ventura County Evaporation Station 227 from 1993 through 2010 and the California Irrigation Management Information System (CIMIS) for the West Hills Station (219) station from 2011 through 2014 (see Figure 31). Potential ET refers to the amount of water a plant or type of land cover could consume given sufficient water at all times. Actual ET is limited by the amount of water available from precipitation and soil moisture. During the winter months, rainfall often exceeds potential ET, so the plant's water needs are fully satisfied and actual ET is equal to potential ET.

Soil moisture holding capacity was derived from the Ventura County soil surveys performed by the National Resource Conservation Service (NRCS). The soil types were divided into four categories based on soil moisture holding capacity: low, medium, high, and very high capacity. **Figure 33** shows the distribution of the four soil categories.

The soil moisture balance was applied on a monthly time step to each element. The one-dimensional rate of deep percolation was applied to each area to calculate the total volumetric rate of deep percolation. The estimated annual volumes of deep percolation in the Simi Valley and Tapo/Gillibrand Basins are shown in Table 9; as indicated, annual deep percolation is highly variable from year to year.

Recharge is not expected to occur in the western portion of the basin, where groundwater levels are at or near ground surface. However, they were considered in the soil moisture balance to assist in prediction of possible recharge, if groundwater levels were lower in the future.

5.1.1.2 Agricultural and Major Municipal Landscape Irrigation Return Flows

The DWR land use map from 2000 shows 58 acres of agriculture (37 acres of strawberries and 21.4 acres of avocadoes), which is assumed to be irrigated. An additional 458 acres have been identified as urban landscaped areas. This includes parks, golf courses, and cemeteries. It is assumed these areas are mainly turf and are actively irrigated in a normal year. The ET demands and estimated applied water of the vegetation are calculated through the soil moisture balance. An irrigation efficiency of 80 percent is assumed; furthermore, it is assumed that the remaining 20 percent of irrigation water is not consumed by vegetation and percolates to the subsurface. As shown in Table 9, these irrigation return flows are relatively steady from year to year. The average annual return flow from agricultural and landscape irrigation totals about 300 AFY.

5.1.1.3 Residential Landscape Irrigation Return Flows

The water supply for the municipal users in Simi Valley is mostly imported water provided by Golden State WC and the City of Simi Valley. Imports (from 1994 to 2013) range from 22,265 to 33,663 AFY. The City of Simi Valley reports that outdoor water use has typically been on the order of 70 percent of total water usage. It is assumed that 70 percent of total urban water supplies is for outdoor applications such as irrigation and other uses such as car washing and pool filling. Of this outdoor water use, 10 percent is assumed to percolate to groundwater after evapotranspiration and losses to runoff (e.g., overspraying, car washing). Municipal irrigation return flow averages about 1,900 AFY.

5.1.1.4 Septic System Return Flows

The Environmental Health Division of Ventura County reports about 360 permits for onsite wastewater treatment systems in Simi Valley (data accessed 12/28/15). Baseline water demand is estimated to be 236 gpcd (RBF, 2011) and the average household size is assumed to be 2.63 persons (US Census, 2015). Under these assumptions, the average household use would be 0.70 AFY. Assuming 30 percent of the water demand is for indoor use, 0.21 AFY per septic system could flow to the aquifer. The total flow from all 360 systems is estimated to be 75.6 AFY.

5.1.1.5 Water System Loses

Additional return flow to groundwater can occur through pipeline leakage. Water system losses from 19 member retail purveyors of Calleguas ranged from 2.9 to 6.4 percent from 2004 to 2009 (email communications from B. Bondy). Applying this range, combined water system losses for the City of Simi Valley and Golden State WC ranged from 400 to 2,261 AFY over this period. Assuming an average water system loss of 4.7 percent, an average of 1,321 AFY recharges the groundwater from water system losses.

5.1.1.6 Stream Recharge

Arroyo Simi can be both a gaining and losing stream depending on the reach of the creek, time of year, and groundwater level conditions. In the western portion of the basin and some eastern areas (where groundwater levels are high), groundwater discharges to Arroyo Simi. In the central portion of the basin where groundwater levels are lower, Arroyo Simi recharges the

groundwater basin. **Figure 34** shows the monthly volume of stream flow at the Ventura County Stream Gages 803, 802, and 842, representing respectively, the west, central and eastern reaches. The gage locations are shown on Figure 31. The data show that the stream flows year round. The western gage (803) shows a higher flow than the central (802) and eastern reach (842) indicating the creek may be gaining in the west. In addition to upstream flow, water flows into the western stretch of the creek from groundwater, tributary inflow, urban runoff, and discharge from the dewatering wells. In a few wet months in 2005, the central gage (802) approached the flow of the western gage (803). If the creek loss between gages 802 and 803 is assumed to be entirely creek loss, the volume of recharge from the creek was 293 AF in March 2005. When groundwater levels are lower than the creek bottom, additional recharge from the creek will be induced. Table 9 represents the estimated creek inflow/outflow during the study period. The methodology used to assess inflow/outflow is discussed in section 5.2.3. Future contributions would depend on the creek flow, creek bed conductance, hydraulic conductivity, and local groundwater elevations.

5.1.1.7 Mountain Front Recharge and Subsurface Groundwater Inflow

Estimation of mountain front recharge/subsurface inflow ideally would be based on data from multiple stream gages at canyon mouths and a network of monitoring wells around the basin perimeter. Such data are typically lacking and often such inflows are assumed minimal. However, perimeter inflow from watersheds may be significant, particularly for basins that are small relative to their watershed and/or have extensive perimeters. Accordingly, this water balance considered potential recharge from the watershed.

A soil moisture balance was applied to the watershed of Simi Valley (Figure 31) in order to derive an independent evaluation of recharge; accordingly, rainfall on the watershed was distributed into evapotranspiration, runoff, and recharge. Conceptually, recharge on the watershed subsequently contributes to downgradient stream baseflow/mountain front recharge and to subsurface groundwater inflow. However, the inflow to the basin depends on ability of fractured or porous formations to transmit the subsurface flow and the availability of groundwater storage in the basin.

If groundwater storage in the basin were available, the mountain front/subsurface inflow would be substantial and a relatively constant flow into the basin. Such a maximum flow is presented in Table 9; this represents a theoretical potential inflow. However, the western basin does not have significant available storage and mountain front recharge and subsurface flow are limited by local high groundwater levels. Based on the soil moisture analysis, the maximum potential recharge is estimated at 3,200 AFY. It should be noted that throughout the study period, the actual mountain front/subsurface inflow has been significantly less than the potential because of high groundwater conditions; this results in the rejected recharge shown in the far right column of Table 9.

The estimated mountain front/subsurface inflow includes seepage from Lake Bard that contributes subsurface flow into the basin through an alluvial channel. This underflow is estimated at approximately 240 AFY.

5.1.2 Groundwater Discharge (Outflows)

5.1.2.1 Groundwater Supply Pumping

Most water supply in Simi Valley is imported water (see Section 2). Golden State WC is the only municipal purveyor in the valley currently using Simi Valley groundwater for water supply. The total groundwater production by Golden State WC between 1996 and 2014 ranged from 151 to 1,272 AFY. The annual volume pumped by Golden State WC is shown in Table 9. The City and the P.W. Gillibrand Company are the primary groundwater pumpers in the Tapo/Gillibrand Basin (Geoscience, 2007). P.W. Gillibrand Company pumping averaged 553 AFY based on data available from 2008 through 2015, however data are incomplete. From 2006 to 2014, the City pumped between 501 and 804 AFY of groundwater from the Tapo/Gillibrand Basin. Data prior to 2006 have not been compiled, but pumping is assumed to be similar to the average conditions of recent years (672 AFY). The pumped water supply is delivered to customers and is either consumed or flows to the wastewater treatment plant. Water used outdoors would be consumed by vegetation, flow as runoff to the creek, or percolate the aquifer (as discussed in the return flow section).

5.1.2.2 Dewatering

High groundwater levels in the western portion of the basin have been mitigated by pumping excess groundwater, which is discharged to Arroyo Simi and assumed to flow out of the basin. The annual volume of dewatering since 2007 is shown in Table 9. Data prior to 2007 have not been compiled, but pumping prior to 2007 is assumed to be the average of dewatering from 2007 to 2014 (1,740 AFY).

5.1.2.3 Groundwater Discharge to Arroyo Simi

As noted, Arroyo Simi is characterized by both inflow and outflow depending on location. Figure 30 shows the locations of the eastern Stream Gage 842 and the western Stream Gage 803. As shown on Figure 34, the monthly volume of flow is much higher at the downgradient Stream Gage 803. This indicates the creek gains water between the two gages from groundwater and other sources including the dewatering well discharge, stream inflow from tributaries, and urban runoff. The western Stream Gage 803 is located at the outflow of the basin and is downgradient of the dewatering disposal but upgradient from the effluent disposal location of the SVWPCP. To calculate the potential contribution to Stream Gage 803 flow that comes from groundwater, the total volume of the dewatering disposal was subtracted from the increased flow between gages 842 to 803. Months with flow over 1,000 AFM are excluded as the base flow is insignificant compared to the stormwater flow. The net result, shown in **Table 10**, is approximately 1,600 AFY of groundwater that may discharge to Arroyo Simi. This volume would likely decrease if groundwater levels decreased in the western portion of the basin.

Table 10 Evaluation of Flow in Arroyo Simi

Date	Creekflow (cfs)			Creekflow (AFM)			Difference in Flow		Dewatering Disposal (AFM)	Groundwater Discharge (AFM)
	802	803	842	802	803	842	802-803	803-842		
1/1/2005	23.97	23	14	1,474	1,414	861	60	553		
2/1/2005	0.56	15	1.95	31	833	108	(802)	725		
3/1/2005	33.77	29	13.87	2,076	1,783	853	293	930		
4/1/2005	3.46	13	2.81	206	774	167	(568)	606		
5/1/2005	3.57	11	3.57	220	676	220	(457)	457		
6/1/2005	0.55	13	1.39	33	774	83	(741)	691		
7/1/2005	0.59	7.4	0.78	36	455	48	(419)	407		
8/1/2005	0	7	0.91	-	430	56		374		
9/1/2005	0	6.5	0.49	-	387	29		358		
10/1/2005		5.1	0.27	-	314	17		297		
11/1/2005		6.7	0.39	-	399	23		375		
12/1/2005		8.1	0.62	-	498	38		460		
1/1/2006		76	20	-	4,673	1,230		3443	872	
2/1/2006		7.5	1	-	417	56		361	872	-511
3/1/2006		9.7	1.5	-	596	92		504	872	-367
4/1/2006		23	8.4	-	1,369	500		869	370	498
5/1/2006		8.8	0.74	-	541	46		496	370	125
6/1/2006		6.9	0.72	-	411	43		368	370	-3
7/1/2006		7.2	0.75	-	443	46		397	282	115
8/1/2006		7	0.64	-	430	39		391	282	109
9/1/2006		7.1	0.5	-	422	30		393	282	111
10/1/2006		8.28	2	-	509	123		386	223	163
11/1/2006		7.27	0.77	-	433	46		387	223	164
12/1/2006		7.06	0.67	-	434	41		393	223	170
1/1/2007		7.32	0.76	-	450	47		403	205	198
2/1/2007		7.69	1.6	-	427	89		338	205	133
3/1/2007		6.7	1.1	-	412	68		344	205	139
4/1/2007		6.7	0.6	-	399	36		363	243	120
5/1/2007		6.93	0.69	-	426	42		384	243	140
6/1/2007		7.19	0.5	-	428	30		398	243	155
7/1/2007		6.37	0.81	-	392	50		342	255	87
8/1/2007		6.65	0.47	-	409	29		380	255	125
9/1/2007		6.57	0.67	-	391	40		351	255	96
10/1/2007		4.8	0.43	-	295	26		269	215	54
11/1/2007		5.6	0.31	-	333	18		315	215	100
12/1/2007		7.3	0.28	-	449	17		432	215	217
1/1/2008		5.3	0.36	-	326	22		304	198	105
2/1/2008		9.5	1	-	546	58		489	198	291
3/1/2008		7.4	0.66	-	455	41		414	198	216
4/1/2008		7.4	0.68	-	440	40		400	279	120
5/1/2008		7.4	0.38	-	455	23		432	279	152
6/1/2008		6.3	0.27	-	375	16		359	279	79
7/1/2008		6.1	0.14	-	375	9		366	213	154
8/1/2008		6.3	0.15	-	387	9		378	213	166
9/1/2008		5.6	0.21	-	333	12		321	213	108
10/1/2008		6	0.29	-	369	18		351	195	156
11/1/2008		29	5.8	-	1,726	345		1380	195	
12/1/2008		5.2	0.5	-	320	31		289	195	94

Table 10 Flow in Arroyo Simi (Continued)

Date	Creekflow (cfs)			Creekflow (AFM)			Difference in Flow		Dewatering Disposal (AFM)	Groundwater Discharge (AFM)
	802	803	842	802	803	842	802-803	803-842		
1/1/2009		5.2	0.36	-	320	22		298	211	86
2/1/2009		5.8	0.47	-	322	26		296	211	85
3/1/2009		6.4	2.8	-	394	172		221	211	10
4/1/2009		7.6	0.97	-	452	58		395	212	183
5/1/2009		6.7	0.56	-	412	34		378	212	166
6/1/2009		4.1	1.6	-	244	95		149	212	-63
7/1/2009		4.9	0.18	-	301	11		290	265	25
8/1/2009		5.2	0.43	-	320	26		293	265	28
9/1/2009		6.7	0.39	-	399	23		375	265	110
10/1/2009		7.6	0.45	-	467	28		440	193	247
11/1/2009		5.2	0.41	-	309	24		285	193	92
12/1/2009		5.7	0.58	-	350	36		315	193	122
1/1/2010		6	0.51	-	369	31		338	159	178
2/1/2010		7.4	0.83	-	411	46		365	159	206
3/1/2010		8.7	2.2	-	535	135		400	159	240
4/1/2010		10	1.7	-	595	101		494	200	294
5/1/2010		12	0.67	-	738	41		697	200	497
6/1/2010		7.3	1.9	-	434	113		321	200	122
7/1/2010		5.6	0.93	-	344	57		287	223	64
8/1/2010		5.2	0.26	-	320	16		304	223	80
9/1/2010		5.8	0.3	-	345	18		327	223	104
10/1/2010		5.8	0.53	-	357	33		324	162	162
11/1/2010		5.3	0	-	315	-			162	
12/1/2010		5.9	0.09	-	363	6		357	162	195
1/1/2011		9.1	0.05	-	560	3		556	158	398
2/1/2011		9.7	0.31	-	539	17		521	158	363
3/1/2011		10	0.31	-	615	19		596	158	438
4/1/2011		9.3	0.29	-	553	17		536	204	333
5/1/2011		12	0.49	-	738	30		708	204	504
6/1/2011		6.5	0.81	-	387	48		339	204	135
7/1/2011		5.2	1.4	-	320	86		234	249	-16
8/1/2011		5.2	0.27	-	320	17		303	249	54
9/1/2011		4.3	0.17	-	256	10		246	249	-4
10/1/2011		4.7	0.17	-	289	10		279	206	73
11/1/2011		6.3	0.18	-	375	11		364	206	159
12/1/2011		5.6	0.18	-	344	11		333	206	128
1/1/2012		4.8	0.21	-	295	13		282	170	113
2/1/2012		5.9	0.23	-	339	13		326	170	156
3/1/2012		6.6	0.15	-	406	9		397	170	227
4/1/2012		5.4	0.2	-	321	12		309	184	125
5/1/2012		5.8	0.18	-	357	11		346	184	162
6/1/2012		5.4	0.18	-	321	11		311	184	127
7/1/2012		5	0.12	-	307	7		300	225	75
8/1/2012		5.3	0.18	-	326	11		315	225	90
9/1/2012		5.1	0.18	-	303	11		293	225	68

cfs - cubic feet per second

AFY - acre-feet per month

5.1.2.4 Evapotranspiration Directly from Groundwater

Another potential source of outflow from the groundwater system is ET from the areas with high groundwater levels. The roots of vegetation could directly use the groundwater that is close to ground surface. This occurs primarily on the west side of the basin. However, this is expected to be small as there is limited vegetation in this urban area. Additional data, including vegetative density and local groundwater levels would be needed to quantify the potential outflow from this source.

5.1.3 Subsurface Outflow

Subsurface groundwater flow out of the Simi Valley Basin into the South Las Posas Basin is minimal. The SWRCB (1956) estimated 100 AF per season as subsurface flow, while Leighton (1982) estimated subsurface outflow at 540 AFY. Due to the limited alluvial thickness in this area, the lower SWRCB estimate is considered to be more reasonable and is included in Table 9.

5.1.4 Overall Current (1994 to 2014) Water Balance

Table 9 shows the estimated annual volume of key basin inflows and outflows. It is important to note that groundwater levels in the western portion of the basin are near or slightly above the ground surface. Shallow groundwater levels in the western portion of the basin likely result in partial rejection of potential basin inflows and, in turn, loss of potential inflows as surface flow via Arroyo Simi out of the basin.

Currently during normal hydrologic conditions, Arroyo Simi recharges the basin in the central portions of the basin, where depth to groundwater is approximately 65 ft-bgs. Groundwater depths are shallower in the eastern portion of the basin at approximately 15 ft-bgs. Depending on local groundwater levels, Arroyo Simi may be gaining or losing in the eastern portion of the basin. Due to high groundwater elevations, groundwater discharges to Arroyo Simi in the western portion of the basin. If future groundwater levels are lowered as a result of increased pumping, the length of Arroyo Simi that recharges groundwater could increase and groundwater recharge from stream leakage would likely increase and discharge to Arroyo Simi would be expected to decrease. Because groundwater levels have remained steady for the recent study period (i.e., no measurable change in groundwater storage), potential recharge is likely rejected during periods when potential basin inflows exceed basin outflows.

5.2 Historical Water Balance

As discussed, the inflows and the outflows of the current water balance are influenced by high groundwater levels in the western portion of the basin. Groundwater in storage has been stable in recent years. In the past, significant agricultural pumping decreased groundwater levels and, in turn, groundwater in storage. By identifying key basin outflows and estimating the change in groundwater storage, the historical water balance provides additional information from which basin inflows and outflows can be estimated. It is noted that this is an order of magnitude estimate conducted to provide a second assessment of potential perennial yield. During the period from 1947 to 1961, groundwater level declined more than 100 feet and there was a significant decrease in groundwater in storage.

5.2.1 Historical Outflow

Agricultural pumping in Simi Valley represented most of the basin outflow before the advent of imported water to the basin (SWRCB, 1956). Other outflows including flow to the creek and subsurface flow are assumed to be small, as historically lower water levels would have reduced much of the estimated current outflow (1,700 AFY).

The SWRCB (1956) estimated that 9,100 AF per season of groundwater was pumped and applied for agricultural irrigation in normal times and up 10,100 AF per season in dry times. Urban/Suburban users used only an estimated 600 AFY.

To confirm the estimated historical agricultural pumping values, the irrigated area was measured and crop water use was calculated. The DWR land use map from 1961 (the earliest available) (**Figure 35**) was digitized and the total area of each crop type was compiled. Major crops at that time included oranges, walnuts, and artichokes. As shown in **Table 11,** consumptive use rates were applied to the acreage and applied water was calculated, assuming 80 percent irrigation efficiency.

Alternative methods to estimate crop water demand were considered. **Table 12** summarizes the water demand estimates for each crop type using three different methods or sources. The first method evaluates the ET needs of the specific crop, taking into account irrigation efficiency and effective precipitation in order to estimate applied water per acre. The ET needs of a crop can be estimated as:

$$ETc = Kc * ETo$$

where ETc is the ET demand of the crop, Kc is the crop coefficient, and ETo is the reference ET of the geographic area, either measured or observed.

Table 11 1961 Simi Valley Crops and Use of Water

General Crop Type	Specfic Crops	Acres	Consumptive Use (AFY/Ac)*	Total Consumptive Use (AFY)	Total Applied Water (AFY)
Citrus	Oranges, Lemon	1,963	2.3	4,515	5,418
Deciduous	Walnuts	1,663	2.8	4,657	5,588
Field	Corn, Sorgum	98	1.6	156	188
Grain	Barley, Wheat	114	1.6	183	219
Pasture	Alfalfa	260	3.4	883	1,060
Truck	Artichokes, Melons	470	2.1	988	1,185
TOTAL		**4,568**		**11,382**	**13,658**

*Based on SWRCB 1956, Table 38

AFY/Ac - acre-feet per year per acre

Table 12 Crop Consumptive Use Estimates

General Crop Type	Specfic Crops	Estimated by Kc	SWRCB (1956)	DWR Data
Citrus	Oranges, Lemon	4.9	2.3	3.2
Deciduous	Walnuts	3.3	2.8	3.2
Field	Corn, Sorgum	2.1	1.6	1.6
Grain	Barley, Wheat	1.8	1.6	1.3
Pasture	Alfalfa	4.4	3.4	4.0
Truck	Artichokes, Melons	2.2	2.1	1.7

Kc - crop coefficient

DWR - California Department of Water Resources

Daily crop coefficients (Kc) and growing season information have been derived from the DWR irrigation estimation tool CPU M+. The second source is the consumptive use by crop type in the SWRCB (1956) report, Table 38. The last source is the average applied water from data published by DWR for Ventura County http://www.water.ca.gov/landwateruse/anaglwu.cfm.

For the purposes of this study, the SWRCB values were selected to better estimate irrigation practices at the time. Because irrigation is not 100 percent efficient, water is applied in excess of the ET demand. Irrigation efficiency, the percent of applied water needed beyond the ET demand of the crop, can vary significantly depending on several factors including geographic setting, irrigation method, and crop types. A typical efficiency of 80 percent has been assumed to calculate the total applied water.

Table 11 shows the estimated water use by major crop type based on the 1961 land use map. A total of 13,658 AFY is similar to the value reported in the SWRCB (1956) report (9,100 AFY). Given that the selected SWRCB consumptive use rates are relatively low (Table 12), the difference may be surmised to be the result of land use changes over that time.

5.2.2 Historical Change in Storage

The volume of water removed through historical agricultural pumping can be estimated from observed historical groundwater level declines and applying a representative aquifer storativity or specific yield.

5.2.2.1 Groundwater Elevation Change

Between the 1930s and the mid-1960s, groundwater levels in Simi Valley declined in large part due to increased agriculture pumping. Figure 18 shows three wells with consistent groundwater level declines and/or record lows experienced in the basin in the early 1960s (08C2 in the western basin area and 12L3 and 10A2 in the central basin area). The western basin area well (08C2) declined 107.5 feet over 15 years, an average of 7.2 feet per year. While the record is incomplete, groundwater levels in the central basin appear to have declined 155 feet over 33 years, or almost 5 feet per year. The hydrographs indicate that groundwater levels recovered quickly (reaching pre-pumping levels within 15 years) after imported water was delivered to the

basin and agricultural groundwater use declined. Well 10A2 shows that groundwater levels recovered over 200 feet from 1966 to 1992 (26 years), a recovery of 7.7 feet per year.

Limited data exist on water levels across the basin from the 1940s to 1960s. While it is recognized that groundwater declines may not have been uniform across the entire basin, assessing the area of maximum groundwater decline provides an estimate of maximum groundwater storage loss.

5.2.2.2 Storativity

The storativity (S) of an aquifer is the volume of water released from or taken into storage per unit surface area of aquifer per unit change in water level. For an unconfined aquifer, the S value is referred to as specific yield. Based on lithology and a pumping test in the basin, the average specific yield is about 5 percent (Leighton, 1985). SWRCB (1956) estimated a specific yield for the area with historic water level change of 8.6 percent, similar to the lithology-based estimate. As discussed above, the basin is not uniformly unconfined and applying a single specific yield value does not capture the hydrogeologic complexity. For the purpose of this preliminary calculation of change of storage, an assumed specific yield of 5 percent was applied.

5.2.2.3 Change in Storage

Given a decline of 7.2 feet per year, a groundwater basin area of 13,467 acres (Simi Valley only; not including Tapo/Gillibrand Basin), and a specific yield (or storativity) of 5 percent, the annual groundwater storage decline was approximately 4,848 AFY. The total groundwater storage decline between 1947 and 1961 represents approximately 72,722 AF over 15 years. For comparison, the SWRCB (1956) estimated a decline in groundwater storage of 21,000 AF from 1944 through 1952 (or 2,333 AFY). This estimate assumes unconfined conditions; in reality, the aquifer at depth has been locally semi-confined to confined and change in storage would be less. However, the historical water balance and specifically the change in storage estimates are provided as an order of magnitude check on current conditions.

5.2.2.4 Historical Inflow

Given the estimated outflow from the basin, agricultural pumping, and the groundwater in storage, the estimated inflow over that period can be approximated. Generally, in water balances, groundwater storage change can be calculated as the inflows less the outflows. In this case, total inflow would be the net difference between the change in storage and the total outflow:

$$\Delta Storage = \Sigma Inflows - \Sigma Outflows$$

$$\Sigma Inflows = \Delta Storage + \Sigma Outflows$$

The average annual change in storage from 1947 to 1961 was a decline of 4,848 AFY and the estimated outflow was about 13,678 AFY; therefore, the total inflows would have been approximately 8,830 AFY.

While the current water balance shows a potential recharge volume of 7,863 AFY, the period of the water balance (1994 to 2014) reflects a drier time than the 1947 to 1961 time period. Potential recharge is expected to be significantly influenced by hydrologic conditions.

Two major conclusions can be drawn from the quantitative water balances (current and historical):

- Current sources of recharge exceed the basin's current available groundwater storage
- Available recharge to the basin could be as much as 8,000 AFY based on the current water balance estimates to 9,000 AFY based on the assessment of historical pumping and observed water levels

The actual recharge volumes will depend on the hydrologic conditions (wet/ dry years), and the amounts and pathways for rejected recharge will depend on local groundwater levels, topography, and geology.

Additional groundwater development and optimized wellfield management may increase basin recharge. Establishing additional stream gages and construction of multiple completion monitoring wells would provide greater understanding of surface water/groundwater dynamics. In addition, as groundwater basin development progresses, basin management would benefit from development of a numerical modeling tool. Because of the significant and dynamic interaction between groundwater and surface water (e.g., Arroyo Simi) and the small size of the basin relative to the watershed, a linked surface-groundwater model is recommended. Complete findings and recommendations are found in Section 7.

6 Groundwater Development Assessment

6.1 Well Siting

Results of the hydrogeologic evaluation indicate that development of municipal supply wells in the study area is feasible. Within the Simi Valley Basin, favorable areas for groundwater development include permeable sand and gravel deposits tapped by historical wells south of Brea Canyon, bounded generally by the Arroyo Simi to the south and the drainage exiting Tapo Canyon to the east (see **Figure 36**). As indicated, well yields in this area commonly exceed 1,000 gpm, suggesting potentially productive municipal wells. Pumping in this area also would help to further mitigate high groundwater level conditions that limit recharge from stream leakage and deep percolation of precipitation. This area is potentially more convenient for future groundwater development than areas identified to the east with better groundwater quality, as it minimizes pipeline conveyance from future wells to a water treatment plant that presumably would be located in the western portion of the basin, near the discharge end of the future Brine Line.

In addition to new wells, the existing dewatering wells provide an existing source of groundwater that is currently discharged to Arroyo Simi without beneficial use within the basin. This groundwater could be treated and incorporated into the City's water supply portfolio. Because water quality is poorer in the western portion of the basin compared with the eastern portion of the basin, water treatment costs may be higher for water extracted from the western basin. Nonetheless, extracting more water from the western basin provides an added benefit in reducing problematic high groundwater and putting wasted water to beneficial use in the basin. It is noted that currently, dewatering groundwater discharged to Arroyo Simi flows into the adjacent South Las Posas Basin and provides significant groundwater recharge in that basin (LWA, 2013). Therefore, eliminating or reducing dewatering water discharge to Arroyo Simi will reduce groundwater recharge in the South Las Posas Basin. While water quality may be better in the eastern portion of the basin, well yields are relatively low and the distance to the brine line and likely groundwater treatment facilities makes the eastern portion of the basin undesirable for municipal well development.

6.2 Well Yields

The Simi Valley Basin is capable of producing well yields sufficient for municipal supplies. A properly designed, installed, developed, and maintained well would likely yield between 500 and 1,000 gpm, depending on location; although based on pumping information from a few wells, yields could be higher than 1,600 gpm. As discussed below, regular maintenance and redevelopment will be key to maintaining high wells yield particularly in the western portion of the basin where water quality is poorer.

6.3 Well Depths

The depth of a new production well will be dependent on location. It is recommended that the entire alluvial thickness be drilled and logged in order to determine optimal well design. The

cross sections provided in Figures 7 through 11 show depth to bedrock based on existing well logs.

6.4 Perennial Yield

In the past, the term *safe yield*—implying a fixed quantity of extractable water basically limited to the average annual basin recharge—has been widely used. The term has now fallen out of favor because a never-changing quantity of available water depends solely on natural water sources and a specified configuration of wells is essentially meaningless from a hydrologic standpoint (Todd and Mays, 2005).

This report uses the term *perennial yield*, which is the rate at which water can be withdrawn perennially under specified operating conditions without producing an undesired result (Todd and Mays, 2005). This term recognizes that the yield is mostly dependent on when and where the pumping occurs and the potential undesirable results.

This concept is embodied and expanded in the term *sustainable yield* (DWR, 2016), which is defined as the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result. Undesirable results are defined specifically as one or more of the following effects caused by groundwater conditions occurring throughout the basin:

1. Chronic lowering of groundwater levels.
2. Significant and unreasonable reduction of groundwater storage.
3. Significant and unreasonable seawater intrusion.
4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
5. Significant and unreasonable land subsidence that interferes with surface land uses.
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

At this time, groundwater development and management of the Simi Valley Basin is relatively limited and data are lacking to define the specific potential undesirable results included in *sustainable yield*. Accordingly, the term *perennial yield* is more appropriate at this time. It should be recognized that the estimates presented in this report are preliminary and subject to revision as additional data become available and more sophisticated analysis tools, such as groundwater flow modeling, can be applied to evaluate the water balance, to assess potential groundwater development and management scenarios, and to evaluate the potential for undesirable results.

Mindful of the above, a preliminary perennial yield can be estimated as water removed from storage that is replaced in time through groundwater inflow. In the case of Simi Valley, the water balance indicated an average of 8,774 AFY of inflow from deep percolation, return flows, mountain front recharge and subsurface inflow (Table 9). This represents a maximum potential value, recognizing that undesired results can occur with pumping at lower rates. Moreover, a

single average perennial yield oversimplifies the flow into the basin. The estimated available inflow has historically ranged from 7,057 AFY (in 1994) to 15,038 AFY (in 2005) and is dependent on climatic conditions (among other factors) and whether there is adequate available storage in the basin to accommodate all of the recharge.

For comparison, in 1956, the SWRCB estimated the safe yield of the Simi Valley Basin to be 4,700 AFY or 6,100 AFY if imports from Tapo/Gillibrand are included. The SWRCB values and this study's estimate (8,774 AFY) are relatively consistent in order of magnitude terms, given the uncertainties in the water balance estimates.

Lowering groundwater levels through increased production may increase available storage space and recharge. This concept of deferred perennial yield consists of two different pumping rates (Todd and Mays, 2005). The initial rate is larger and exceeds perennial yield, thereby reducing the groundwater levels and potentially increasing recharge and reducing losses by ET and surface and subsurface outflow. After groundwater levels have been lowered, a subsequent, comparable rate, (i.e., revised perennial yield), is established so that a general balance of water entering and leaving the basin is maintained thereafter. Wellfields also can be operated in conjunction with imported surface water supplies, particularly in drought. Such operation would involve increased pumping in dry years (or when imported water supplies are curtailed) with reduced pumping in wet years or when imported supplies are more readily available.

Perennial yield also can be enhanced by developing managed aquifer recharge (MAR) projects that recharge local stormwater, surplus imported water, and/or recycled water (potentially either tertiary or advanced treated) via spreading grounds, instream recharge facilities (i.e., check dams), or (advanced treated only) injection wells. Use of dewatering water for water supply could provide an additional supply if used directly as a water source and not discharged downstream.

Taking all this into account, the average estimated inflow of 8,774 AFY provides a general annual yield guideline that should be regularly reevaluated as groundwater resources are developed over time, additional data are collected, and more sophisticated analysis tools are applied to evaluate the water balance and assess undesired results.

6.5 Subsidence

Subsidence of the ground surface can occur as a result of excessive groundwater or petroleum withdrawal; it is one of the undesirable results listed above. Significant subsidence has occurred in alluvial valleys such as the Central Valley Basin and Santa Clara Plain in Santa Clara. Unlike Simi Valley, these basins are characterized by significant thicknesses of alluvial fan and lake- or marine-deposited sediments. Subsidence produces cracks in pavements and buildings and may dislocate wells, pipelines, and water drains.

No large-scale local subsidence has been reported in the City due to either groundwater or oil extraction (City of Simi Valley 1999). If the basin is actively managed to avoid over-pumping in the future, subsidence is unlikely. Nonetheless, subsidence has been identified by DWR as a criterion for sustainability (or conversely, as an undesirable effect of overdraft) and

consideration of subsidence would be needed if the City chooses to develop a Groundwater Sustainability Plan.

6.6 Numerical Modeling

The impacts of pumping on the groundwater basin cannot be determined using the basin-wide water balance. The location, depth, and timing of pumping will control the dynamics of groundwater recharge and flow into and out of the basin. As groundwater resources are developed over time and additional data become available, such as from new stream gages and multiple completion monitoring wells, the District may want to consider development of a numerical groundwater flow model. Given the importance of surface water-groundwater interactions in this small basin, the City should consider a linked surface water-groundwater flow model. Such modeling would allow definition and simulation of proposed pumping scenarios and evaluation of pumping impacts. The model can also be a tool to evaluate management alternatives, such as MAR, and to optimize groundwater development, among other analyses.

6.7 Water Quality

Groundwater quality in the basin is naturally poor, particularly in the central and western portions of the basin. Historical agricultural, urban and industrial land uses also have contributed contaminants to the basin. The typically-observed basin groundwater concentrations of TDS, sulfate, nitrate, and boron exceed water quality objectives and groundwater would require treatment to make the water acceptable for municipal use. In addition, siting of new production wells should avoid the local areas where environmental release sites in the unconfined portion of the basin have contaminated groundwater at significant depths.

6.8 Well Design and Maintenance

As discussed in the Well Yields Section, Leighton (1988) noted that wells located in the western portion of the basin have a short lifespan due to corrosive water and have calcium carbonate cementation and iron bacteria encrustation problems. Accordingly, dewatering wells were installed with stainless steel screens and acidation pipes to facilitate cleaning and pump columns and bowl assemblies were covered with epoxy to limit encrustation. It is also noted that since 2012, there has been a decline of about 300 AFY of production from the dewatering well system, which may be related to these problems. A regular maintenance and redevelopment program is recommended for existing and new wells to increase the life and efficiency of existing and new production wells.

6.9 Simi Valley Groundwater Management

Currently, various divisions, districts and sections of Ventura County collect (by County staff and from local agencies and water purveyors) and prepare annual reports on groundwater conditions in the County (Ventura County Water Protection District, undated). The County monitors and collects both groundwater level and quality data and reports the water level data

to DWR under the CASGEM Program and the water quality data to the SWRCB under the GeoTracker GAMA program.

The County also regulates groundwater well construction and destruction through its Well Ordinances, but does not regulate groundwater extraction. The Simi Valley Basin is not adjudicated and normally groundwater could be developed unrestricted by individual property owners and water purveyors. However, in light of the recent drought and declining groundwater levels in many basins in the County, Ventura County recently enacted a prohibition on new well drilling.

The monitoring, data collection and reporting conducted by the County (as well as studies conducted by other state and federal agencies) have been very helpful in establishing the hydrogeologic setting of the Simi Valley Basin for this study. Nonetheless, additional development of groundwater resources should be accompanied by additional monitoring and management of groundwater resources. In some cases, additional monitoring and management are required by State regulations. The following sections describe recommended actions to further groundwater management in Simi Valley.

6.9.1 Sustainable Groundwater Management

On September 16, 2014, Governor Edmund G. Brown Jr. signed a three-bill package known as the Sustainable Groundwater Management Act (SGMA). SGMA creates a framework for sustainable, local groundwater management and is the first legislation in California to comprehensively regulate groundwater. Building on the recognition that groundwater management in California is best accomplished locally, it provides local water agencies with considerable new powers, most notably the power to regulate pumping. Nonetheless, the Act also imposes substantial responsibility to find solutions for overdraft and to achieve long-term sustainability of groundwater supply. If local agencies fail to achieve sustainability, it establishes the power of the State to manage a groundwater basin and regulate groundwater use.

The Act provides a priority list of groundwater basins, defines Groundwater Sustainability Agencies (GSAs), outlines the contents of Groundwater Sustainability Plans (GSPs), establishes the roles of State agencies, and sets a timeline with deadlines for high and medium priority basins. While the Simi Valley Basin has been designated as a low priority basin, SGMA provides guidance on basin management moving forward as additional groundwater development in Simi Valley is planned and implemented.

In short, SGMA:

- Enhances local management of groundwater consistent with rights to use or store groundwater
- Establishes minimum standards for effective, continuous management of groundwater
- Provides local groundwater agencies with the authority, technical, and financial assistance needed to maintain groundwater supplies
- Avoids or minimizes impacts for land subsidence

- Improves data collection and understanding of groundwater resources and management
- Increases groundwater storage and removes impediments to recharge
- Empowers local agencies to manage groundwater basins, while minimizing state intervention

SGMA recognizes that groundwater is best managed at the local or regional level. It also recognizes that there are geographic, geologic, and hydrologic differences and various levels of readiness experienced by local and regional agencies across the state. SGMA requires local agencies to establish a new governance structure, known as Groundwater Sustainability Agencies (GSAs), prior to developing groundwater sustainability plans for groundwater basins or subbasins that are designated as medium or high priority. Even though the Simi Valley Basin is a low priority basin now, as additional groundwater resources are developed, it is likely to move up in priority ranking. Accordingly, it is recommended that the City engage with stakeholders such as the County and Golden State WC to discuss issues associated with SGMA and future establishment of a GSA for the Simi Valley Basin. It is also recommended that the City begin working toward development of a Groundwater Sustainability Plan in compliance with the water code.

There are many components to a Groundwater Sustainability/Management Plan, many of which have been described in this report. While some plan components are required, plans are intended to be flexible to address basin-specific issues. Recommended components include the following:

- Local and Regional Water Management
- Stakeholder Outreach
- Hydrogeologic Setting and Groundwater Conditions
    - Geographic Setting
    - Surface Water Conditions
    - Geology and Aquifers
    - Groundwater Levels and Flow
    - Surface Water Groundwater Interaction
    - Groundwater Production
    - Water Balance
    - Recharge Areas
    - Groundwater Quality
- Basin Management Objectives
    - Establish Perennial Yield
    - Avoid Subsidence
    - Protect Groundwater Quality
    - Encourage Conjunctive Use
    - Improve Understanding of Groundwater System

- Groundwater Management Actions
    - Stakeholder Outreach
    - Monitoring Programs (levels and quality)
    - Groundwater Sustainability
    - Groundwater Protection
    - Coordinated Planning and Management
- Implementation Plan
    - Strategy and Schedule

6.9.2 County Well Ordinance

Ventura County regulates and permits well drilling in the County. In 2014, the County updated Well Ordinance No. 4184 (now No. 4486) with various additional well requirements including incorporation of Urgency Well Ordinance No. 4466. Due to the drought, beginning October 28, 2014, the County well ordinance states that:

"…no permits for the construction of new water wells or modification or repair of existing wells shall be issued under Section 4813.B.(1) and no person shall construct a new water well or modify or repair an existing water well under Section 4813.B.(1) within the area described in Section 2 "Applicability" of Ventura County Ordinance No.4468, except as provided in Sections 4826.2 and 4826.3.

Sec 4826.2- EXCEPTIONS TO WATER WELL AND PERMIT PROHIBITIONS

The water well and permit prohibitions in Section 4826.1 shall not apply to:

A. Water well permits for the repair, modification or replacement of an existing permitted water well or legal nonconforming water well involving no increase in well capacity. Well capacity means the name plate performance rating for the existing well equipment.

B. Water well permits for backup or standby wells which do not initiate any new or increased use of groundwater. For purposes of this Section, a new or increased use of groundwater is a use that did not exist before October 22, 2014.

C. Water well permits within areas in which groundwater rights have been adjudicated by a court where this water well permit prohibition would interfere with the court's order, decree, or physical solution.

D. County water well permit applications approved for processing by a Groundwater Management Agency, provided that on October 22, 2014, the Groundwater Management Agency is prohibiting new groundwater extraction facilities. For purposes of this Section 4826.2, Groundwater Management Agency shall mean an agency formed under Water Code Appendix Sections 121- 102 et seq.

E. County water well permit applications filed on or before October 22, 2014.

F. Water well permits applications within groundwater basins designated as High or Medium Priority under the Department of Water Resources ("DWR") California

Statewide Groundwater Elevation Monitoring Program (CASGEM) Groundwater Basin Prioritization for which designations are made pursuant to Water Code Section 10722.4 and for which a groundwater sustainability agency has adopted and submitted to DWR a groundwater sustainability plan or alternative plan pursuant to Water Code Sections 10727 and 10733.6 (effective January 1, 2015).

Sec. 4826.3 --WAIVERS OF THE WATER WELL AND PERMIT PROHIBITIONS

A waiver of the water well and permit prohibitions in Section 4826.1 may be granted by the Director on a case-by-case basis, upon receipt of an application for a waiver and upon the Director's determination that the application demonstrates that:

A. There are special circumstances or exceptional characteristics of the real property and groundwater which do not apply generally to comparable real property and groundwater conditions in the same vicinity, and that the granting of such waiver will not be detrimental to the condition of groundwater resources; or

B. Strict application of the prohibition as it applies to the real property or its groundwater conditions will result in practical difficulties or unnecessary hardships inconsistent with the purpose and findings of Ventura County Ordinance No. 4466 and that the granting of such waiver will not be detrimental to the condition of groundwater resources."

This blanket ordinance for the County does not specifically address the unique groundwater conditions in the Simi Valley Basin. In contrast to the over-pumping and dropping groundwater levels found in many basins in Ventura County, the Simi Valley Basin currently has stable groundwater levels. In fact, the basin has problematic high groundwater in its western portion to such an extent that groundwater is pumped and discharged to Arroyo Simi. Increased groundwater pumping at sustainable levels in the Simi Valley Basin would provide multiple benefits of providing an additional water supply source and reducing problematic high groundwater conditions. The County prohibition would not affect treating groundwater from existing dewatering wells to provide a new source of water supply. And it seems likely that, given the unique hydrogeologic conditions in Simi Valley, a waiver of the water well and permit prohibitions would likely be approved by the County for the development of new groundwater resources. This report provides the initial estimates the basin perennial yield. Nevertheless, if additional groundwater resources are developed, additional monitoring should be conducted to confirm these initial estimates, as discussed below.

6.9.3 Groundwater Level Monitoring Program

DWR has developed requirements for CASGEM submittals to maintain consistency throughout the state (DWR, 2010). Groundwater level monitoring plans are required to describe the basin, provide information about and justification for the wells that will be part of the monitoring program, define the monitoring frequency, document field methods for data collection, and identify any data gaps.

The DWR guidelines (2010) include a lengthy discussion of monitoring well density. The resulting recommendations for monitoring well density in CASGEM monitoring plans is between

2 and 20 per 100 square miles, depending on geologic complexity, relative volume of groundwater use, slope of groundwater gradient, and the availability of wells.

The guidelines also provide recommendations for frequency of groundwater elevation data collection for CASGEM programs. The goal of the CASGEM program is to track seasonal and long term trends in groundwater elevations in all the designated basins in the state. The guidelines discuss the importance of higher frequency monitoring to accurately characterize these trends. At a minimum, the frequency must be semiannual to coincide with the high and low groundwater elevations in a specific basin.

It is recommended that a formal groundwater level monitoring program be developed for the basin and included in the Groundwater Sustainability/Management Plan. The existing groundwater level monitoring network is relatively sparse in the central and eastern portion of the basin and measurements are only collected semi-annually. However it is anticipated that, based on the analysis of favorable areas for groundwater development presented in this report, that future groundwater development will likely take place in the central to western potions of the basin. The network of dewatering observation wells in the western portion of the basin provides good areal coverage in this area for both the shallow and deep aquifers as well as providing data on vertical gradients. The Simi Valley Basin is only 19 square miles in size and therefore, the current network of water level monitoring meets the DWR guidelines.

It is recommended that the City maintain and continue water level monitoring in paired observation wells and engage with the County and well owners to maintain the wells currently used for water level monitoring by the County. In particular, maintaining Well 10A2, which has a relatively long water level record, is important for evaluating general water level trends in the basin. In addition, **Figure 37** shows an existing well (07A1) located in the eastern portion of the basin that could be added to the regular water level monitoring program if the well still exists and the owners are agreeable. Two additional areas are shown that represent data gaps in water level information. In the future, the City may want to consider installing dedicated monitoring wells within these locations to improve the groundwater level monitoring program.

Multiple-completion nested monitoring wells, which are discretely screened at multiple depths allow for evaluation of vertical gradients and should be considered for any new dedicated well installation. In addition, shallow water table monitoring wells in the central portion of the basin near Arroyo Simi would be useful in characterizing surface water/ groundwater dynamics.

All wells in the water level monitoring program should be monitored at least twice per year in the wet and dry season, or quarterly, if feasible. A better alternative to periodic manual water level monitoring is to install transducers in the monitoring wells so that nearly continuous water level measurements can be collected. As groundwater in Simi Valley is developed, the groundwater level monitoring program should be periodically reevaluated to assess if additional wells would provide needed data.

6.9.4 Groundwater Quality Monitoring Program

Figures 23 and 25 show available monitoring sites for the recent time frame (1990 to present). As with water level data, there is adequate TDS and nitrate groundwater quality monitoring in the western and eastern portion of the basin and more sparse water quality monitoring in the

central portion of the basin. **Figure 38** shows the proposed groundwater quality monitoring wells and data gap areas. It is recommended that three existing wells in the eastern portion of the basin (16A10, 09N5, and 07A1) be monitored for water quality at least once per year, if the owners are agreeable. Well 10A2 in the central portion of the basin should also be included in the monitoring program. Dewatering wells 08D4, 09E1, and 08K7 are currently included in the County's groundwater quality monitoring program and this water quality monitoring should continue. Two additional areas where new dedicated monitoring wells would fill data gaps are also shown on Figure 37.

It is recommended that a formal water quality monitoring plan be included in the Groundwater Sustainability/Management Plan. Based on the discussion in the Water Quality Section, it is recommended that groundwater be monitored for general mineral and physical parameters, metals, gross alpha radioactivity, and perchlorate at a minimum. The monitoring program may be initiated with a more comprehensive suite of analytes to establish a baseline. Those analytes, which are not detected or detected below WQOs may then be deleted from subsequent sampling events. Annual monitoring is recommended. **Appendix B** contains recommended sampling protocols.

7 Findings and Recommendations

7.1 Key Findings

- The Simi Valley Basin is underlain and surrounded by bedrock composed of alternating layers of conglomerate, sandstone, siltstone, shale and minor amounts of volcanic rocks. The thickness of unconsolidated alluvial deposits in the basin ranges from less than 100 feet along the basin margins up to 800 feet in the central portion of the basin.
- The saturated aquifer thickness in the Simi Valley Basin reaches up to 600 feet in the western and central portions of the valley (west of the drainage from Tapo Canyon) and gradually thins to less than 200-300 feet to the east.
- Unconfined aquifer conditions occur in the eastern and central portions of the Simi Valley Basin. Semi-confined to confined aquifer conditions occur in the western portion of the basin.
- Groundwater recharge areas coincide with unpaved areas where soils with moderate to high infiltrating capacity overlie unconfined aquifer conditions. Such conditions occur primarily in the central and eastern portions of the Simi Valley Basin. Recharge also occurs along mountain front areas with moderate to high infiltrating capacity and unlined stream channels with sufficient depth to groundwater.
- Groundwater levels are currently stable. Groundwater flows from east to west across the basin. Groundwater levels in the deep aquifer are above the ground surface in the western portion of the basin and the vertical hydraulic gradient in this area is upward.
- Water quality is naturally poor and further degraded from anthropogenic releases. Groundwater will require treatment or blending with imported water supplies for potable use.
- Because groundwater levels have remained steady for the recent study period, potential recharge that exceeds the current outflow is likely rejected and results in outflow from the basin (through the creek or subsurface) and/or decreased mountain front recharge.
- The current and historical water balances indicate that potential inflow to the groundwater basin is as much as 9,000 AFY. Perennial yield can be estimated as water removed from storage that is replaced in time through groundwater inflow. This inflow represents a maximum potential value, recognizing that undesired results can occur with pumping at lower rates. Moreover, a single average perennial yield oversimplifies the flow into the basin; inflows vary with on climatic conditions (among other factors) and depend on whether there is adequate available storage in the basin. Nonetheless, 9,000 AFY may be considered as a general guideline of potential perennial yield.

- Successful development of this inflow as a water supply is dependent on well location and yields, plus monitoring and management.
- The Simi Valley Basin is capable of yielding sufficient groundwater to supply municipal water supply wells.
- New production wells can be installed to develop additional groundwater resources. The recommended location for new production wells is the area south of Brea Canyon, bounded generally by the Arroyo Simi to the south and the drainage exiting Tapo Canyon to the east. Yields from properly designed, constructed, developed, and maintained wells in this area are expected to yield between 500 and 1,000 gpm. Yields as high as 1,600 gpm have been reported.
- Groundwater pumped from active dewatering wells in the western portion of the Simi Valley Basin can also be treated and used for water supply.

7.2 Data Gaps

- Currently, the network of wells monitored for groundwater levels and quality is sparse in selected areas.
- The available stream gage data are inadequate to determine gaining and losing stretches along Arroyo Simi within the basin.
- Aquifer parameters estimated from long-term pumping tests are sparse.

7.3 Recommendations

- Pursue treatment of dewatering water for water supply and develop additional groundwater resources in the basin.
- Review the County well destruction program. If deemed helpful, develop a local program to encourage/require proper well destructions. This could be made a requirement at the time of property transfers or major remodels.
- Apply to the County for an exemption from the new well construction ban.
- Consider conducting one or more synoptic stream surveys to document gaining and losing reaches along Arroyo Simi.
- Conduct long-term aquifer tests for new production wells. Consider running long-term pumping tests for existing production and dewatering wells.
- Maintain a basin management database of driller's log information, water level, pumping and groundwater quality.

- Currently, totalizer flow meter readings from dewatering wells are recorded. Estimating pumping from these records is difficult due to meter replacements and changes in recorded units. Therefore, monthly pumping volumes should be recorded and entered into the basin management database.
- Develop a Groundwater Sustainability/Management Plan in accordance with the Water Code including a formal water level and water quality monitoring plan. Include perchlorate as a monitored constituent in the plan.
- Prepare Groundwater Management Reports annually or at least once every three years.
- Develop a Salt and Nutrient Management Plan.
- Protect recharge areas from development and/or encourage LID in recharge areas.
- Evaluate the feasibility of managed aquifer recharge in the basin in the future.
- Consider development of a coupled surface water-groundwater flow model to evaluate the impacts of future pumping and other basin management strategies in the future as water supplies are developed and data are collected to support the model.
- Track remedial progress at Joes Cleaners and Moving Solutions environmental release sites. Periodically review GeoTracker for sites in Simi Valley that pose a water quality risk to the water supply aquifer.

8 References

Black & Veatch (B&V), 2011. 2010 Urban Water Management Plan, prepared for Calleguas Municipal Water District, May 2011. Accessed at: http://www.calleguas.com/images/docs-water-resources-and-quality/cmwd2010uwmpfinal.pdf

Boeing, 2015, Report on Annual Groundwater Monitoring, 2014, Santa Susana Field Laboratory, Ventura County, California, report to Department of Toxic Substances Control.

Bondy, Bryan, 2016. Email correspondence, January 4.

California Department of Conservation, 1992. Division of Oil, Gas, and Geothermal Resources (DOGGR), California Oil & Gas Fields, Volume II – Southern, Central, and offshore California. Accessed at: ftp://ftp.consrv.ca.gov/pub/oil/publications/Datasheets/Dtasheet_vol_2.pdf

California Environmental Protection Agency, Department of Toxic Substances Control (DTSC), 2003. Update on Perchlorate Investigation in Simi Valley, September. Accessed: https://www.dtsc.ca.gov/SiteCleanup/Projects/upload/SSFL_FS_Perc-Update.pdf

California Department of Water Resources (DWR), 1959. Water Quality and Water Quality Problems, Ventura County, Bulleting No. 75, February 1959. Accessed at: http://www.water.ca.gov/waterdatalibrary/docs/historic/Bulletins/Bulletin_75/Bulletin_75-1__1959.pdf

California Department of Water Resources (DWR), 1968. Water Well Standards, Ventura County, Bulletin No. 74-9, August. Accessed at: http://www.water.ca.gov/waterdatalibrary/docs/historic/Bulletins/Bulletin_74/Bulletin_74-9__1968.pdf

California Department of Water Resources (DWR), 1998. California Water Plan Update. DWR Bulletin 160-98, November. Accessed at: http://www.water.ca.gov/pubs/planning/california_water_plan_1998_update__bulletin_160-98_/b16098_vol1.pdf

California Department of Water Resources (DWR), 2004. California's Groundwater, Bulletin 118, Coastal Plain of Los Angeles Groundwater Basin, Central Subbasin and West Coast Subbasin, February 2004. Accessed at: http://www.water.ca.gov/pubs/groundwater/bulletin_118.

California Department of Water Resources (DWR), 2010. Groundwater Elevation Monitoring Guidelines, December 2010. Accessed at: http://www.water.ca.gov/groundwater/casgem/pdfs/CASGEM%20DWR%20GW%20Guidelines%20Final%20121510.pdf

California Department of Water Resources (DWR), 2016. SGMA Definitions. Accessed at: http://www.water.ca.gov/groundwater/sgm/definitions.cfm

California Environmental Protection Agency, Regional Water Quality Control Board, Los Angeles Region (LARWQCB), 1994. Water Quality Control Plan, Los Angeles Region (Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties), adopted on June 13, 1994 and amendments dated October 28, 2011. Accessed at: http://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan/basin_plan_documentation.shtml.

California Environmental Protection Agency, Regional Water Quality Control Board, Los Angeles Region (LARWQCB), 2007. Resolution No. R4-2007-016, Amendment to the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load for Boron, Chloride, Sulfate, and TDS (Salts) for Calleguas Creek Watershed, October 4. Accessed at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/calleguas_salts/rs_r42007016attachment.pdf

California Office of Environmental Health Hazard Assessment (OEHHA), 2008. Public Notice, Initiation of Risk Assessments for Chemicals in Drinking Water, July 2008. Accessed at: http://oehha.ca.gov/water/phg/pdf/PHGinitiation073008.pdf

Cardno ERI, 2015. First Quarter 2015 Groundwater Monitoring and Status Report, Former Exxon/Mobil Station 70462, 2395 Ettinger Road, Simi Valley, California, report to Los Angeles Regional Water Quality Control Board, April 14. Accessed at: http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/1271187961/T0611100221.PDF

CH2MHILL, 2007. Reconnaissance Study Report, Simi Valley Perchlorate Study, Ventura County, California, prepared for United States Army Corps of Engineers, Los Angeles District, August 2007. Accessed at: http://www.dtsc-ssfl.com/files/lib_offsite_investig%5Cperchlorate/65782_7510_USACE-Final-ReconRptSimi-drd2081.pdf

Converse Consultants (Converse), revised 2015. Revised Remedial Design and Implementation Plan for Groundwater Remediation, Joe's Cleaners, 2890 Cochran Street, Simi Valley, California, prepared for ASB Property Management, April 29. Accessed at: http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/3724325597/SL0603707010.PDF

Driscoll, F.G., 1986. Groundwater and Wells, Johnson Division, Signal Environmental Systems, St. Paul, MN.

Evenson, J. M. Jr., 1997. Hydrogeology of the Simi Valley Hydrologic Basin, Ventura County, thesis California State University, Northridge.

Geoscience Support Services, Inc. (Geoscience), 2007. Groundwater Management Plan Gillibrand Groundwater Basin, prepared for Ventura County Waterworks District No. 8 – City of Simi Valley and P.W. Gillibrand Co. Accessed at: http://www.water.ca.gov/groundwater/docs/GWMP/SC-14_VenturaCountyWaterworksGillibrandGroundwaterBasinGWMP_May2007.pdf

Hantush, M.S., and C.E. Jacob, 1955. Non-steady radial flow in an infinite leaky aquifer, Am. Geophys. Union Trans., vol. 36, pp. 95-100.

Hem, John D., 1989, Study and Interpretation of the Chemical Characteristics of Natural Water, USGS Water Supply Paper 2254, Third Edition.

Kennedy/Jenks Consultants (K/J), 2008. Final Recycled Water Master Plan Update, prepared for Ventura County Waterworks District No. 8/ City of Simi Valley, July 2008. Accessed at: http://www.ventura.org/wcvc/prop84/docs/Implementation2/Att3_IG2_WorkPlan_3of7.pdf

Kennedy/Jenks Consultants (K/J), 2011. 2010 Urban Water Management Plan – Simi Valley, prepared for Golden State Water Company, August 2011. Accessed at: http://www.water.ca.gov/urbanwatermanagement/2010uwmps/Golden%20State%20Water%20Company%20-%20Simi%20Valley/GSWC_SimiVly_2010_UWMP-with%20appendix.pdf

Kew, S. W., 1918. Structure and Oil Resources of the Simi Valley, Southern California, USGS. Accessed at: http://pubs.usgs.gov/bul/0691m/report.pdf

Larry Walker Associates, 2013. Draft Data Report for the Phase II Program for Long-Term Monitoring of Flow and Recharge in Arroyo Las Posas, report to Calleguas Municipal Water District, August 12.

Leighton and Associates (Leighton), 1972. Groundwater Study (Phase II) of East and West Basin Areas, City of Simi Valley, Ventura County, CA, prepared for City of Simi Valley, November 22, 1972.

Leighton and Associates (Leighton), 1985. Simi Valley West End Ground Water Study, prepared for Simi Valley County Sanitation District, September 1985.

Leighton and Associates (Leighton), 1988. Ground Water Dewatering Program Implementation West End of Simi Valley Groundwater Basin, prepared for Simi Valley County Sanitation District, September 1985.

Leymaster Environmental Consulting, LLC (Leymaster), 2015a. Semi-Annual Groundwater and Vapor System Monitoring Report, 1st Quarter 2015, 45 West Easy Street, Simi Valley, California, report to Los Angeles Regional Water Quality Control Board, April 16. Accessed at: http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/4137520968/SLT4L3711811.PDF

Leymaster Environmental Consulting, LLC (Leymaster), 2015b. Quarterly Groundwater and Vapor System Monitoring Report, 1st Quarter 2015, 45 West Easy Street, Simi Valley, California, report to Los Angeles Regional Water Quality Control Board, April 16. Accessed at: http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/1946825146/SLT4L3711811.PDF

Metropolitan Water District of Southern California (MWD) and U.S. Department of Interior, Bureau of Reclamation (USBOR), 1999. Salinity Management Study, Final Report: Long-term Strategy and Recommended Action Plan, prepared by Bookman-Edmonston, June 1999. Accessed at: http://www.socalsalinity.org/pdfs/1999salinityreport.pdf

Miller, C.S, 19684. The Changing Agricultural Landscape of the Simi Valley from 1795 to 1960, Ventura County Historical Quarterly, Volume XIII, Number 4, Ventura, California.

Motzer, William, E, 2001. Perchlorate: Problems, Detection, and Solutions, Environmental Forensics, vol. 2, no. 4, December 2001.

National Research Council (NRC), 2005. Health Implications of Perchlorate Ingestion, National Academies Press, Washington, DC, 2005.

Nzengung, V.A., C. Wang, and G. Harvey, 1999. Plant-mediated Transformation of Perchlorate into Chloride, Environ. Sci. Technol. 33, 1999.

Padre Associates, Inc. (Padre), 2014. Draft Environmental Impact Report for the Calleguas Regional Salinity Management Project Phase 2 (Upper Reach), lead Agency: Calleguas Municipal Water District, January 2014. Accessed at: http://www.calleguas.com/images/docs-documents-reports/deirsmpphase2ur.pdf

RBF Consulting, 2011. 2010 Urban Water Management Plan, prepared for Ventura County Waterworks, District No. 8, June 2011. Accessed at: http://www.ci.simi-valley.ca.us/index.aspx?page=117

Simi Valley, City of, 1999. Final Safety Element, Technical Appendix J. *City of Simi Valley General Plan*. July 1999.

Soil Conservation Service (SCS), 1953, Ground Water Replenishment by Penetration of Rainfall, Irrigation, and Water Spreading in Zone 3, Ventura County Flood Control District, California, April, 1953.

Squires, R.L., 1997. Geologic Profile of Simi Valley, California State University, Northridge. Accessed at: http://decapoda.nhm.org/pdfs/37041/37041.pdf

State Water Resources Control Board (SWRCB), 1953. Ventura County Investigation, Bulletin 118, October and revised April 1956. Accessed at: http://www.water.ca.gov/waterdatalibrary/docs/historic/Bulletins/Bulletin_12/Bulletin_12__1956.pdf

State Water Resources Control Board (SWRCB), 2010. Groundwater Information Sheet Boron, revised July 13, 2010. Accessed at: http://www.waterboards.ca.gov/gama/docs/coc_boron.pdf

State Water Resources Control Board (SWRCB), 2010. Groundwater Information Sheet Nitrate, revised August 2010. Accessed at: http://www.waterboards.ca.gov/gama/docs/coc_nitrate.pdf

State Water Resources Control Board (SWRCB), 2012. Low-Threat Closure Policy, effective August 17, 2012. Accessed at: http://www.swrcb.ca.gov/ust/lt_cls_plcy.shtml#policy081712

Tabidian, M. A., 2006. Land-use conversion and its potential impact on stream/aquifer hydraulics and perchlorate distribution in Simi Valley, California, prepared under contract to the Santa Susana Field Laboratory Advisory Panel, October 2006. Accessed at: https://assets.documentcloud.org/documents/2506686/tabidian.pdf

Todd, D.K. and L.W. Mays, 2005, Groundwater Hydrology, John Wiley & Sons, Inc.

United States Environmental Protection Agency (USEPA), 2008. Interim Drinking Water Health Advisory for Perchlorate, USEPA 822-R-08-025, December 2008. Accessed at: http://nepis.epa.gov/Exe/ZyNET.exe/P1004X7Q.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&

United States Department of Agriculture (USDA), Natural Resources Conservation Service, Conservation Engineering Division, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, June. Accessed at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

United States Geological Survey (USGS), 1957. H.C. Troxell, Southern California with Special Reference to the Drought of 1944-51, Water Supply Paper 1366. Accessed at: http://pubs.usgs.gov/wsp/1366/report.pdf

United States Geological Survey (USGS), R.F. Yerkes and R.H. Campbell., 1997. Preliminary Geologic Map of the Simi 7.5' Quadrangle, Southern California, A Digital Database, Open-File Report 97-259. Accessed at: http://pubs.usgs.gov/of/1997/of97-259/

United States Geological Survey (USGS), Treiman, J., 2000. Fault number 98, Simi-Santa Rosa fault zone, Camarillo-Santa Rosa Valley section, in Quaternary fault and fold database of United States. Accessed at: http://earthquakeslusgslgov/hazards/qfaults

United States Geological Survey (USGS), CA. Burton, J. Montrella, M.K. Landon, and K. Belitz, 2011. Status and Understanding of Groundwater Quality in the Santa Clara River Valley, 2007: California GAMA Priority Basin Project, Scientific Investigation Report 2011-5052, prepared in cooperation with the California State Water Resources Control Board. Accessed at: http://pubs.usgs.gov/sir/2011/5052/pdf/sir20115052.pdf

United States Census, 2015. Quickfacts, Accessed at: http://quickfacts.census.gov/qfd/states/00000.html

Ventura County Watershed Protection District, Water & Environment Resources Division, undated, 2013 Groundwater Section Annual Report. Accessed at: http://obgma.com/wp-content/uploads/2015/05/WPD_Grndwtr_Annual_Rpt_2013.pdf

Ventura County Star, 2011. Council approves $22.7 million water recycling project, July 36, 2011.Accessed at: http://www.vcstar.com/news/council-approves-227-million-water-recycling-project-ep-364651678-340330111.html

Wayne Perry, Inc., 2015. Quarterly Status and Groundwater Monitoring Report, First Quarter 2015, Former Shell Service Station, 1196 East Los Angeles Ave., Simi Valley, California, report to Los Angeles Regional Water Quality Control Board, April 20. Accessed at: http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/1254049718/T0611100120.PDF

Wong, E., 2015. Verbal communications, March 2015.

Figures

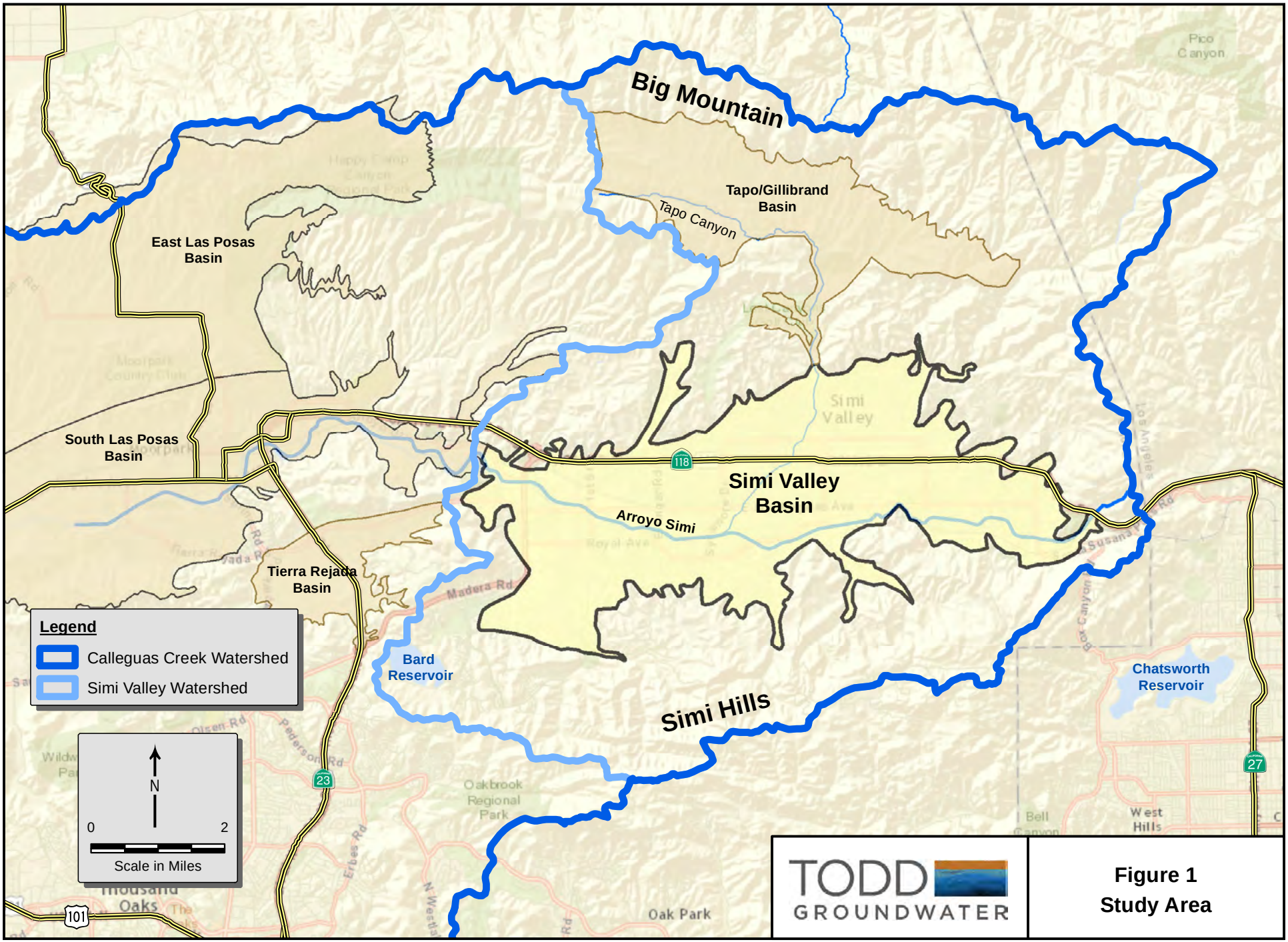


Figure 1
Study Area

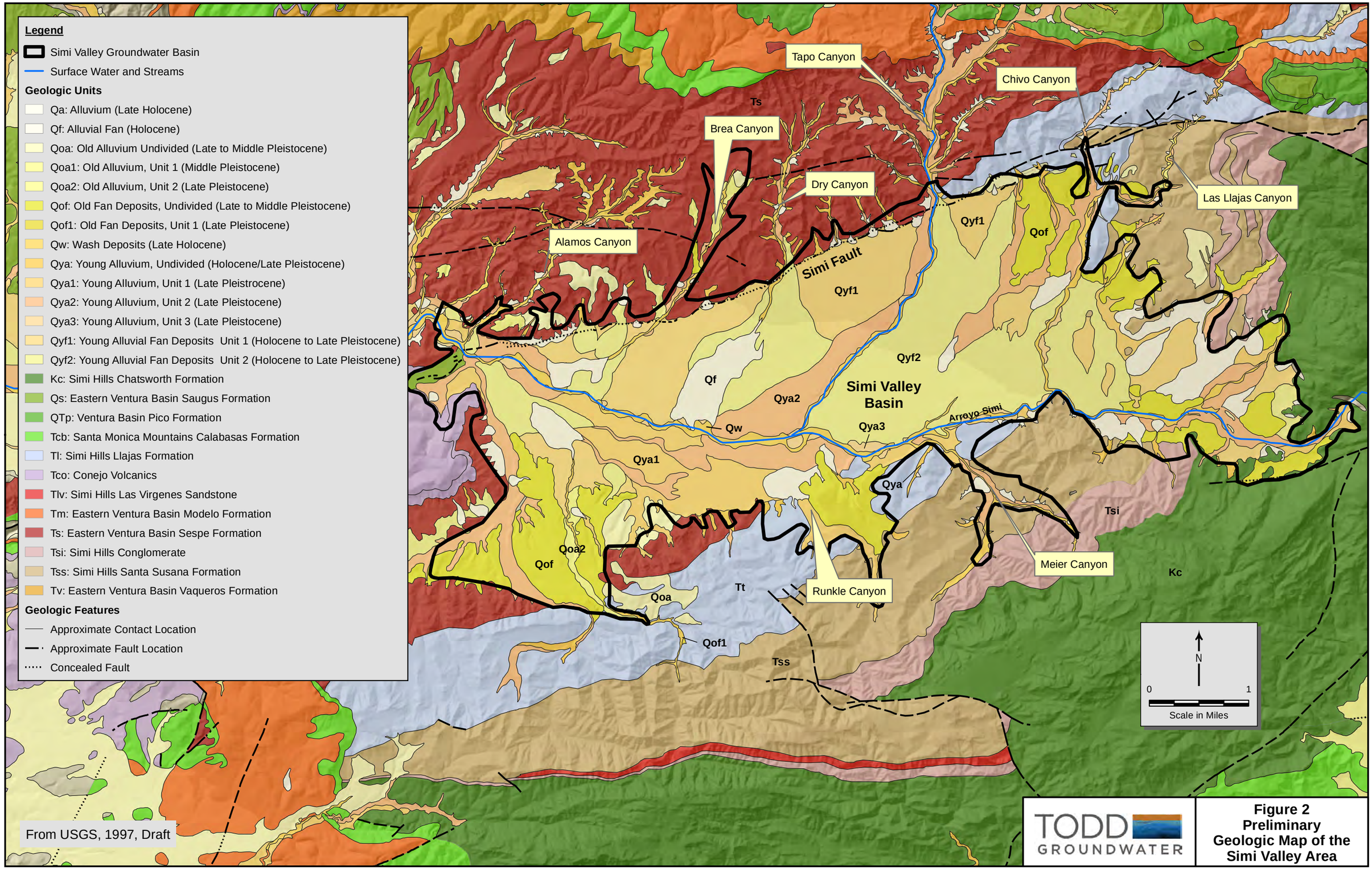
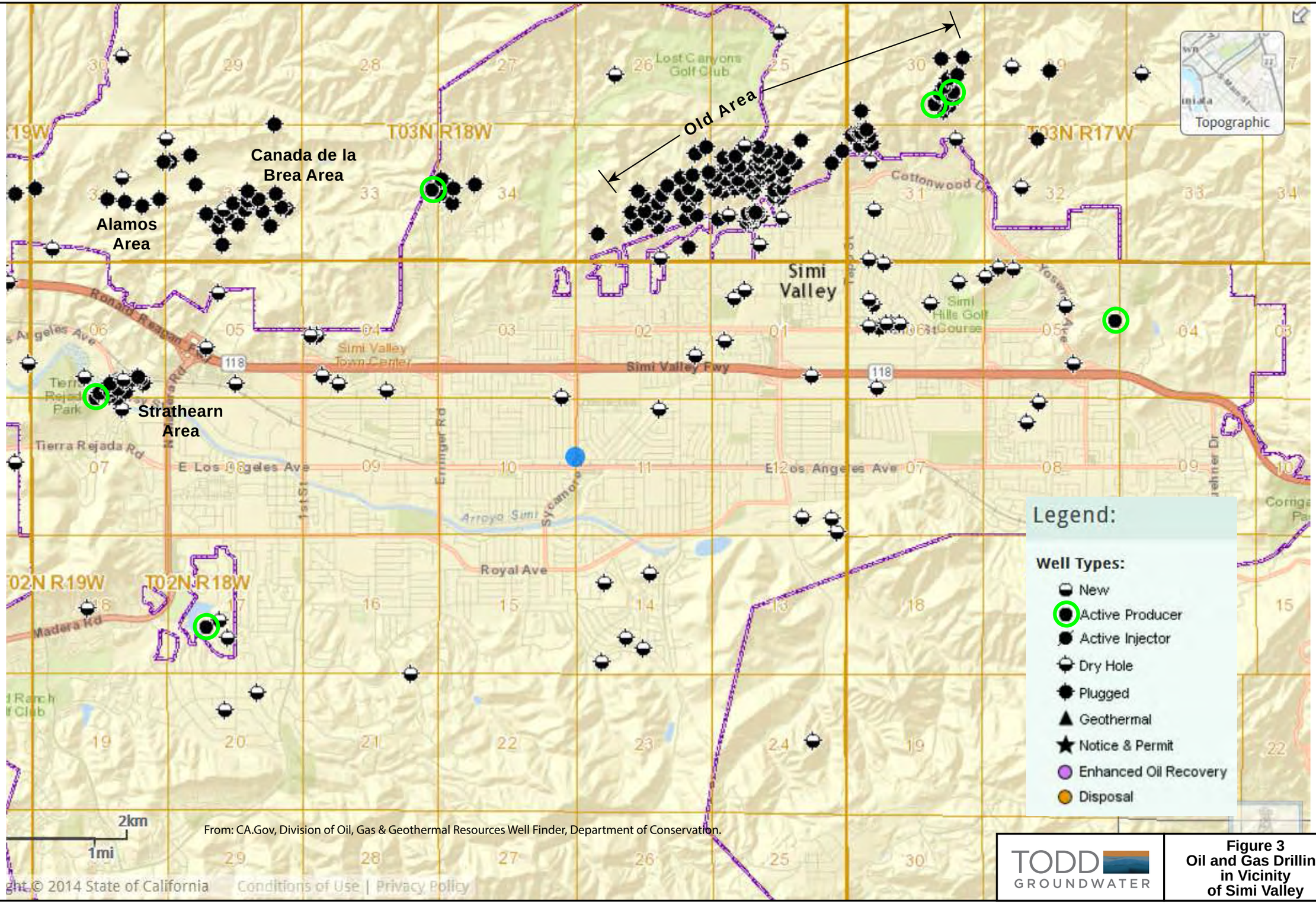


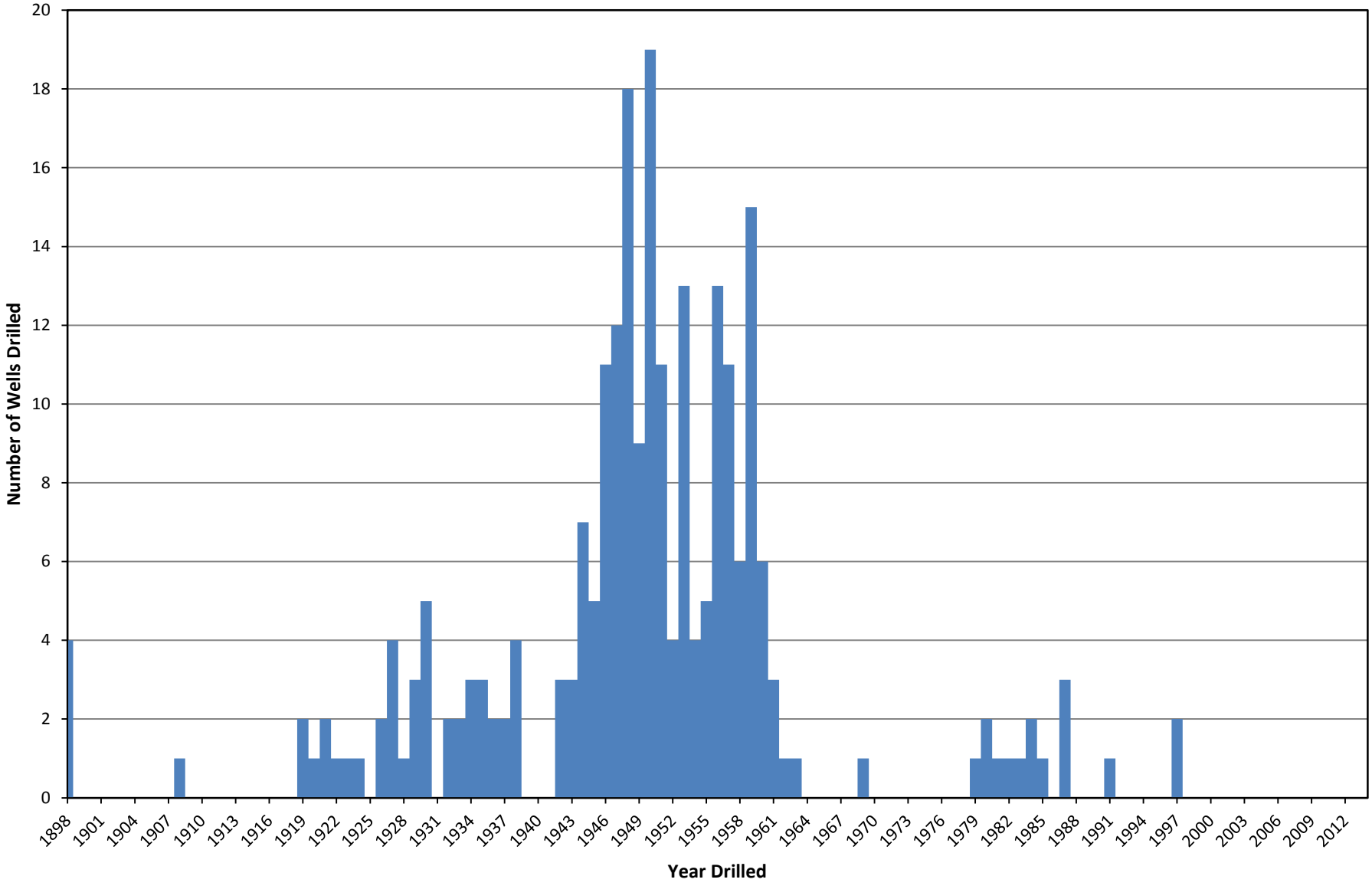
Figure 2
Preliminary Geologic Map of the Simi Valley Area



From: CA.Gov, Division of Oil, Gas & Geothermal Resources Well Finder, Department of Conservation.

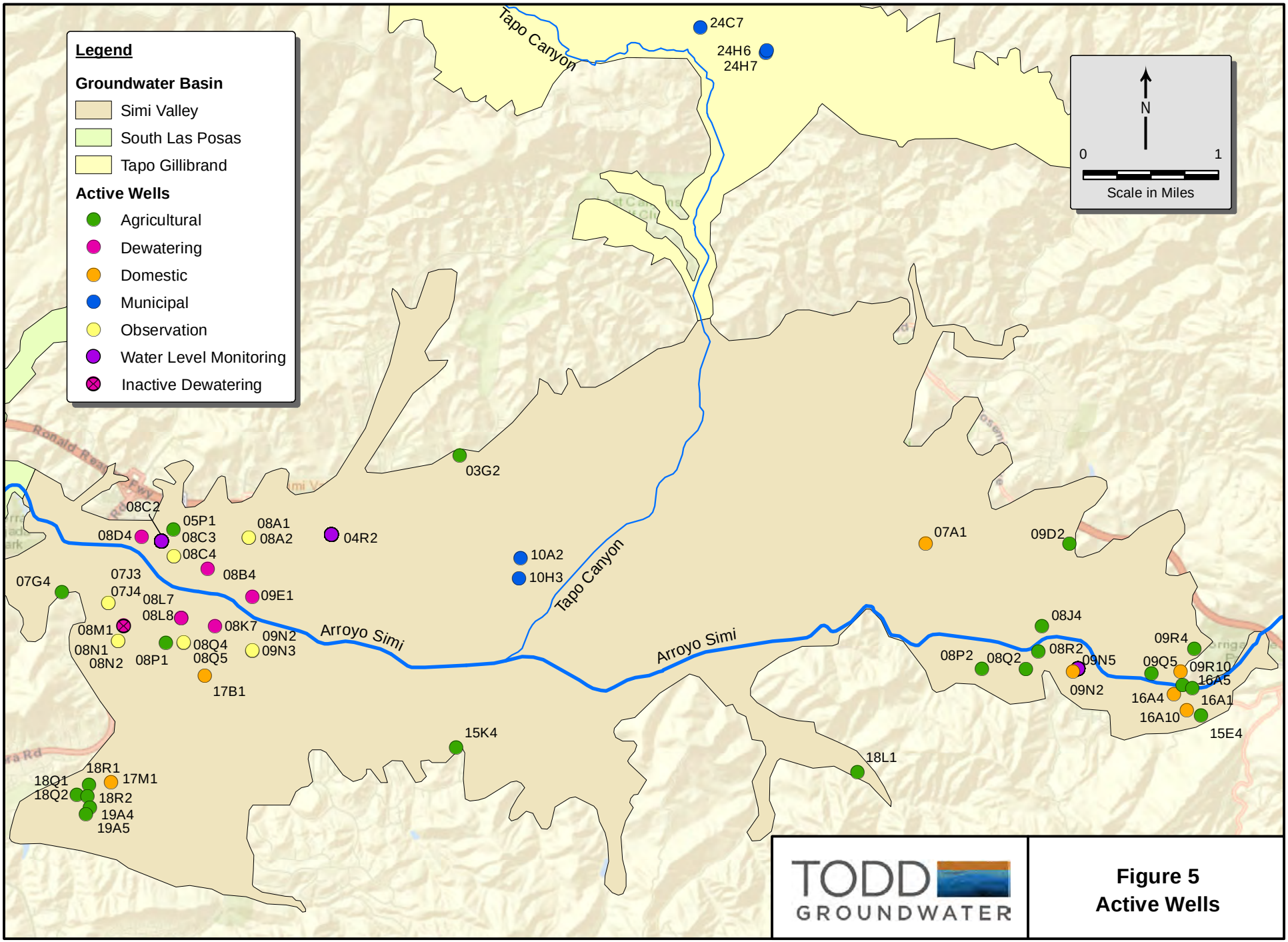
TODD GROUNDWATER

Figure 3
Oil and Gas Drilling in Vicinity of Simi Valley



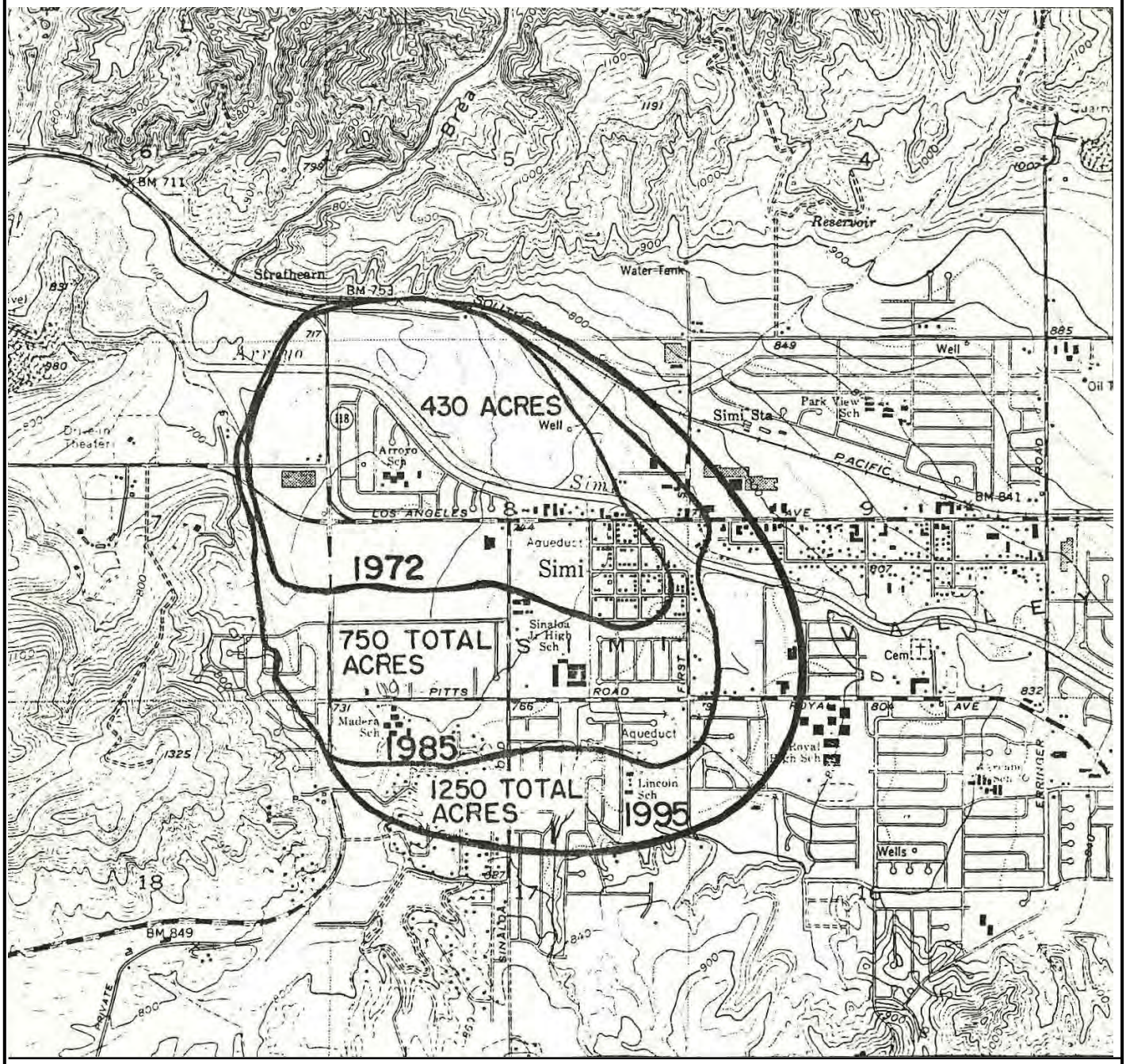
TODD GROUNDWATER

Figure 4
Wells Drilled by Year



TODD GROUNDWATER

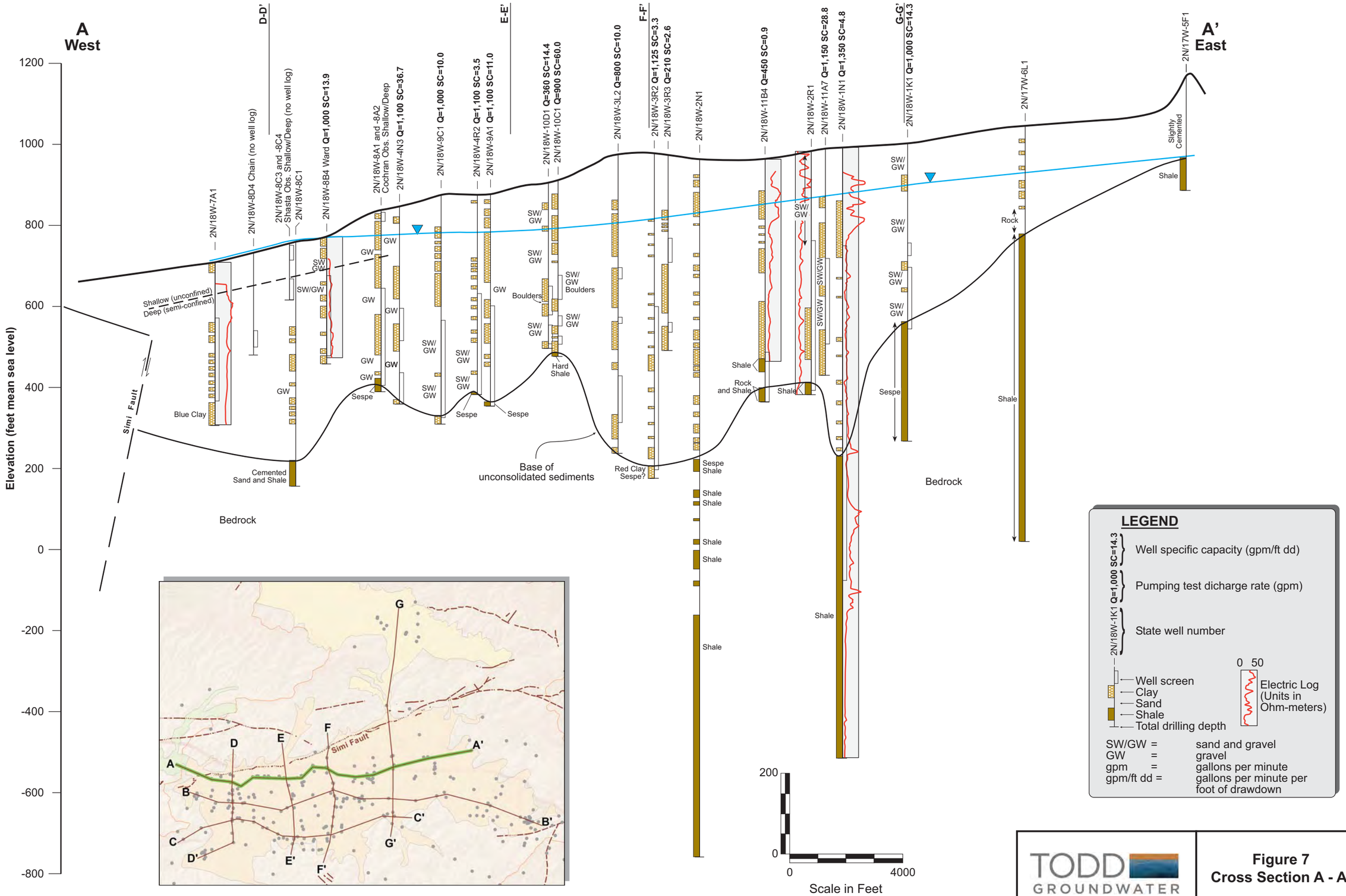
Figure 5
Active Wells



From: Leighton & Associates, 1985

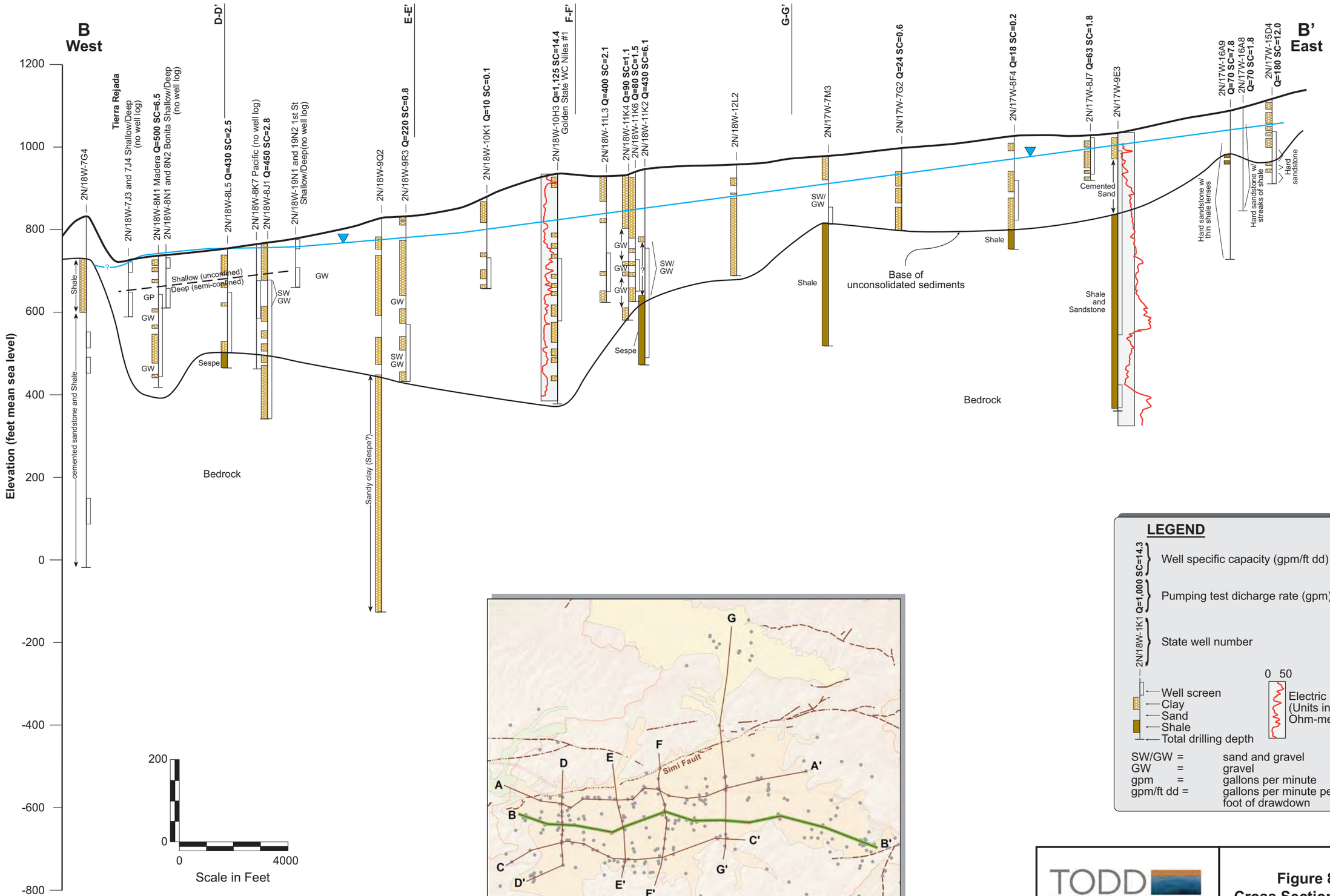
TODD GROUNDWATER

Figure 6
Estimated Historical Area of Artesian Conditions



TODD GROUNDWATER

Figure 7
Cross Section A - A'



LEGEND

2N/18W-1K1 Q=1,000 SC=14.3

- Well specific capacity (gpm/ft dd)
- Pumping test dicharge rate (gpm)
- State well number

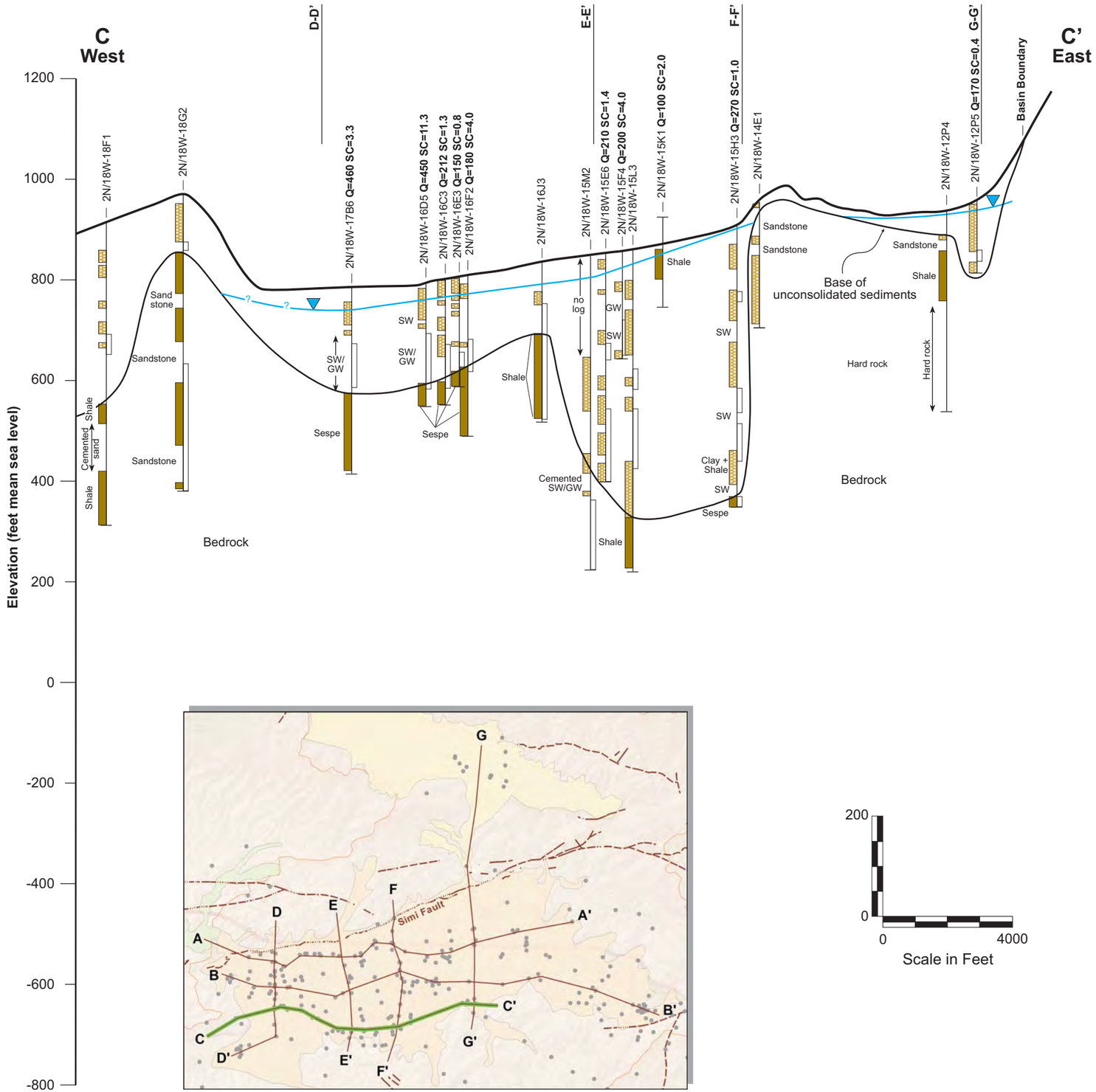
- Well screen
- Clay
- Sand
- Shale
- Total drilling depth

0 50 — Electric Log (Units in Ohm-meters)

SW/GW = sand and gravel
GW = gravel
gpm = gallons per minute
gpm/ft dd = gallons per minute per foot of drawdown

TODD GROUNDWATER

Figure 8
Cross Section B - B'



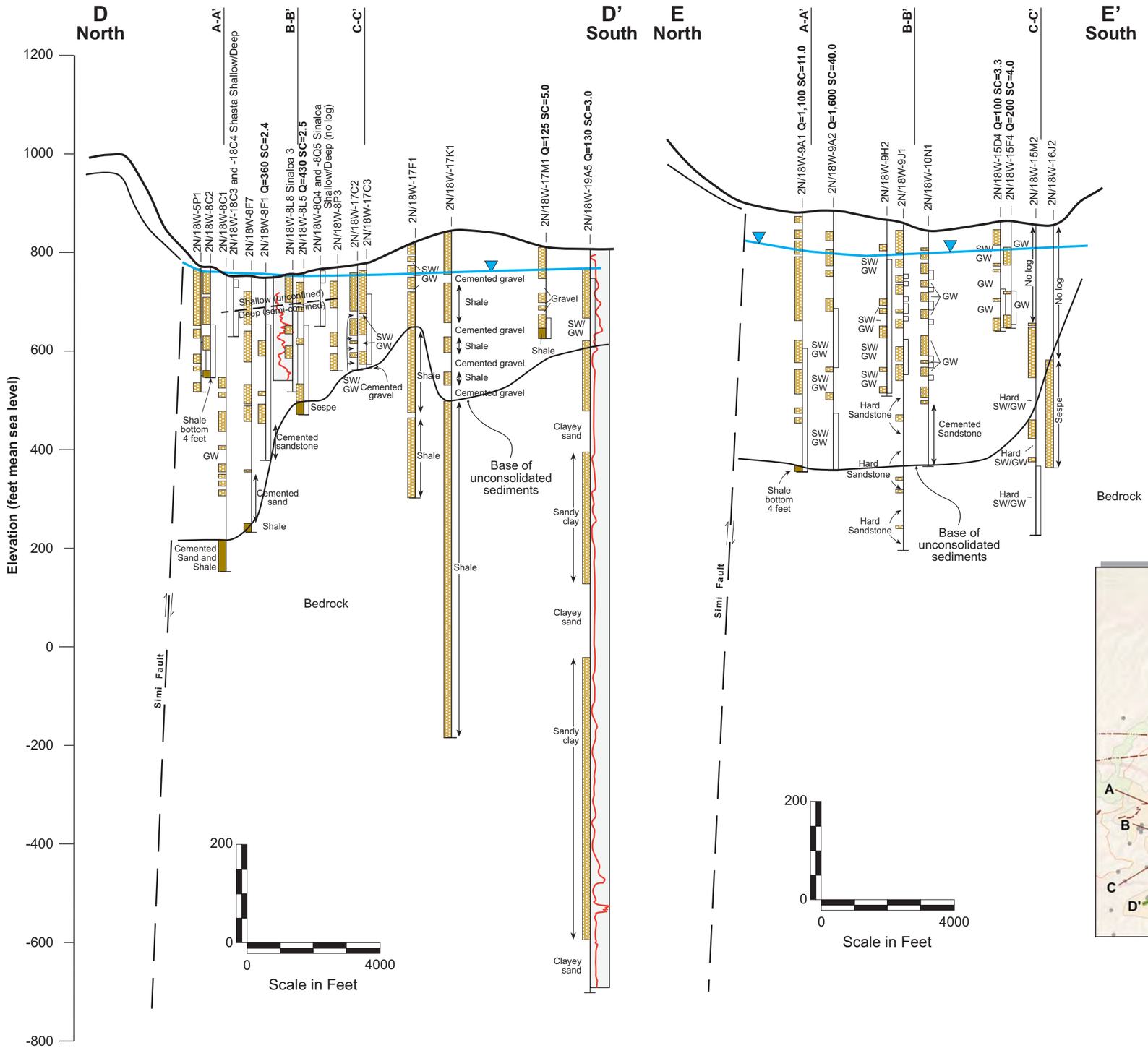
LEGEND

- 2N/18W-1K1 Q=1,000 SC=14.3
  - Well specific capacity (gpm/ft dd)
  - Pumping test dicharge rate (gpm)
  - State well number
- Well screen
- Clay
- Sand
- Shale
- Total drilling depth

SW/GW = sand and gravel
GW = gravel
gpm = gallons per minute
gpm/ft dd = gallons per minute per foot of drawdown

TODD GROUNDWATER

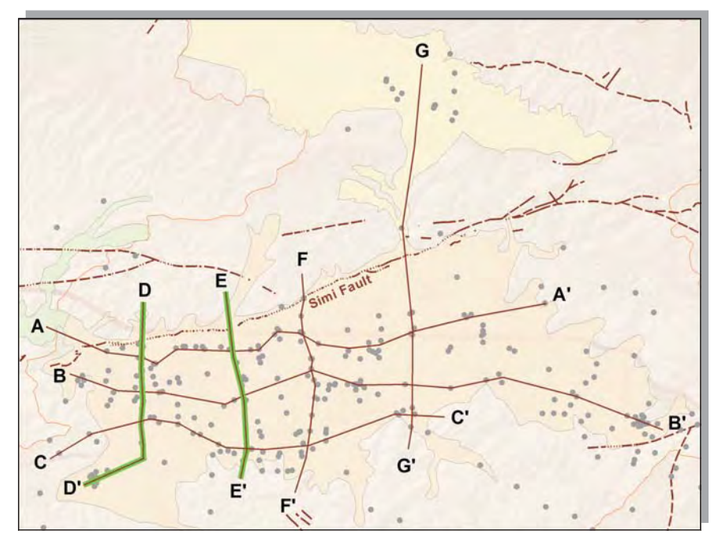
Figure 9
Cross Section C - C'



LEGEND

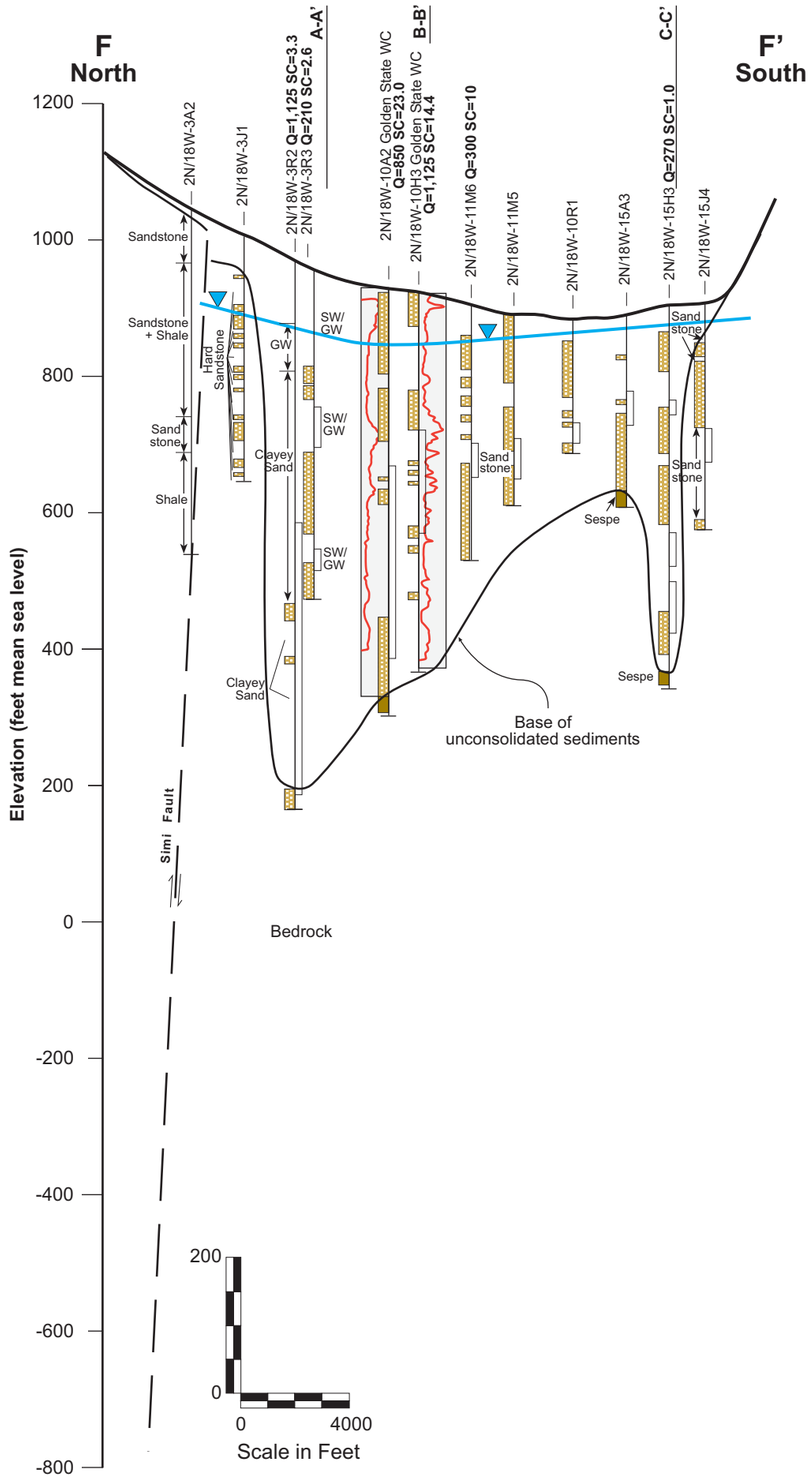
- 2N/18W-1K1 Q=1,000 SC=14.3 — Well specific capacity (gpm/ft dd); Pumping test dicharge rate (gpm); State well number
- Well screen
- Clay
- Sand
- Shale
- Total drilling depth
- 0 50 — Electric Log (Units in Ohm-meters)

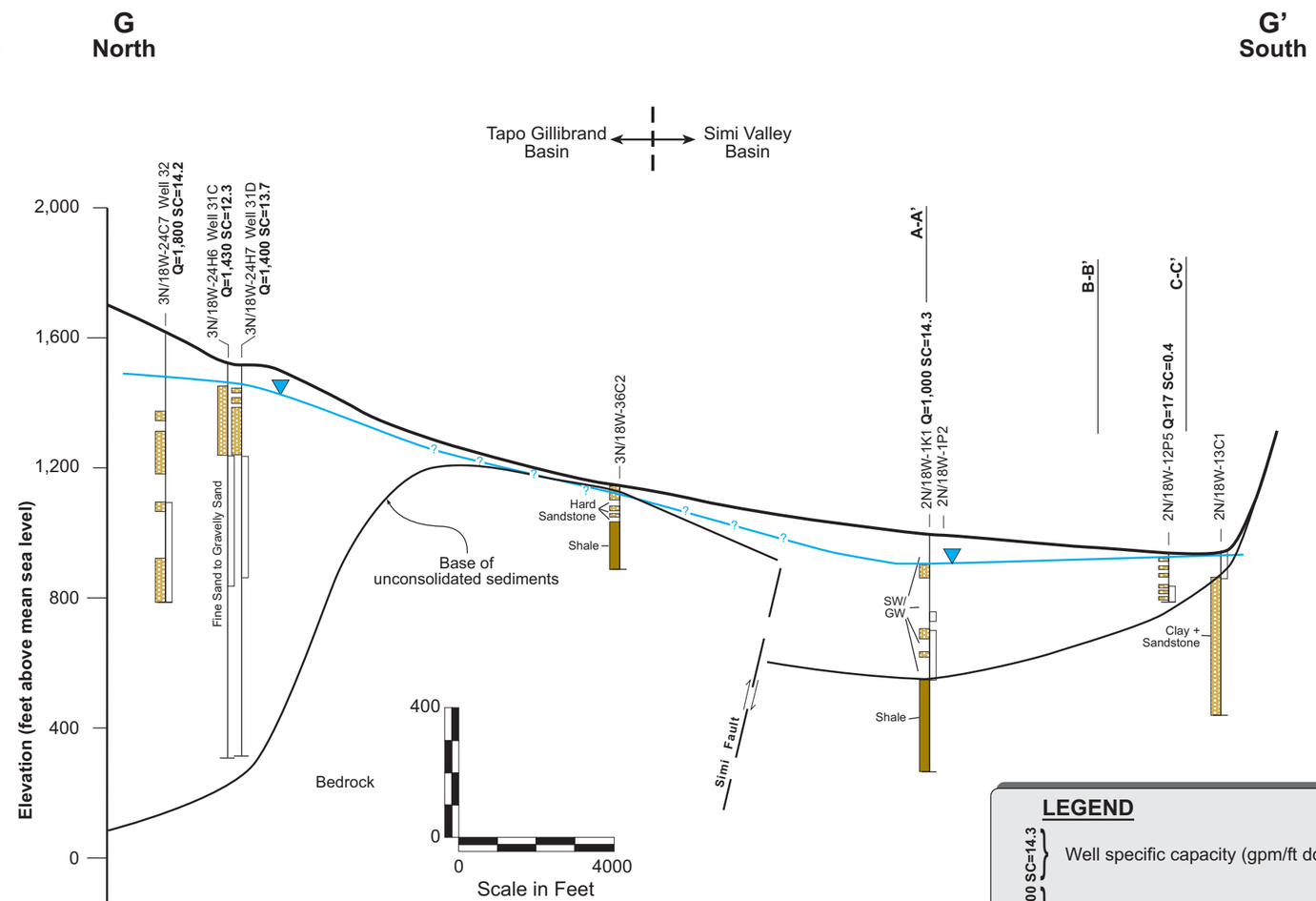
SW/GW = sand and gravel
GW = gravel
gpm = gallons per minute
gpm/ft dd = gallons per minute per foot of drawdown

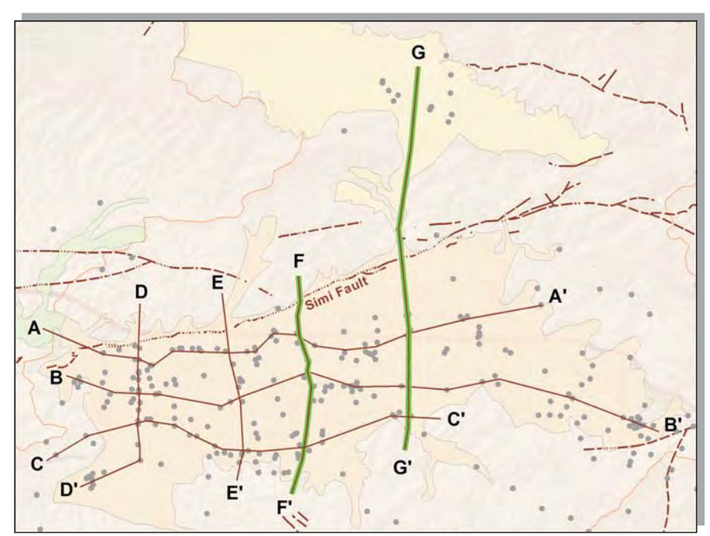


TODD GROUNDWATER

Figure 10
Cross Section
D - D' and E - E'







LEGEND

2N/18W-1K1 Q=1,000 SC=14.3

- Well specific capacity (gpm/ft dd)
- Pumping test dicharge rate (gpm)
- State well number

- Well screen
- Clay
- Sand
- Shale
- Total drilling depth

0 50 — Electric Log (Units in Ohm-meters)

SW/GW = sand and gravel
GW = gravel
gpm = gallons per minute
gpm/ft dd = gallons per minute per foot of drawdown

TODD GROUNDWATER

Figure 11
Cross Section
F - F' and G - G'

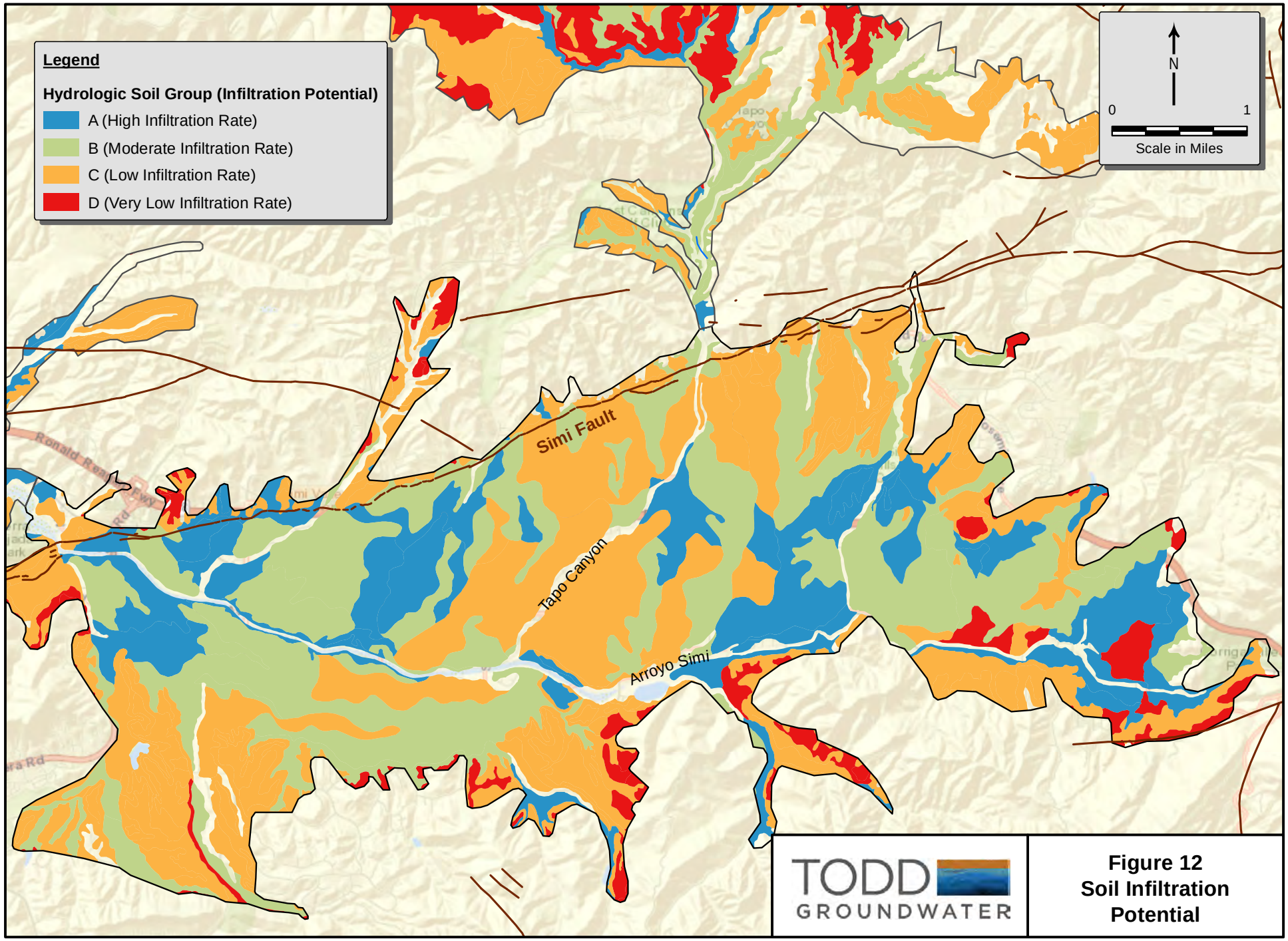


Figure 12
Soil Infiltration Potential

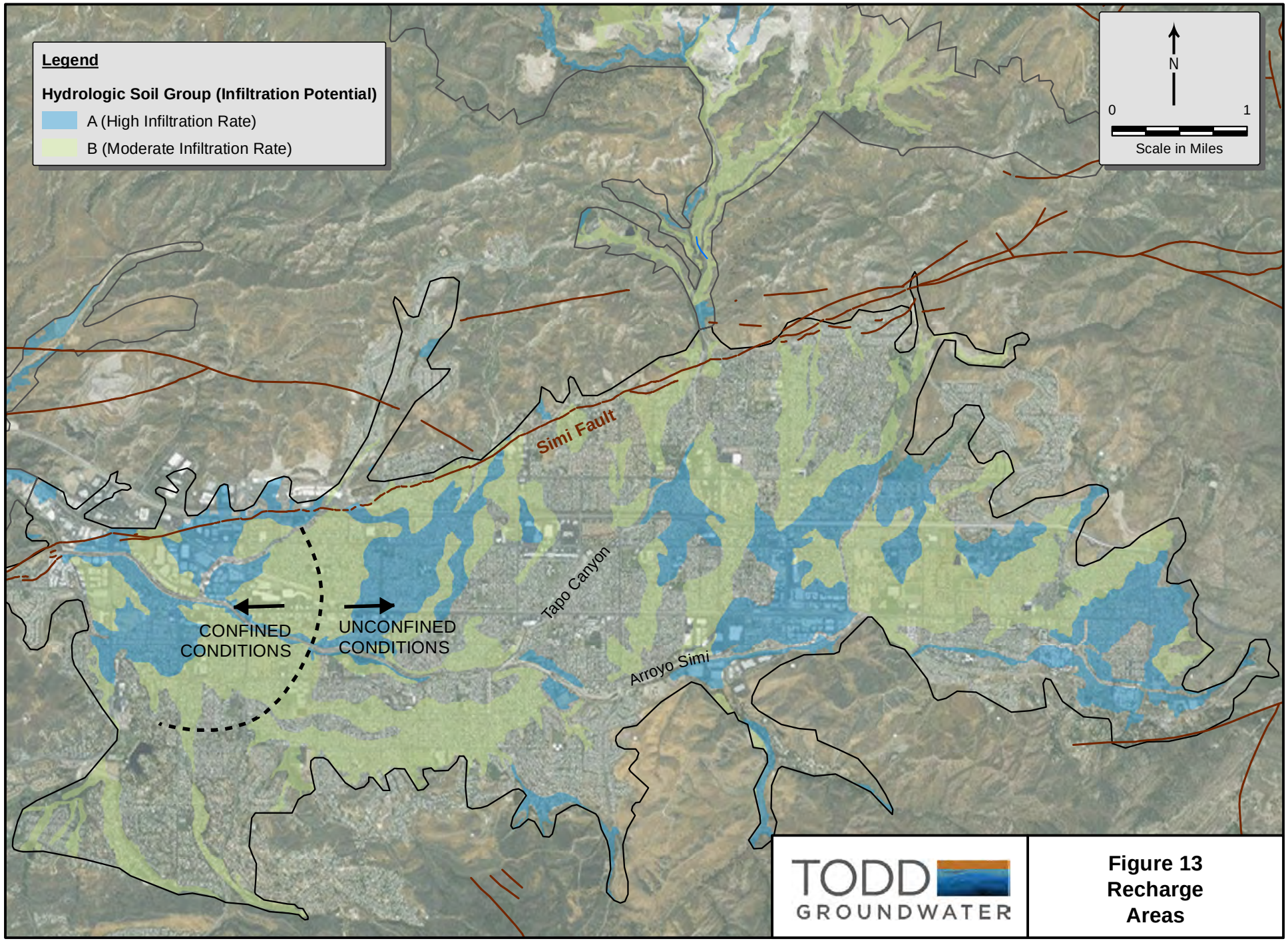


Figure 13
Recharge Areas

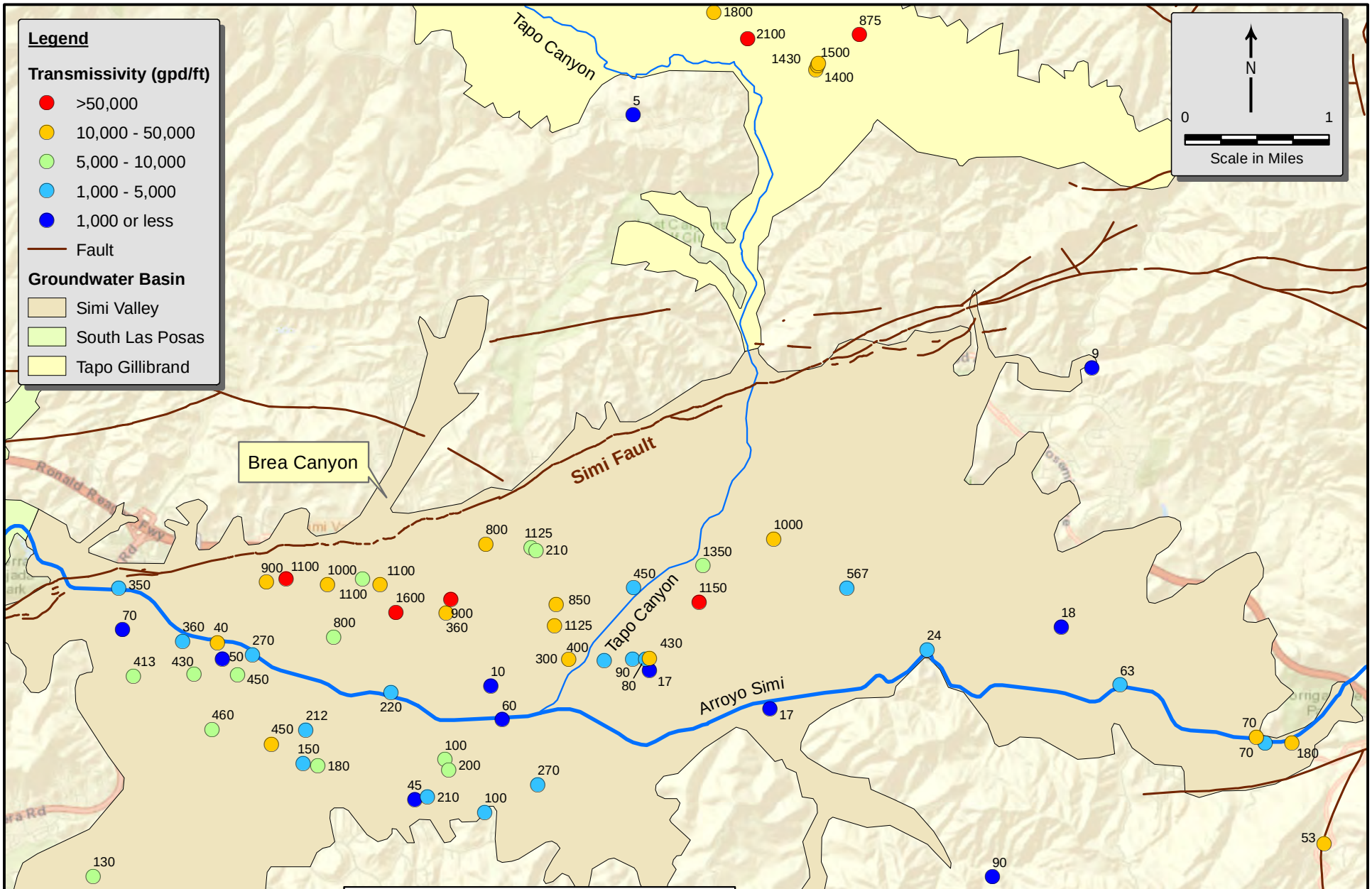
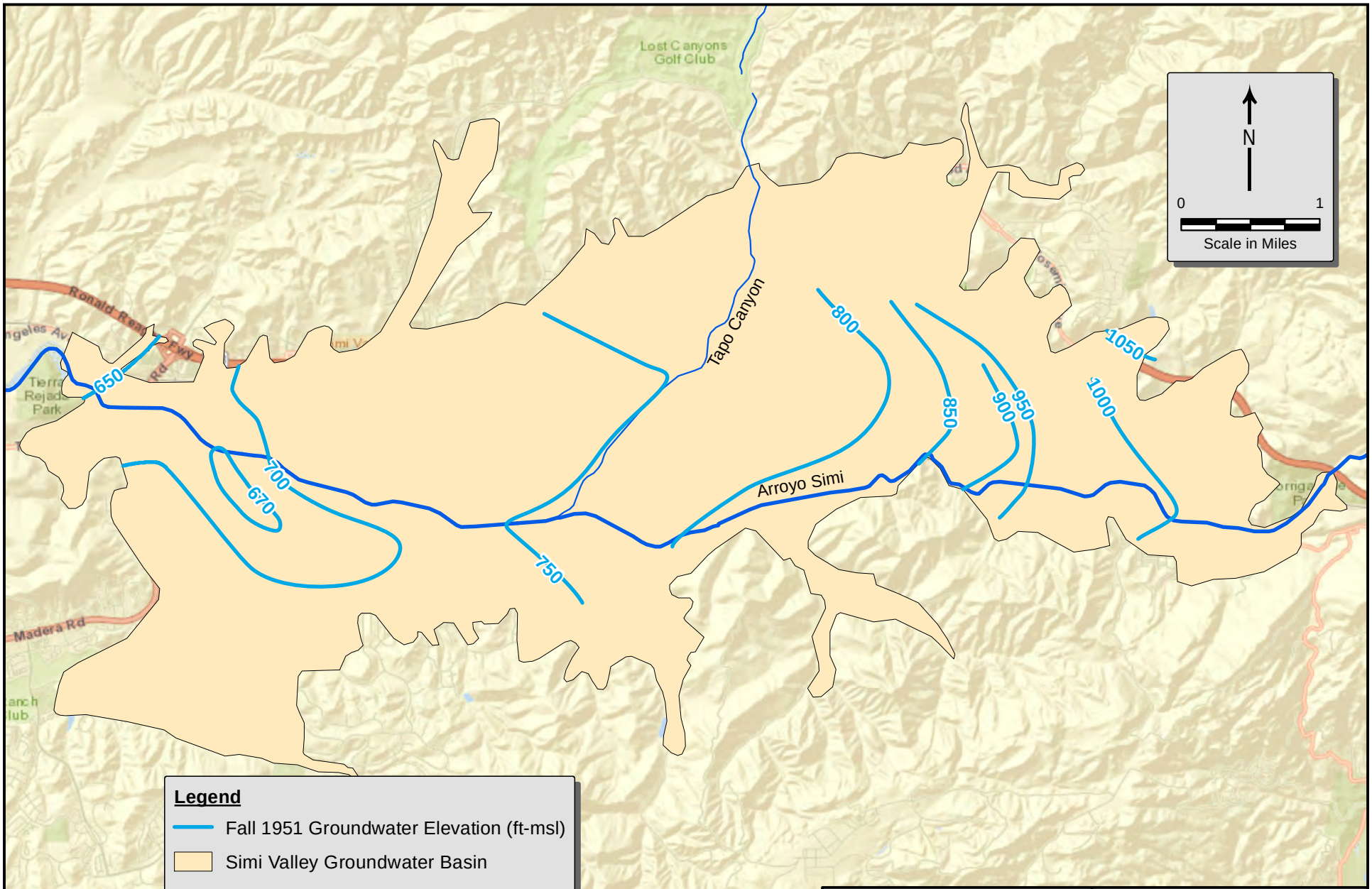


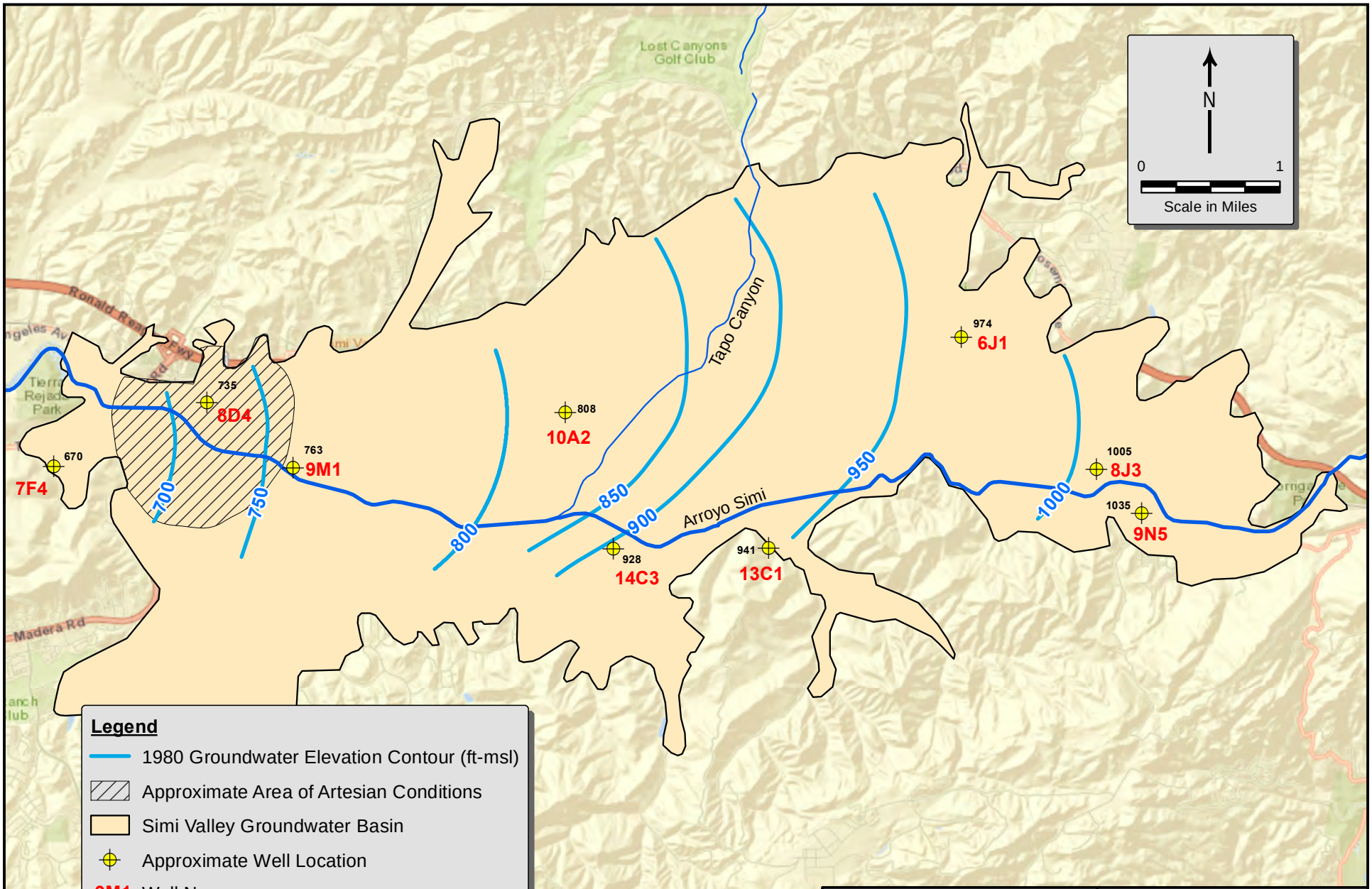
Figure 14
Aquifer Transmissivity and Well Yield



Note: Modified from SWRCB, 1956

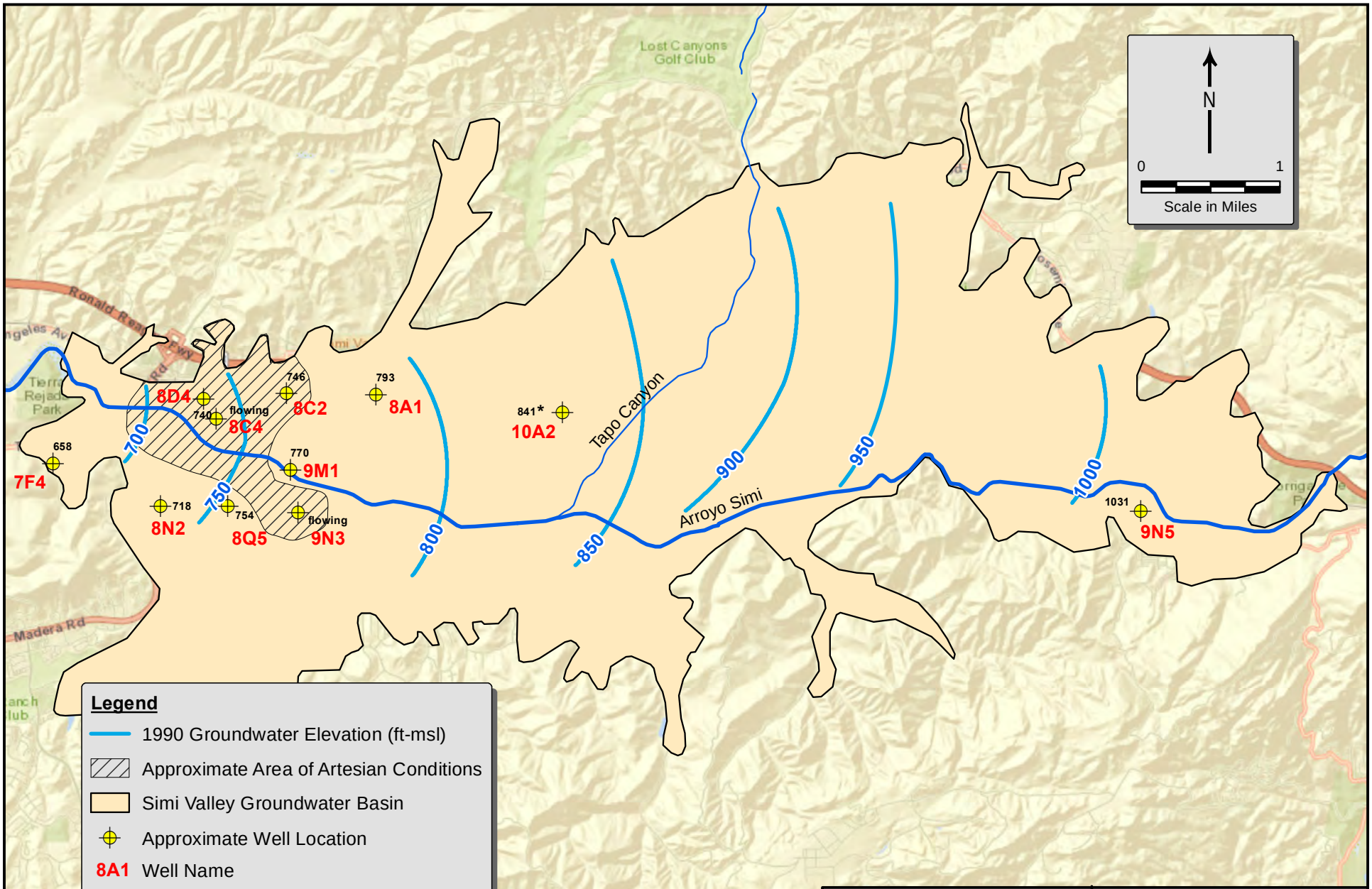
TODD GROUNDWATER

Figure 15
Groundwater Elevation Contours - Fall 1951



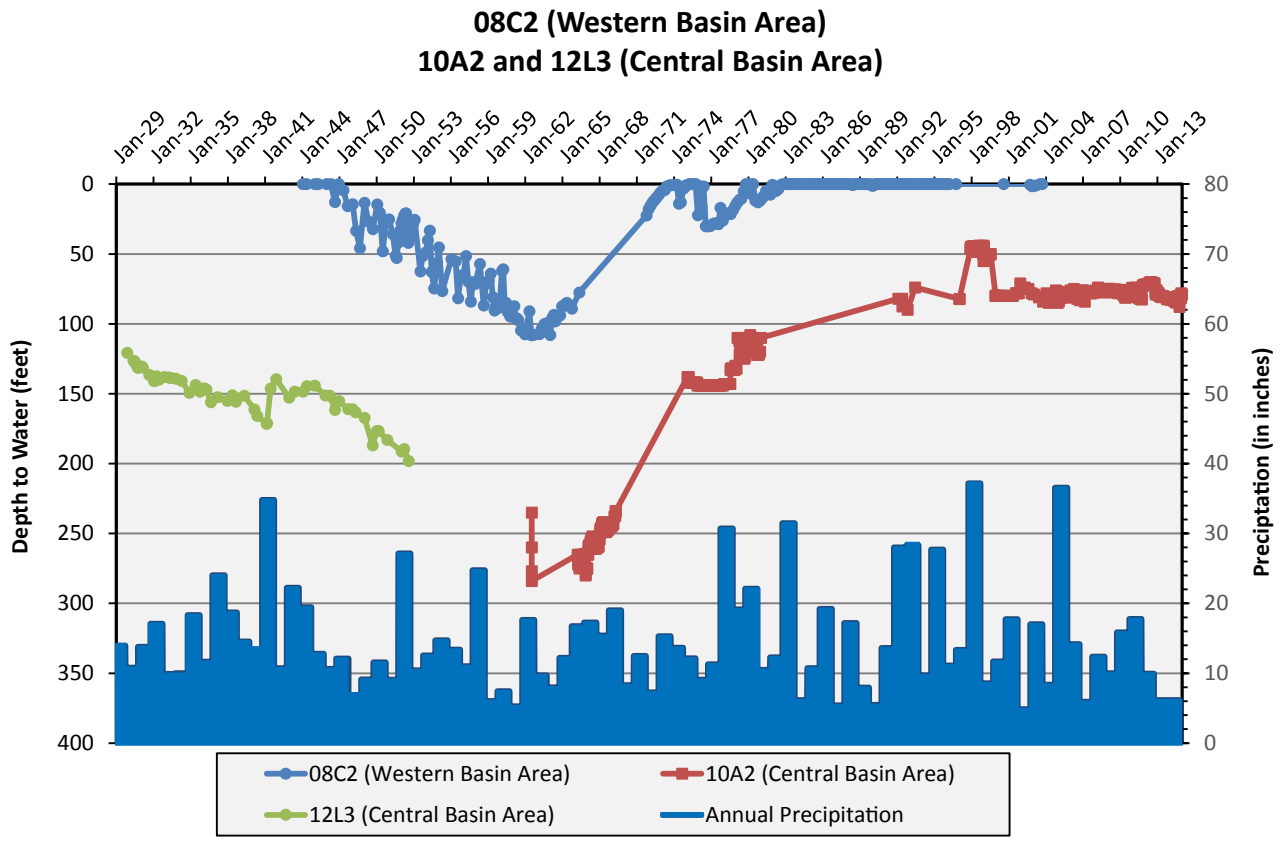
TODD GROUNDWATER

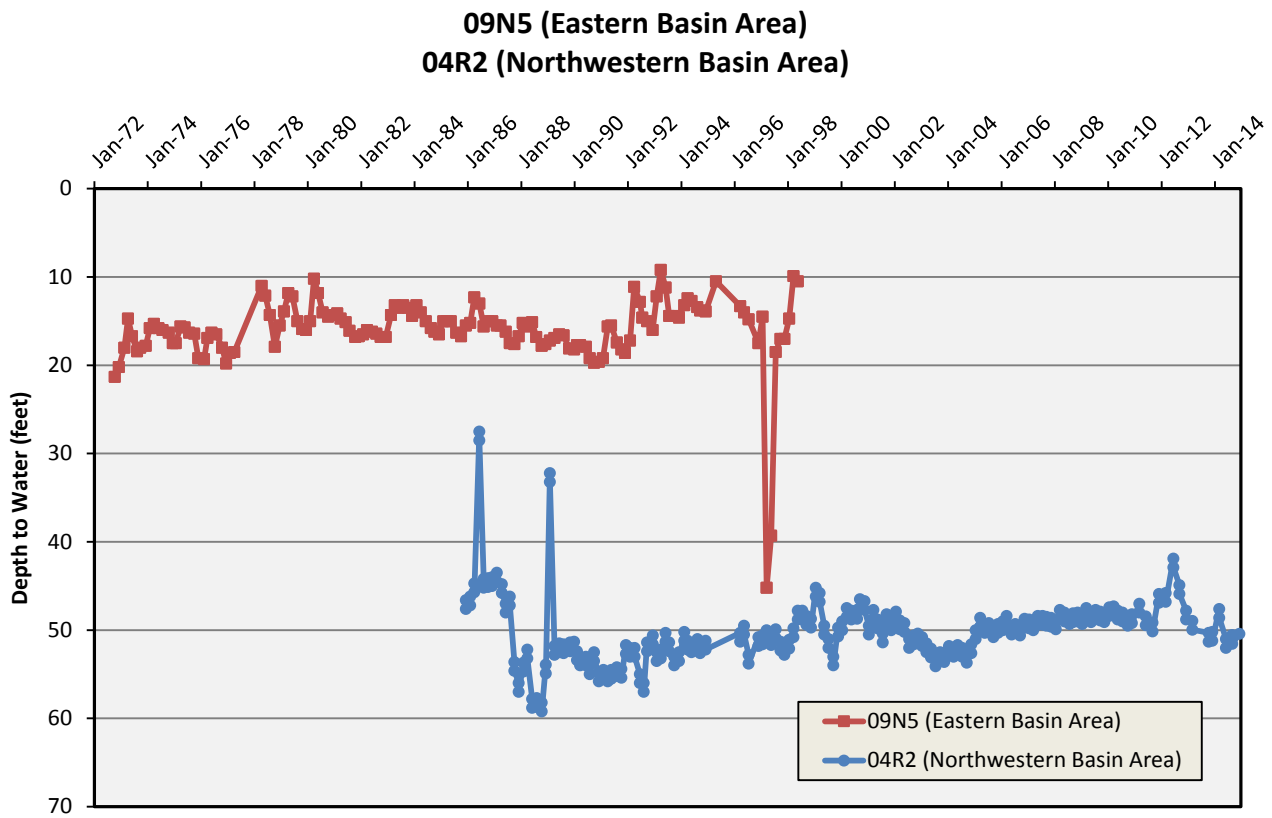
Figure 16
Groundwater Elevation Contours – 1980



TODD GROUNDWATER

Figure 17
Groundwater Elevation Contours – 1990

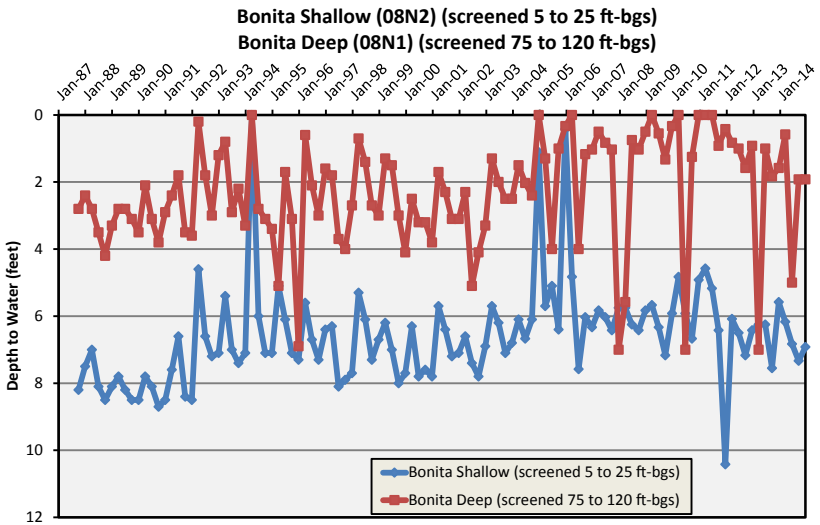


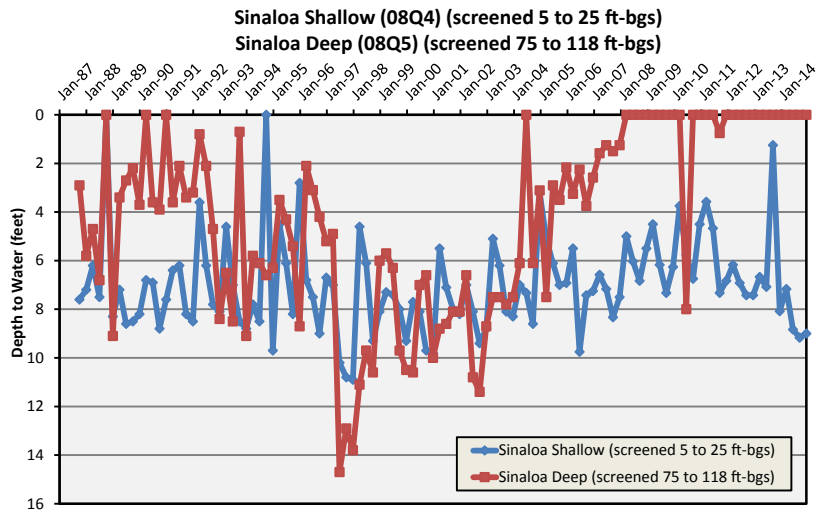


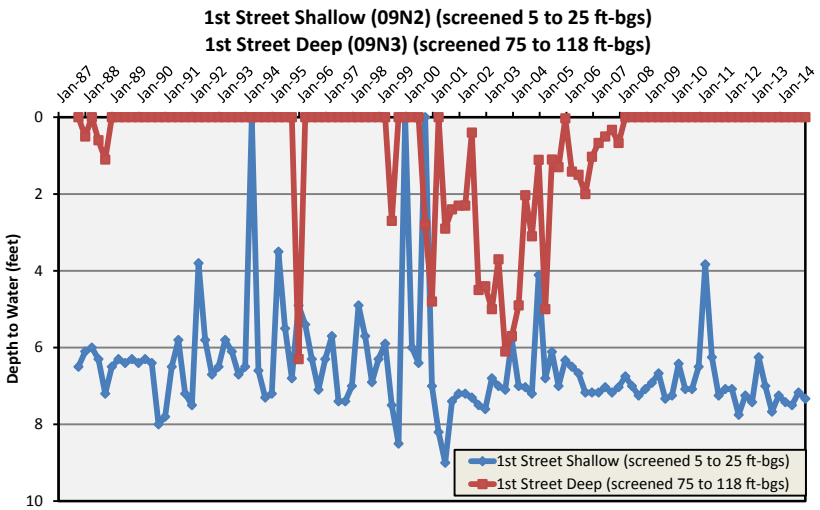
Note: Depths to groundwater plotted at zero are typically above the ground surface

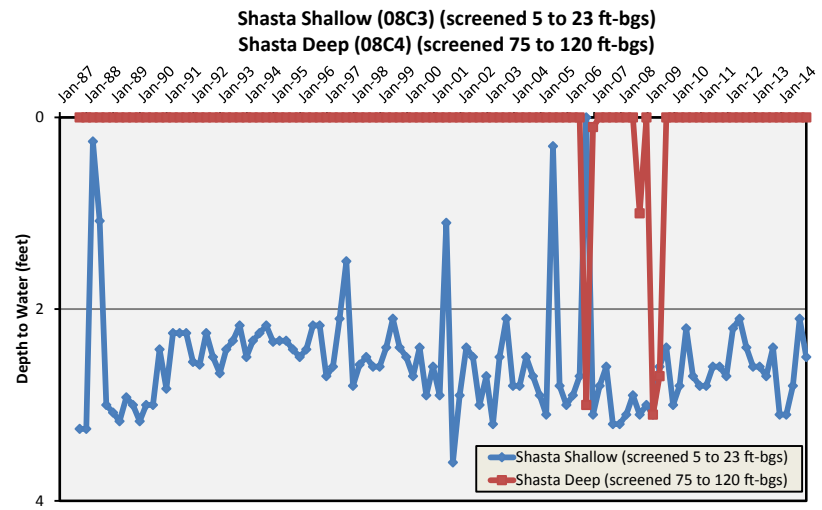
TODD GROUNDWATER

Figure 18
Depth to Groundwater in Selected Wells





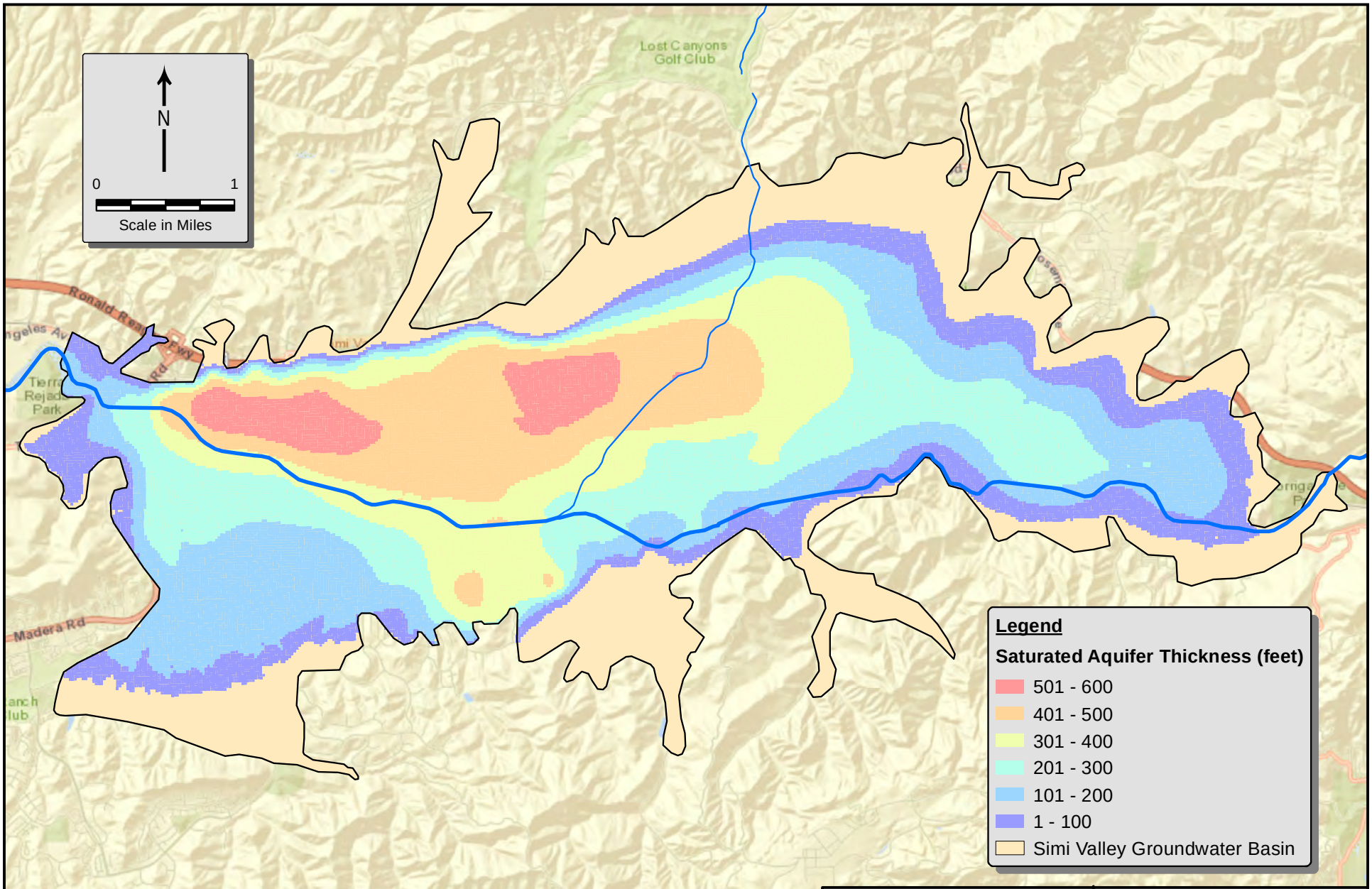




Note: Depths to groundwater plotted at zero are typically above the ground surface

TODD GROUNDWATER

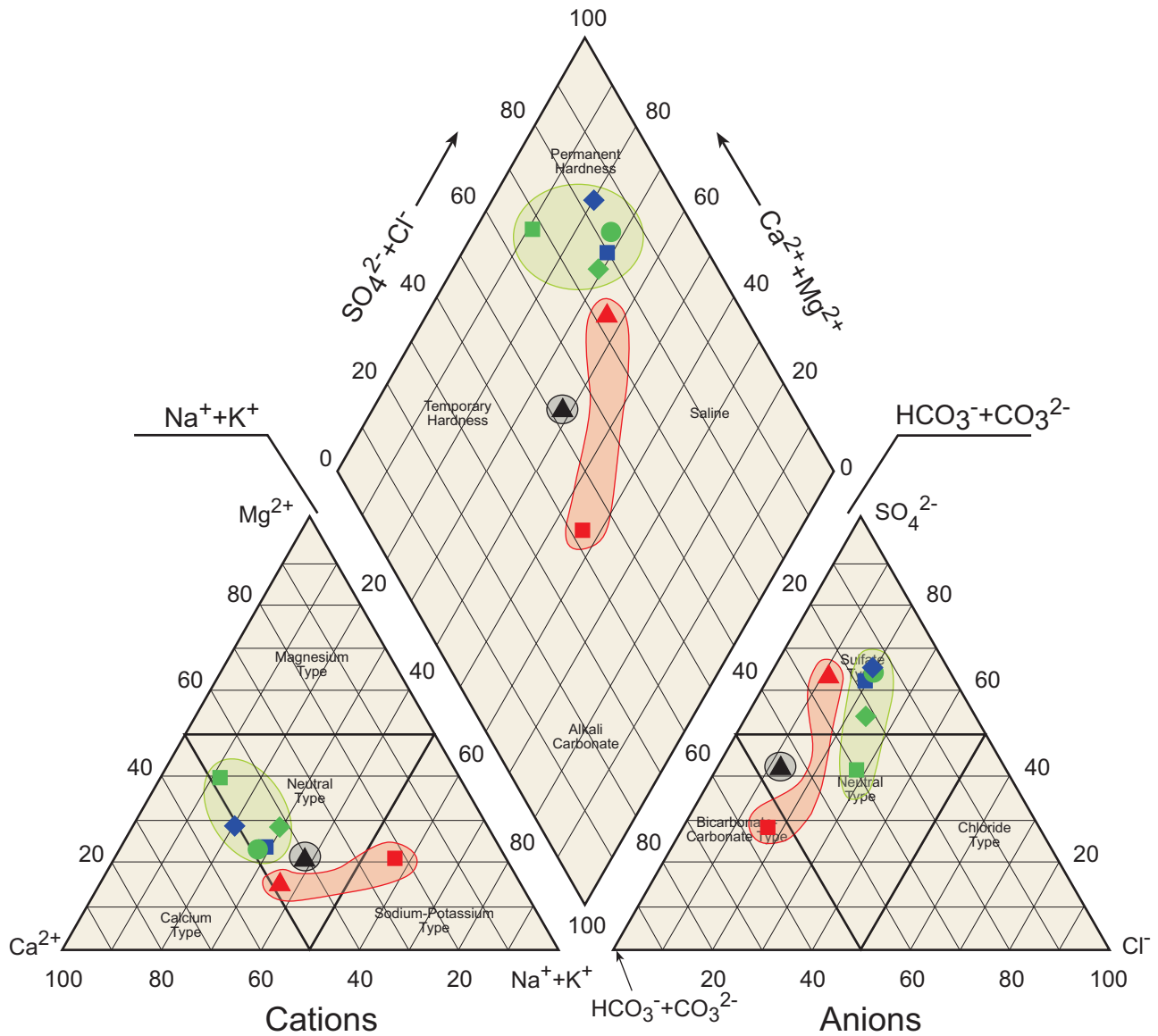
Figure 19
Dewatering Observation Well Depth to Groundwater



Note: Unhighlighted areas along basin margins represent areas of limited saturated alluvial sediments.

TODD GROUNDWATER

Figure 20
Saturated Aquifer Thickness



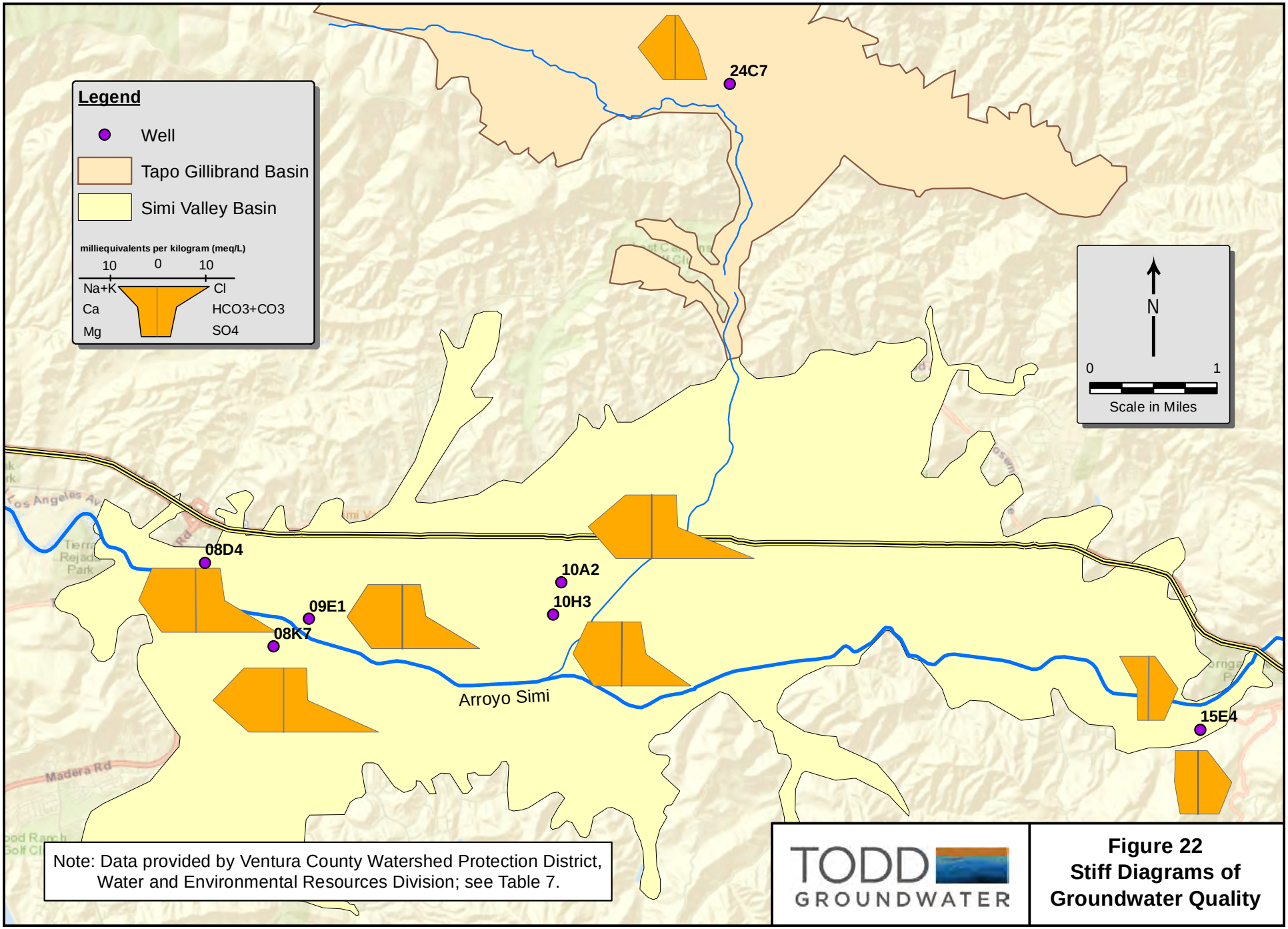
Legend

- 16A10 - Eastern Simi Valley Basin
- 15E4 - Eastern Simi Valley Basin
- 10A2 - Central Simi Valley Basin
- 10H3 - Central Simi Valley Basin
- 09E1 - Western Simi Valley Basin
- 08K7 - Western Simi Valley Basin
- 08D4 - Western Simi Valley Basin
- 24C7 - Gillibrand Basin

Note: Data provided by Ventura County Watershed Protection District, Water and Environemtal Resources Division; See Table 7.

TODD GROUNDWATER

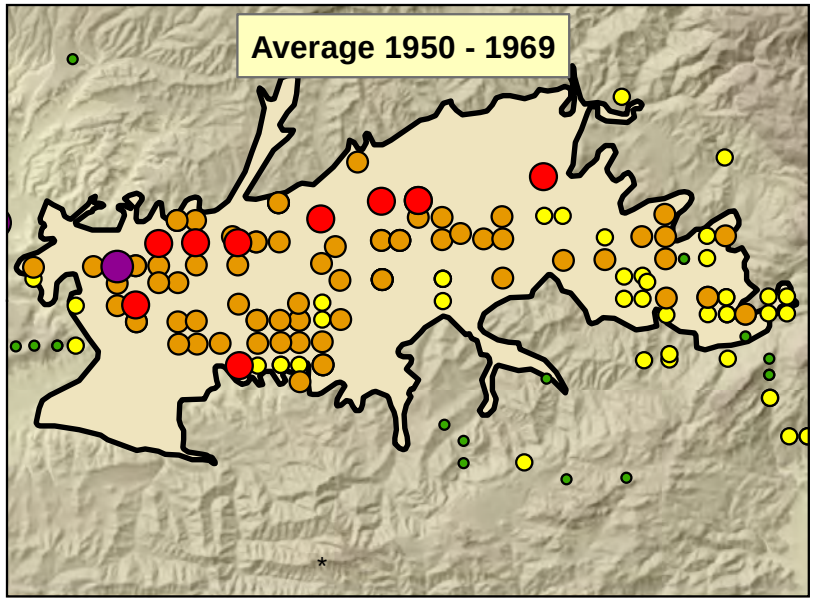
Figure 21
Trilinear Diagram of Groundwater Quality

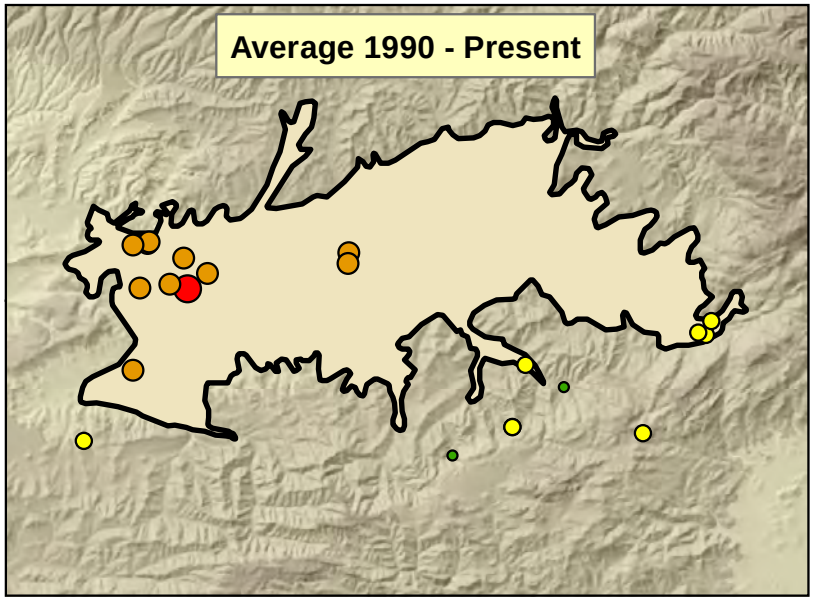


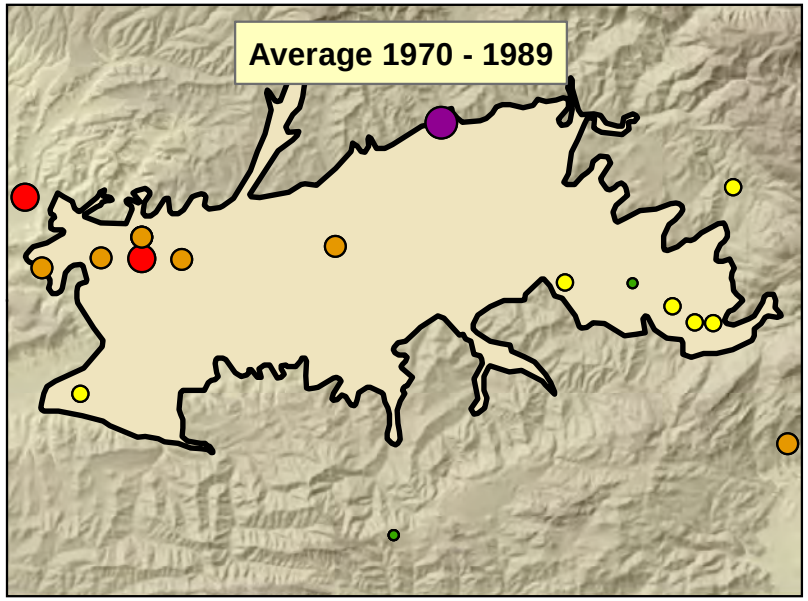
Note: Data provided by Ventura County Watershed Protection District, Water and Environmental Resources Division; see Table 7.

TODD GROUNDWATER

Figure 22
Stiff Diagrams of Groundwater Quality







Legend

Average TDS (mg/L)

- >3000
- 2000-3000
- 1000-2000
- 500-1000
- <500
- Simi Valley Groundwater Basin

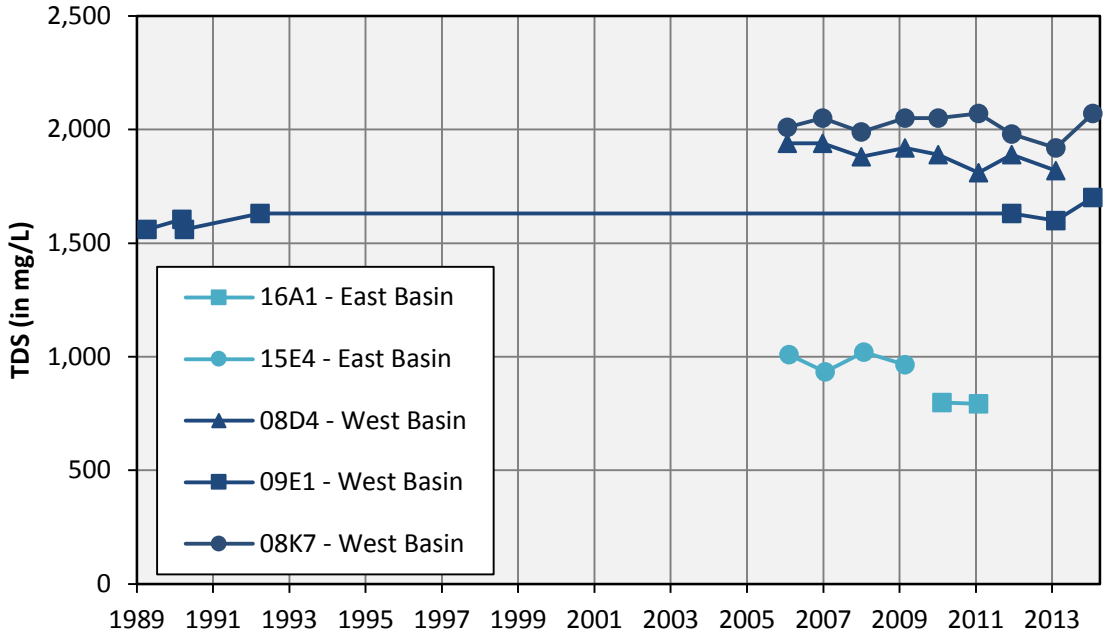
N

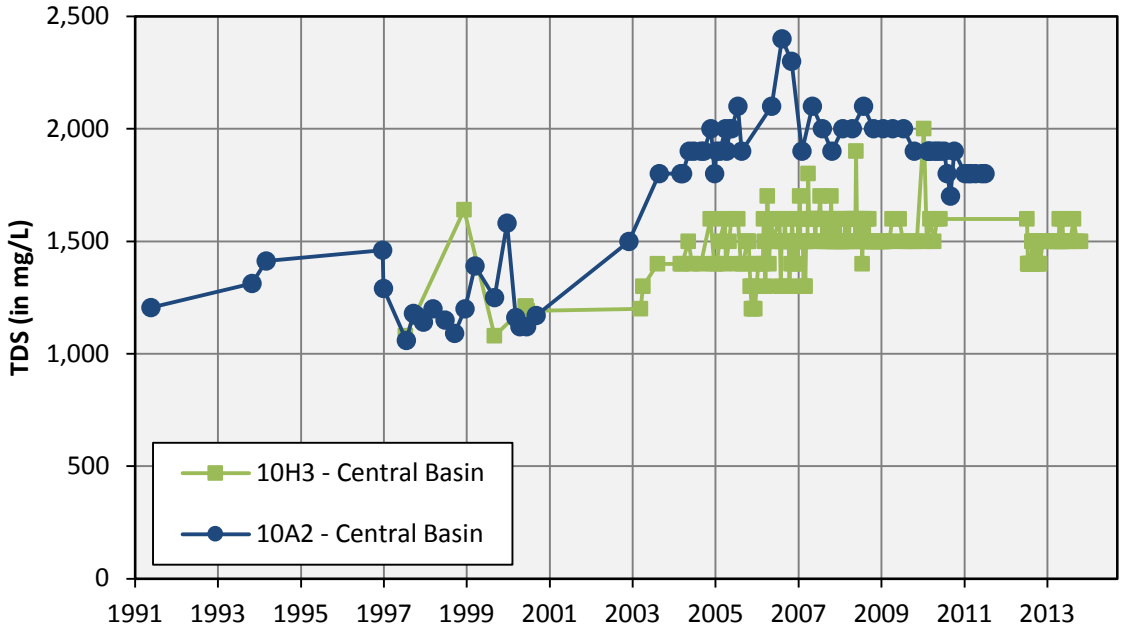
0 2

Scale in Miles

TODD GROUNDWATER

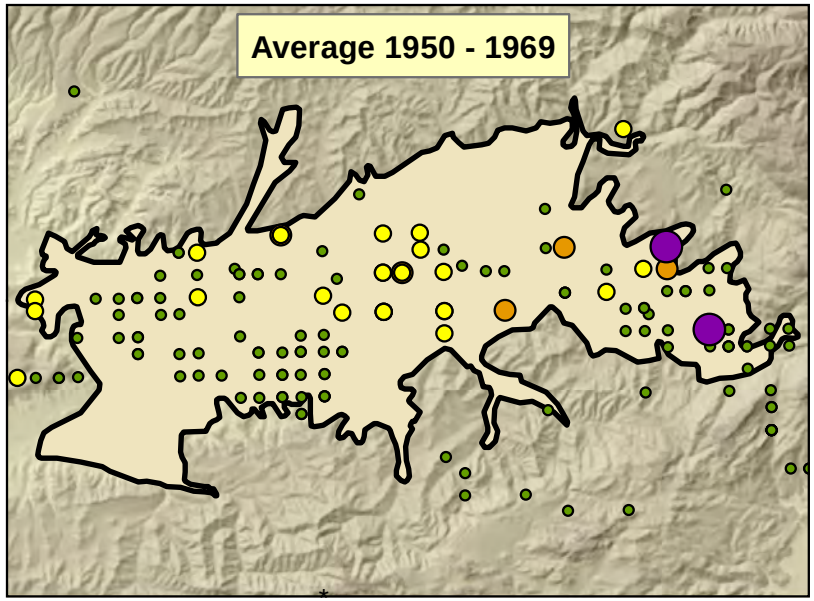
Figure 23
TDS
in Groundwater

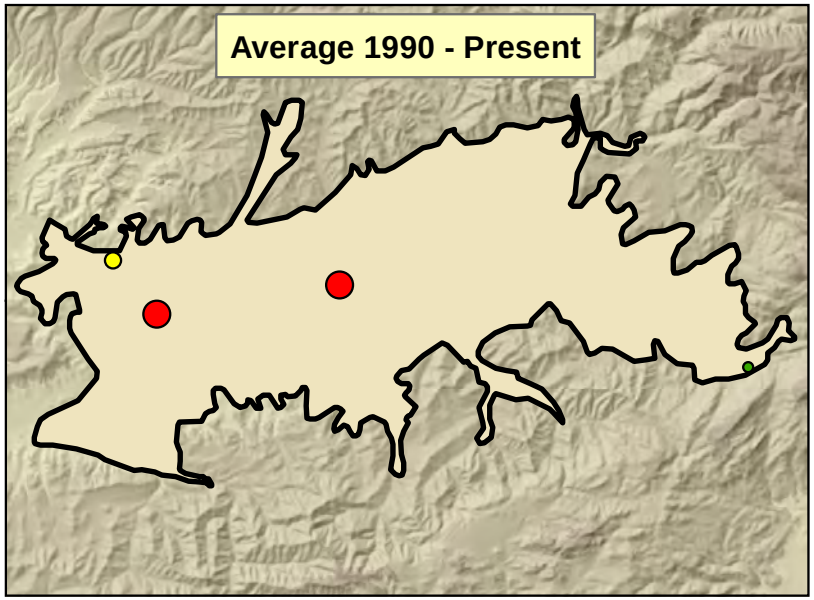


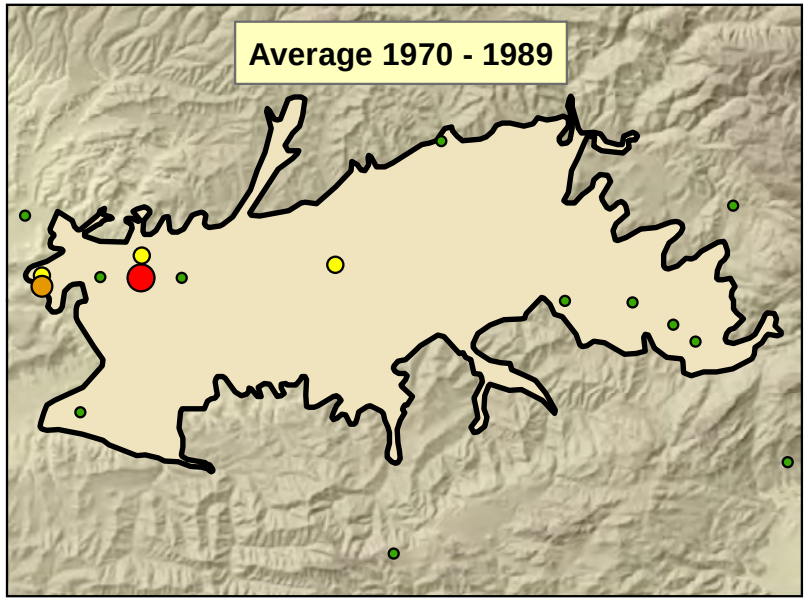


TODD GROUNDWATER

Figure 24
TDS
Time-Concentration Graphs







Legend

Average Nitrate (mg/L)

- >60
- 45-60
- 30-45
- 15-30
- <15
- Simi Valley Groundwater Basin

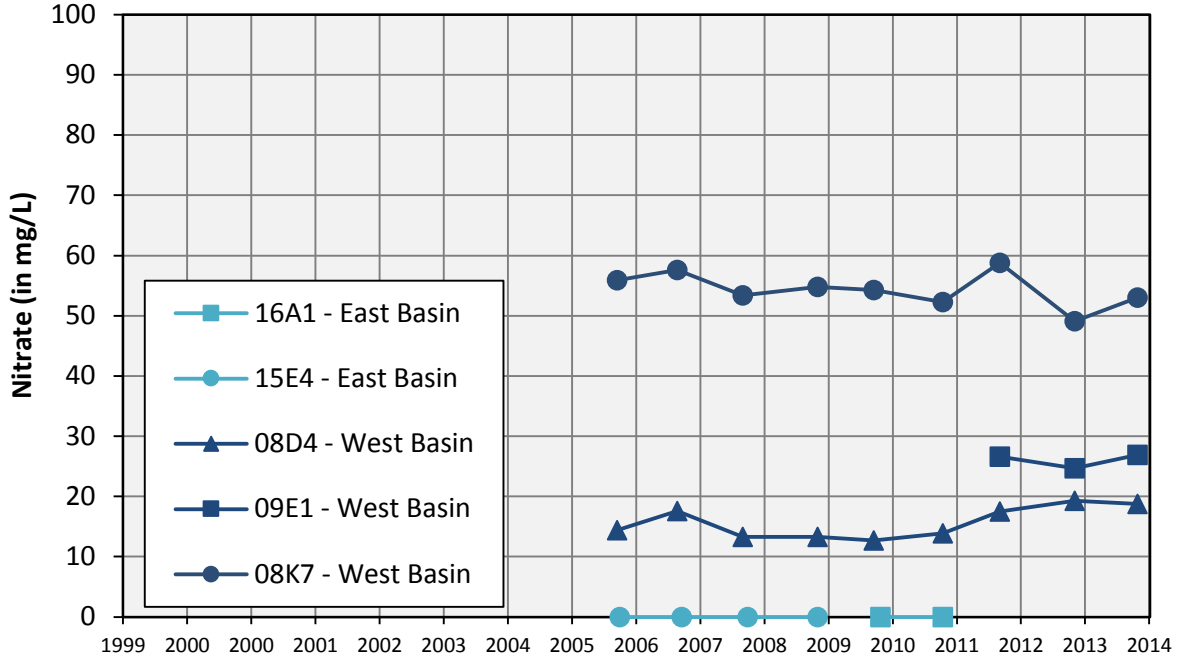
N

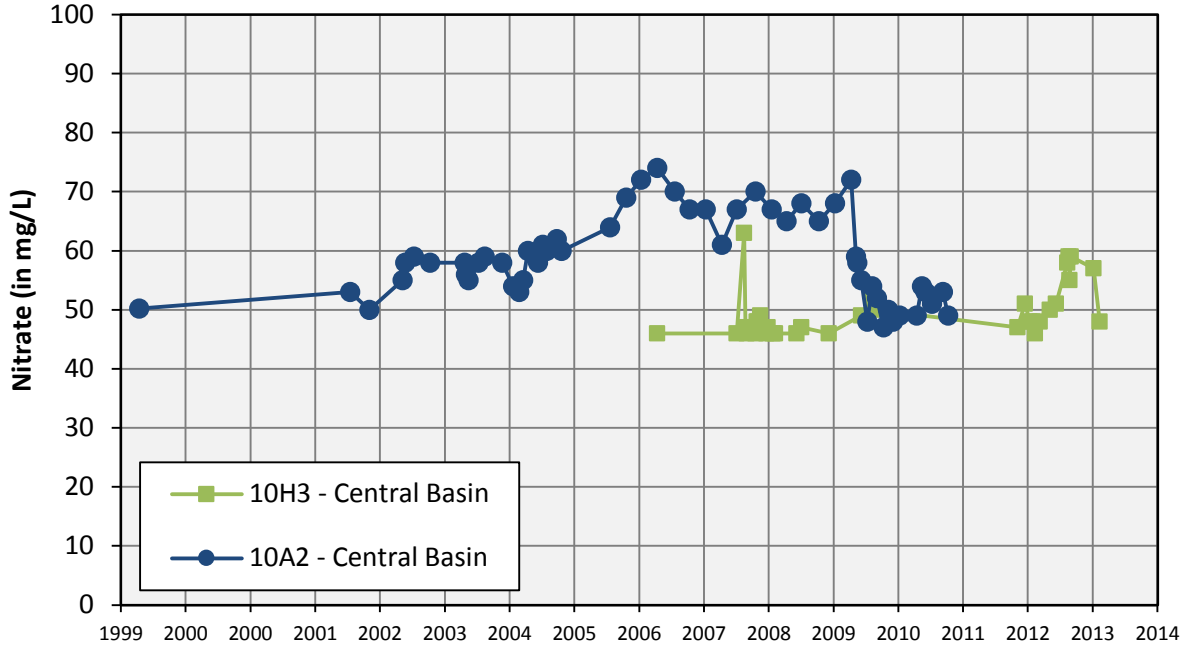
0 2

Scale in Miles

TODD GROUNDWATER

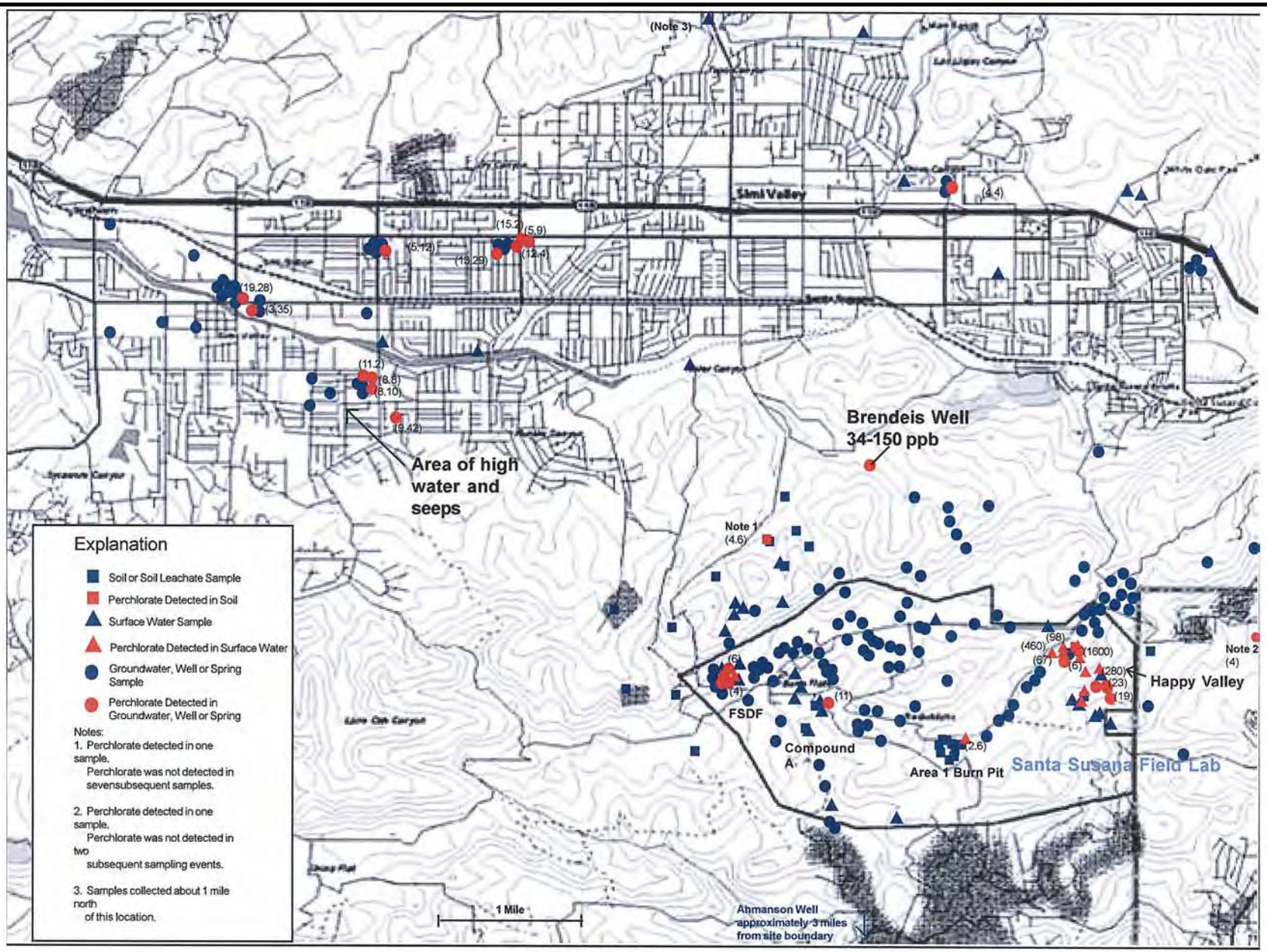
Figure 25
Nitrate
in Groundwater





TODD GROUNDWATER

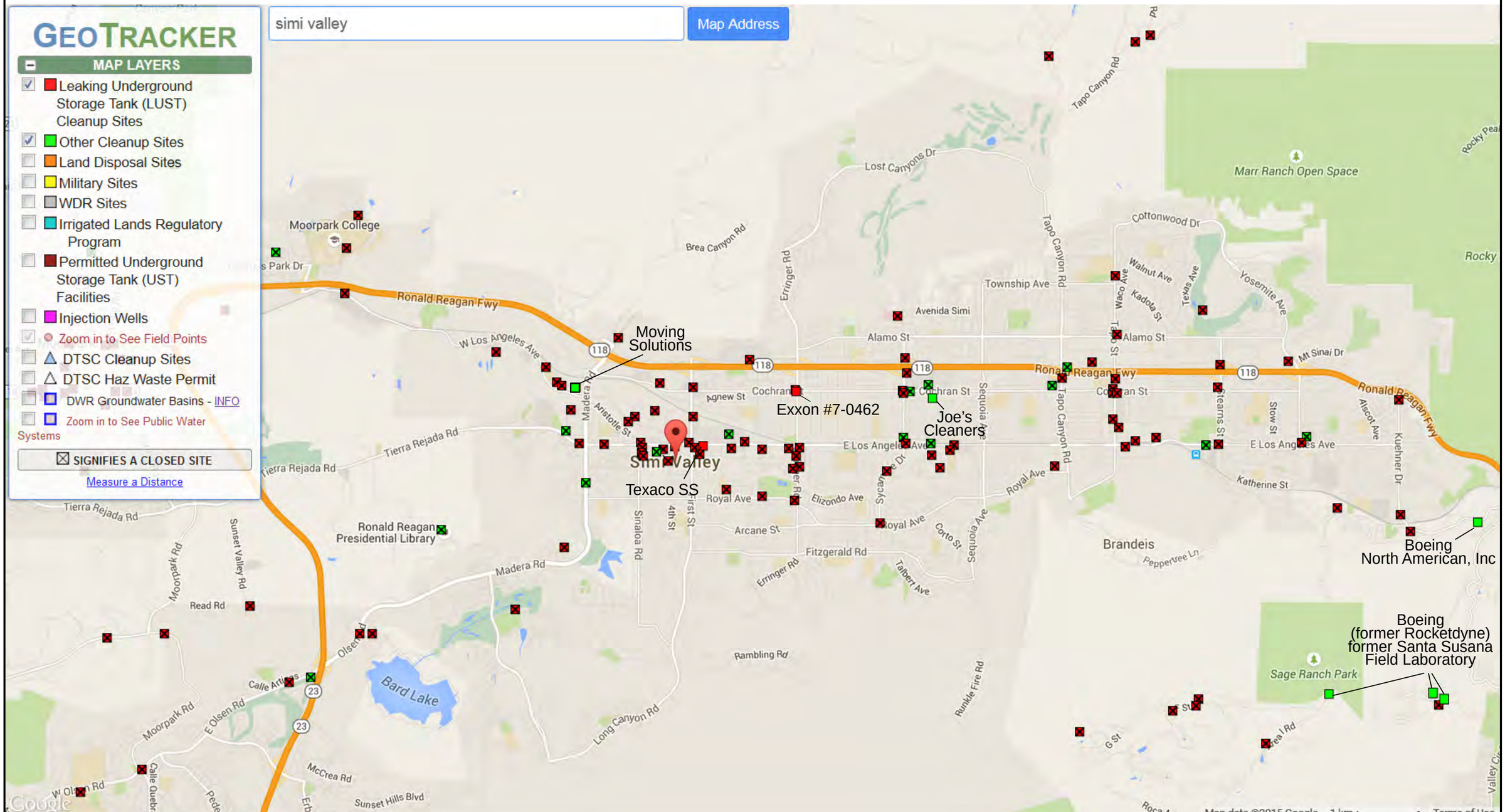
Figure 26
Nitrate
Time-Concentration Graphs



From: DTSC, 2003

TODD GROUNDWATER

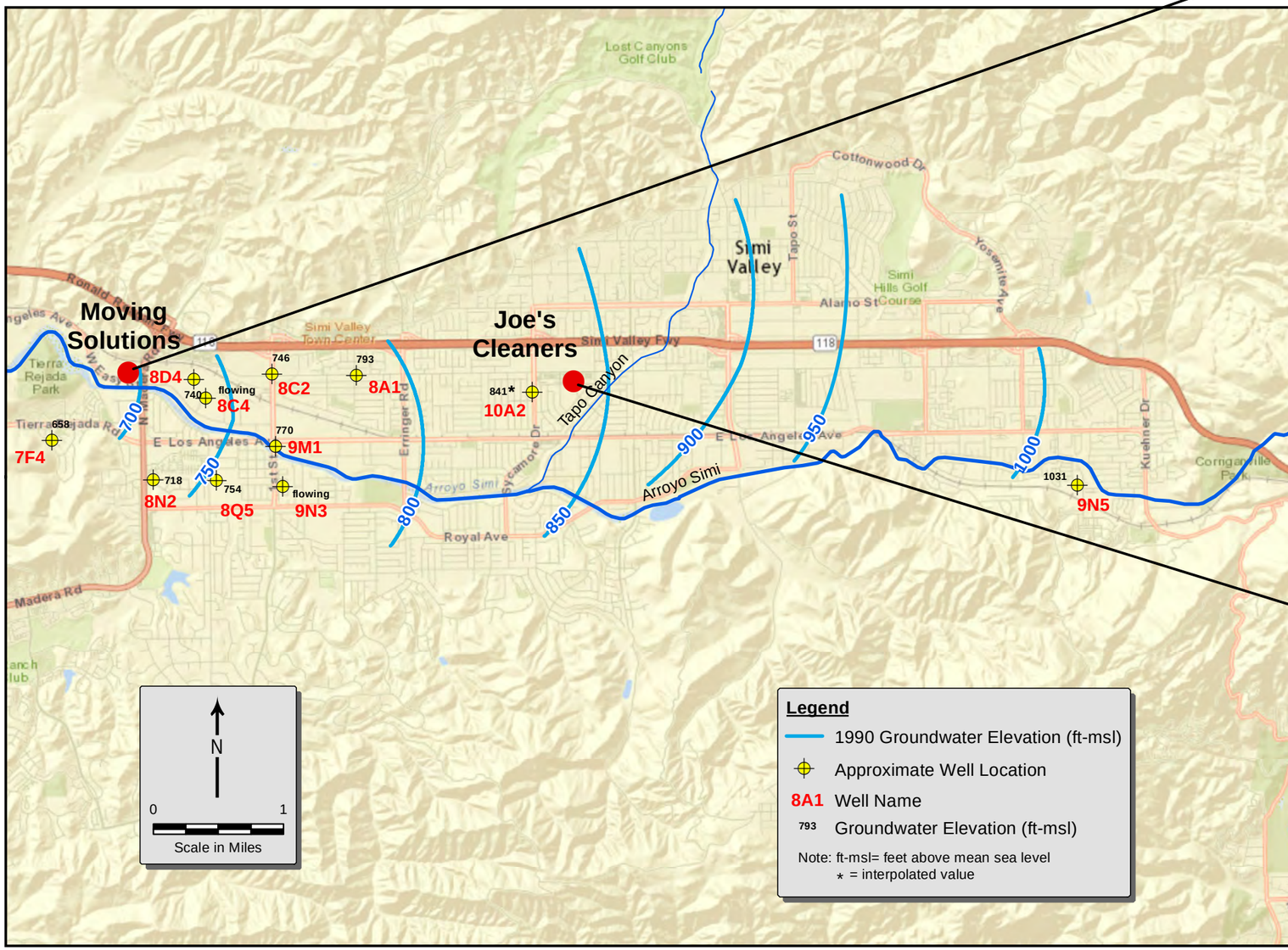
Figure 27
Perchlorate Sampling in and near Simi Valley

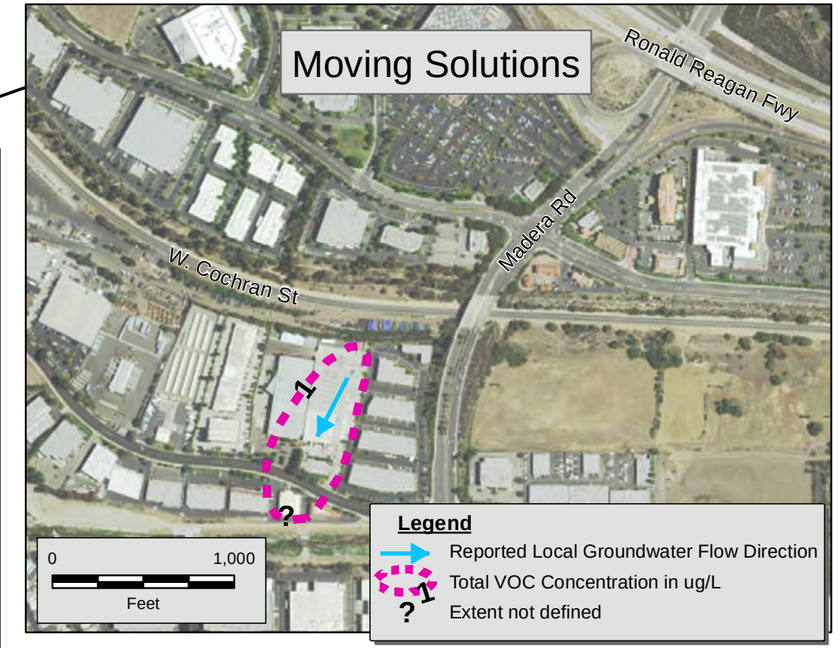


Site Accessed September 2015

TODD GROUNDWATER

Figure 28
GeoTracker Sites

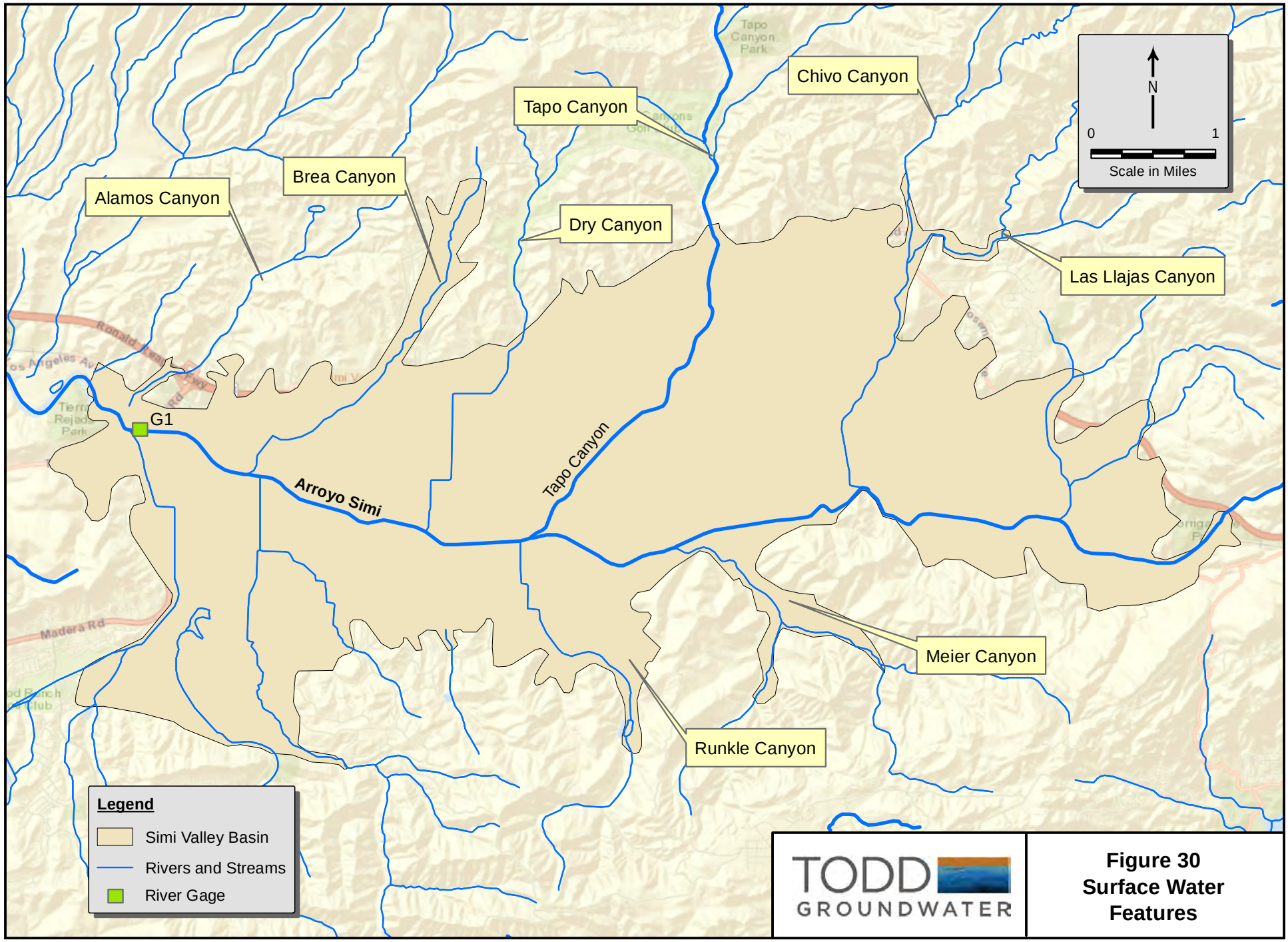




Site Accessed September 2015

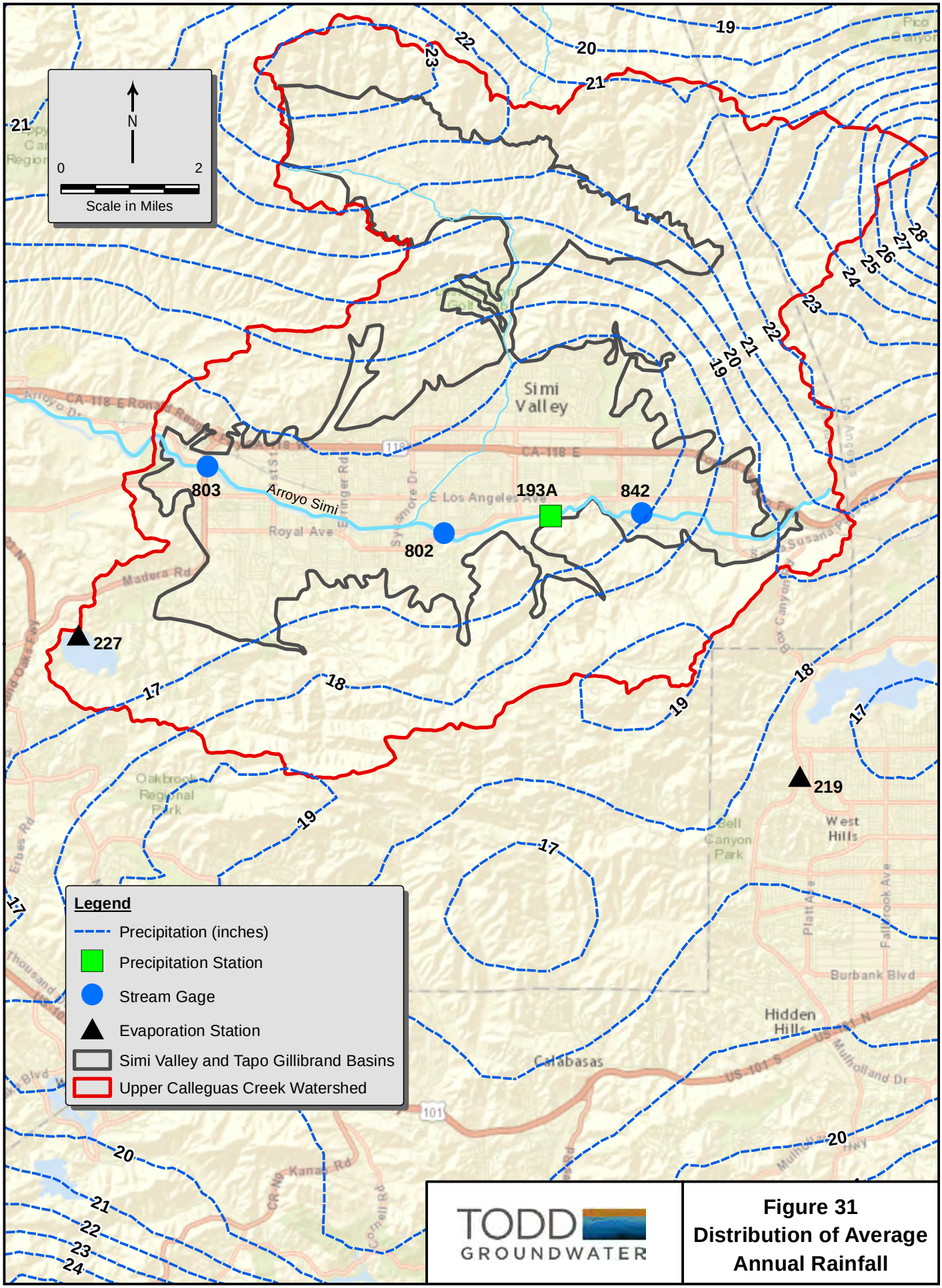
TODD GROUNDWATER

Figure 29
Extent of Groundwater Contamination at SLIC Sites



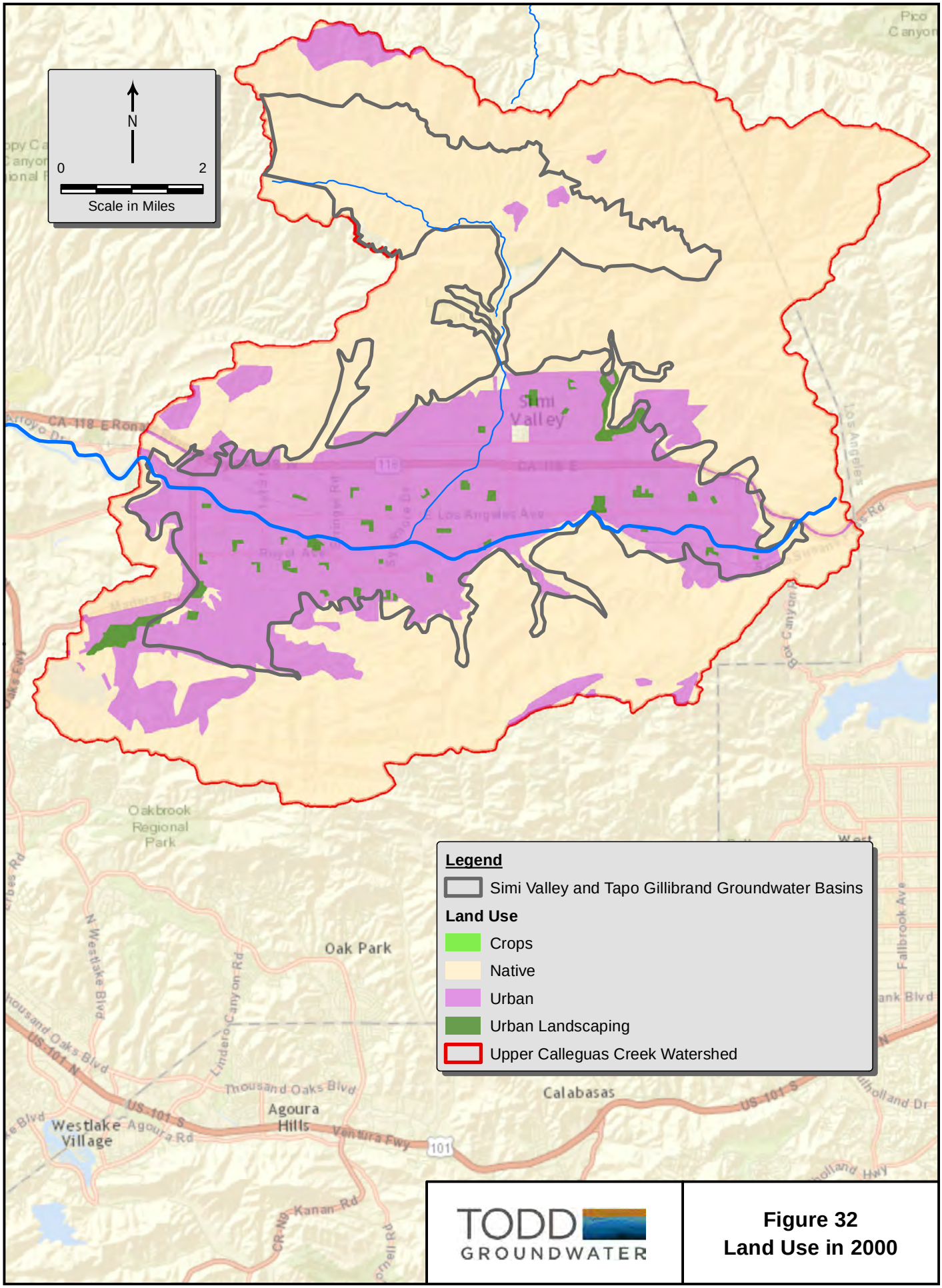
TODD GROUNDWATER

Figure 30
Surface Water Features



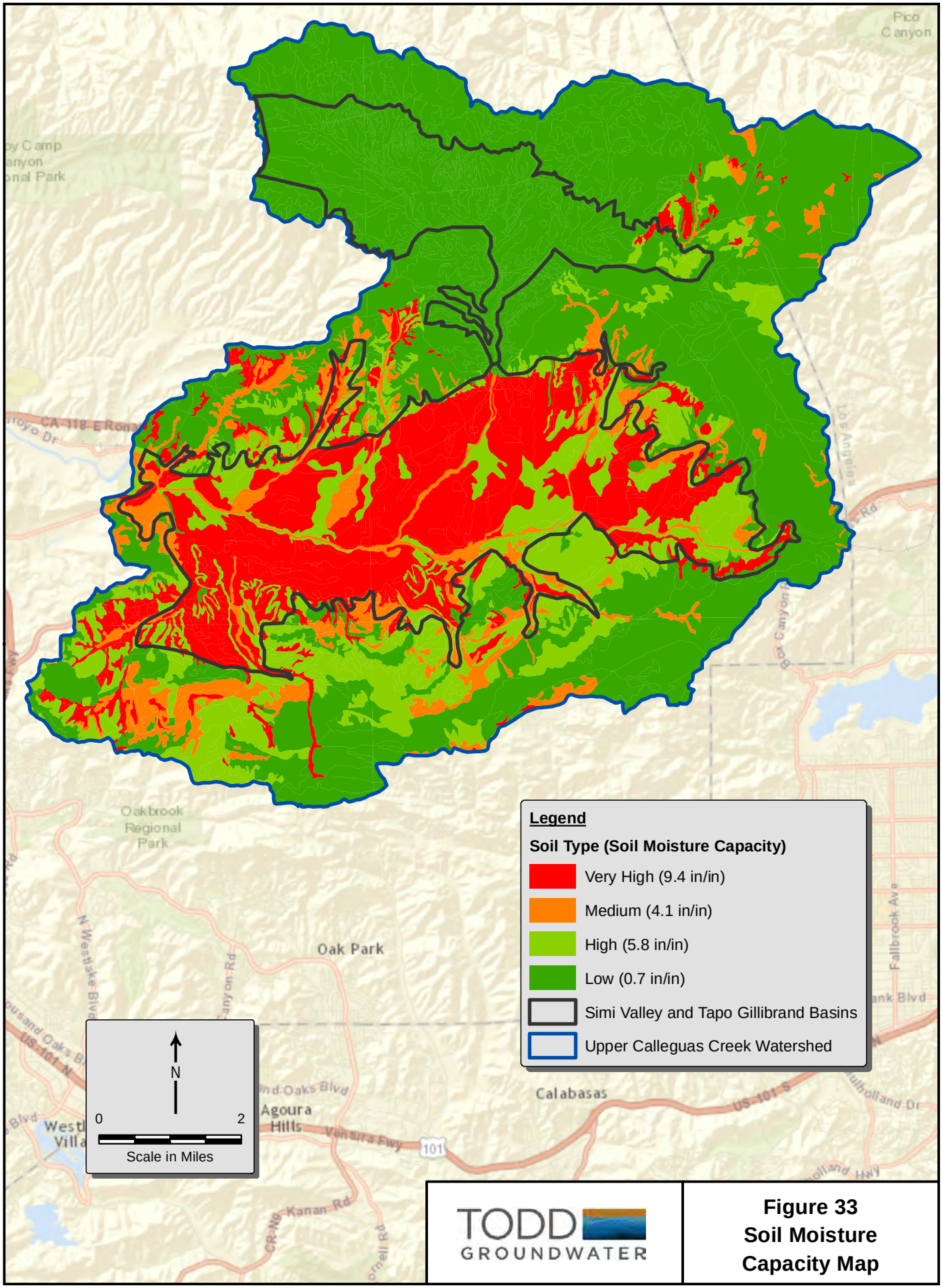
TODD GROUNDWATER

Figure 31
Distribution of Average Annual Rainfall



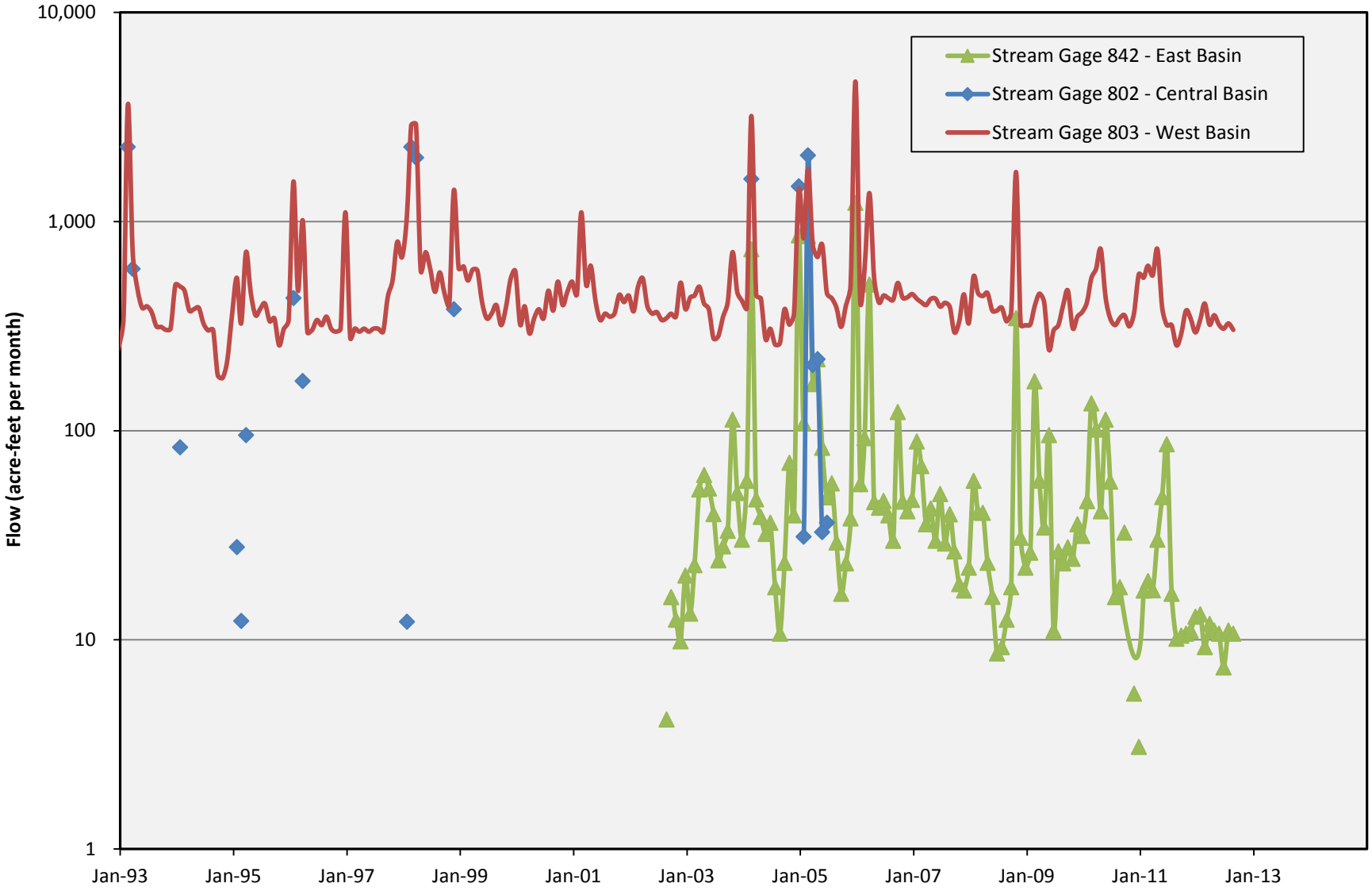
TODD GROUNDWATER

Figure 32
Land Use in 2000



TODD GROUNDWATER

Figure 33
Soil Moisture Capacity Map



TODD GROUNDWATER

Figure 34
Streamflow at Selected Gage Stations

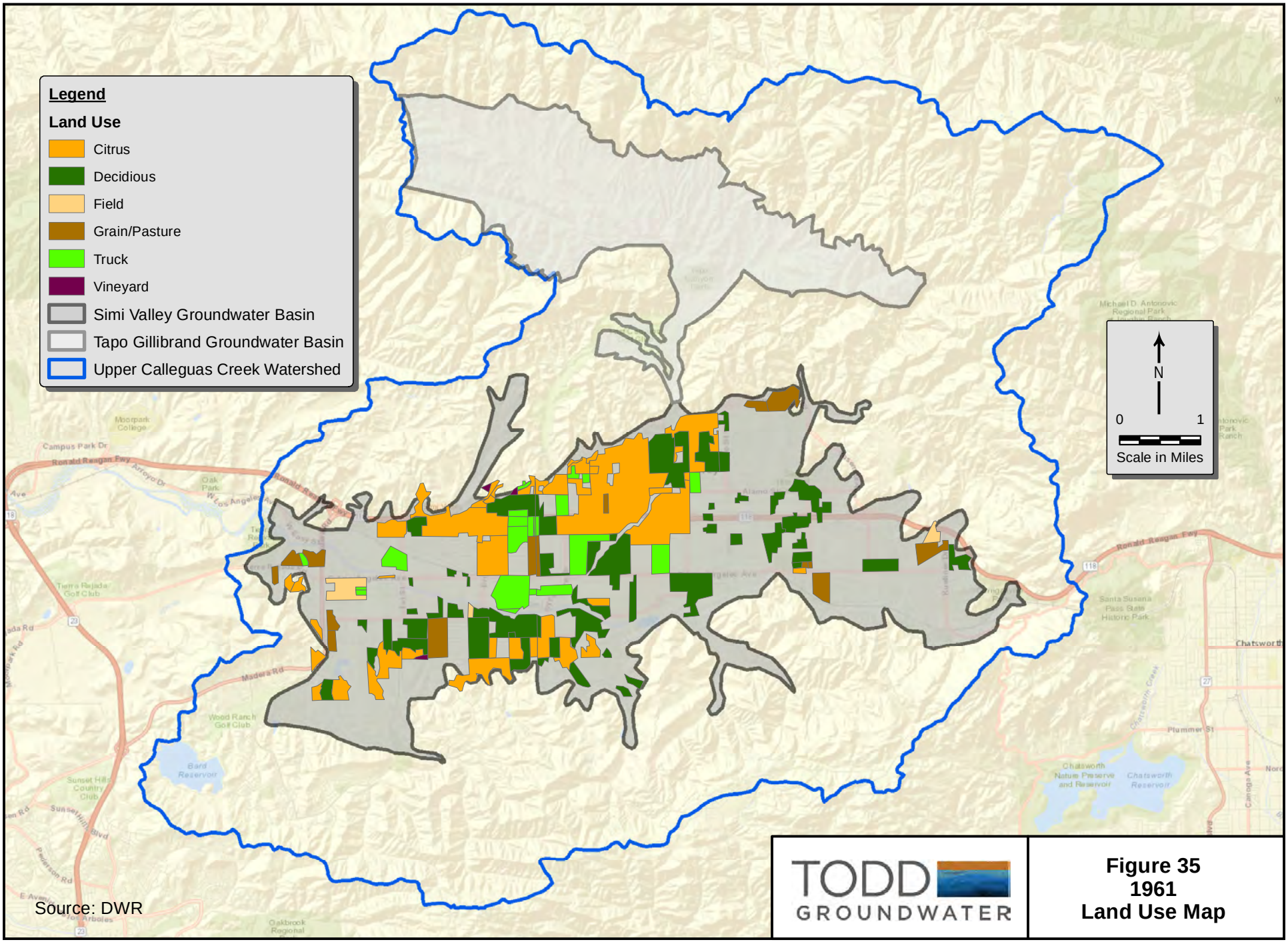


Figure 35
1961
Land Use Map

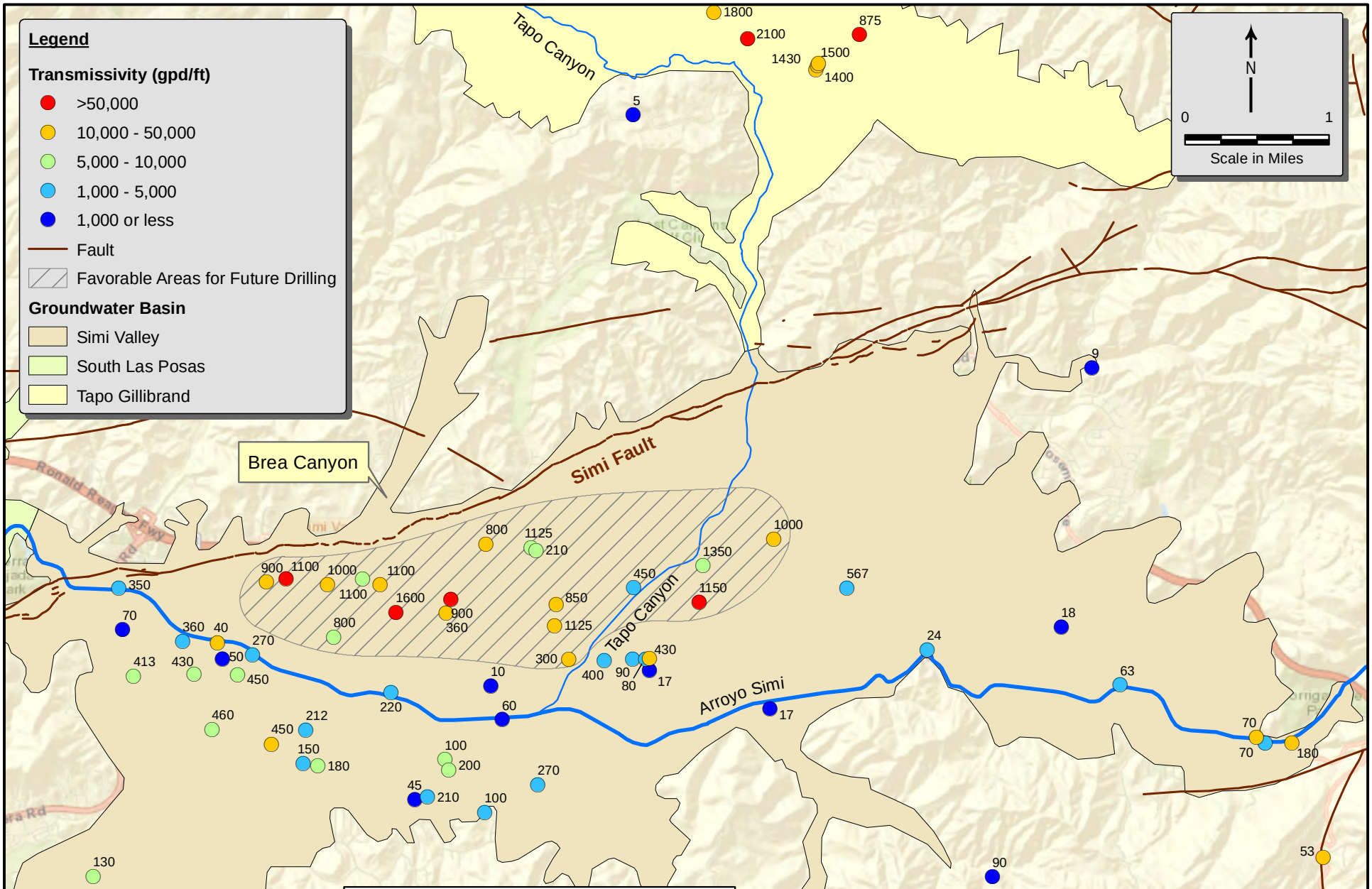
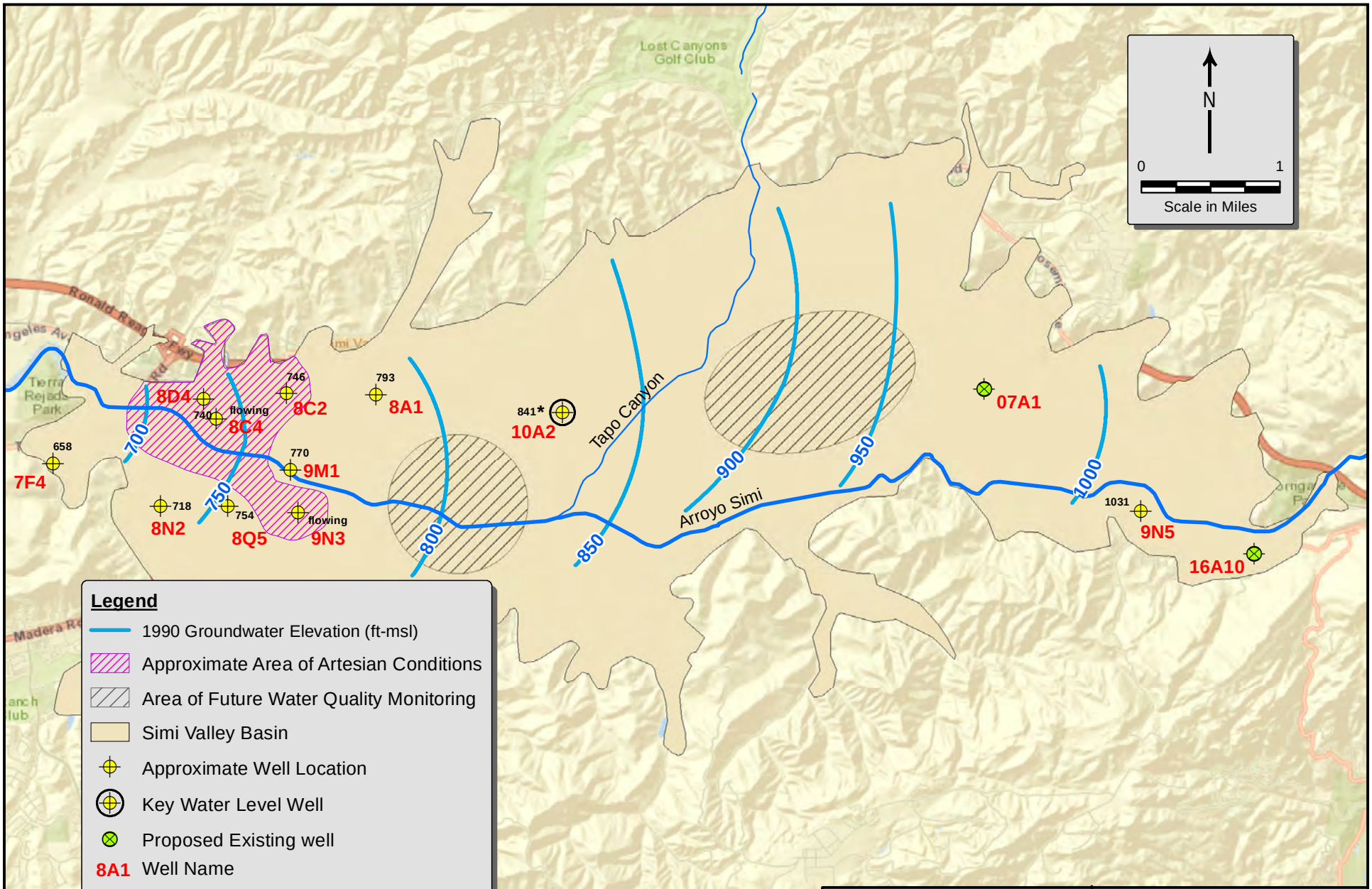
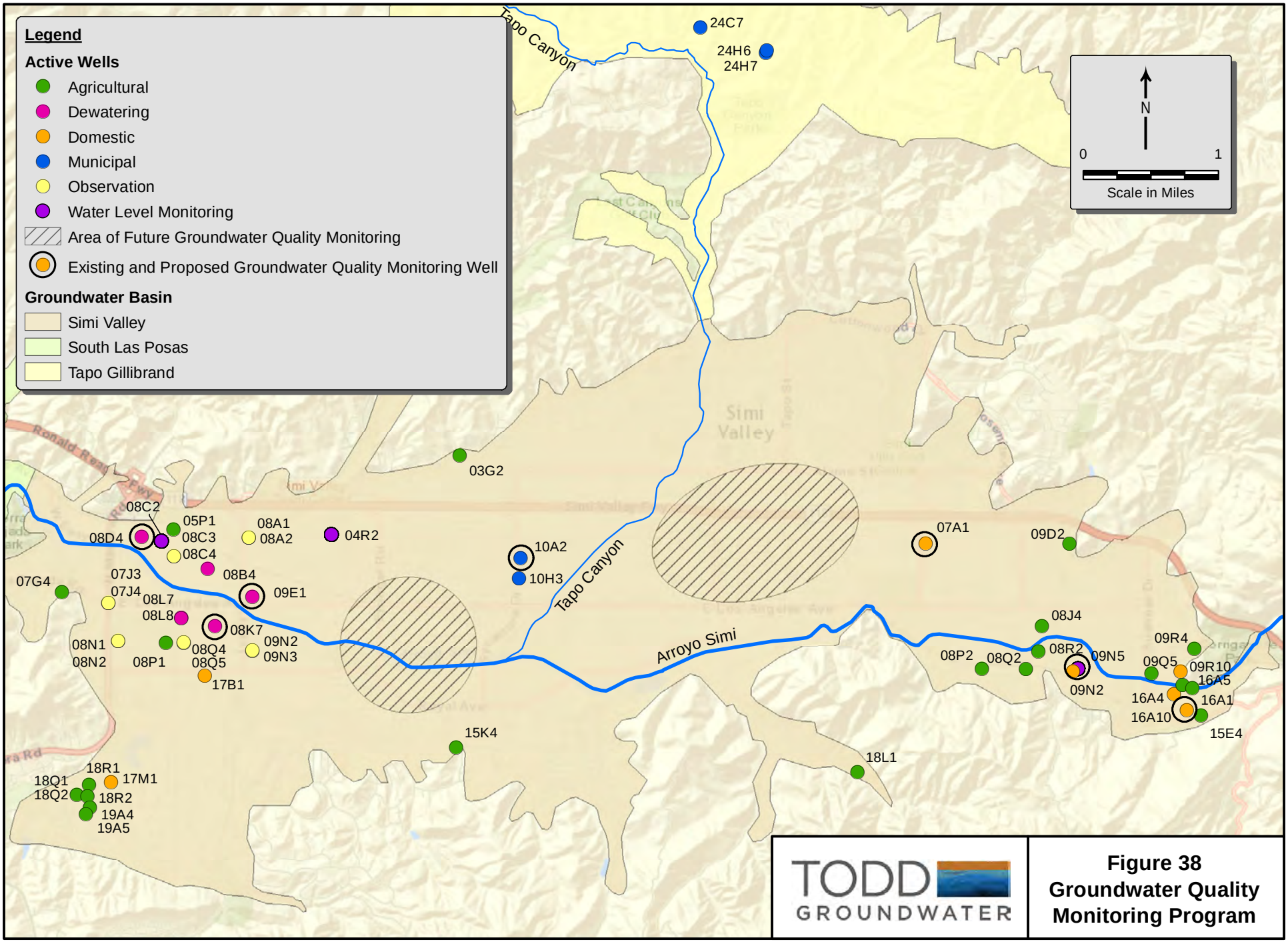


Figure 36
Favorable Areas for Future Drilling



TODD GROUNDWATER

Figure 37
Groundwater Level Monitoring Program

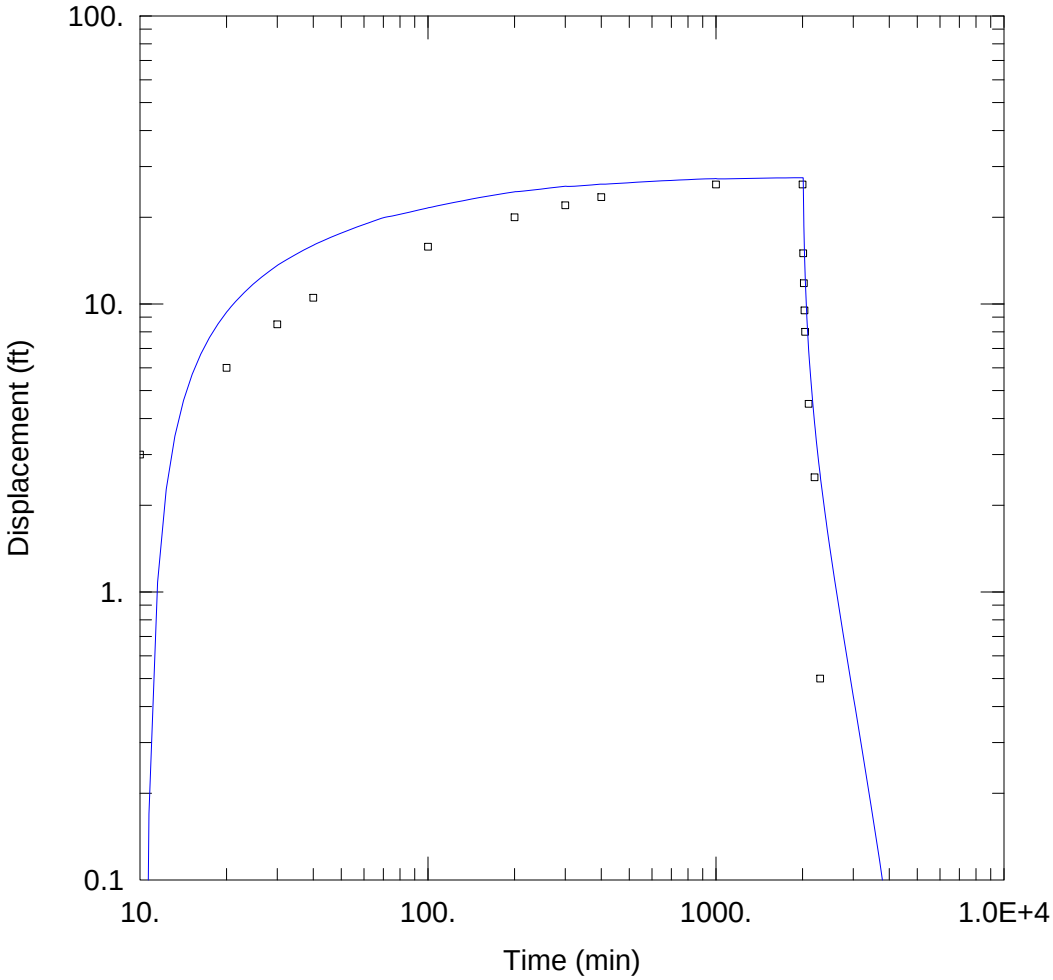


TODD GROUNDWATER

Figure 38
Groundwater Quality Monitoring Program

Appendix A

Aquifer Test Analysis



WELL TEST ANALYSIS

Data Set: T:\...\Sinaloa Pump Test OW-1.aqt
Date: 08/27/15 Time: 17:51:31

PROJECT INFORMATION

Company: Todd Groundwater
Client: Simi Valley
Project: 73901
Location: Simi Valley
Test Well: Sinaloa
Test Date: May 1985

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Sinaloa	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ OW-1	19.5	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 2305.7 ft^2/day
r/B = 0.1
b = 400. ft

S = 0.03281
Kz/Kr = 0.4

Appendix B

Groundwater Sampling Protocol

Laboratory Analysis

All groundwater samples should be analyzed at a California state-certified laboratory with reporting limits below WQOs.

Preparation

Preparation for groundwater sampling should begin with notification production well owners of the sampling schedule. Secondly, the analytical laboratory should be contacted to prepare the sample bottles. The laboratories sample bottles should contain appropriate preservatives and have labels showing the well number. Groundwater samplers should fill in the sample date and time upon collection.

Active Groundwater Production Well Sampling

Assuming the production well is active, to collect a groundwater sample at a production well, the technician will open the sample port at the wellhead to a low flow setting (200 ml/minute) and fill the sample bottles supplied by the laboratories. For samples that require filtration (typically, metals), the technician will run the water through a 0.45-micron filter before decanting into the appropriate sample bottle.

Groundwater Monitoring Well and Idle Production Wells Sampling

Sampling at the groundwater monitoring wells and idle or standby production wells should collected using the purge and sample method. The technician should begin by sounding the depth to water in the well and recording the readings on a standard purge and sample form. The volume of water in the casing will then be calculated and recorded on the form. The well will then be purged using the dedicated submersible pump. During purging, water samples will be collected and measured for field parameters including electrical conductivity, pH, and temperature, and the readings recorded on the form. The well purging will be completed when minimum of three wetted-casing volumes have been removed and successive measurements of the field parameters are within 10 percent of each other.

After purging is complete, the pumping rate will be reduced to 200 ml/minute and groundwater samples will be collected in the appropriate containers supplied by the laboratory. For samples that require filtration, we will run the water through a 0.45-micron filter before decanting into the appropriate sample bottle.

Sample Handling and Control

When the groundwater samples are collected, the technician should complete the sample labels with date and time collected, and technician's initials. The sample containers should be stored in a cooler with ice and kept chilled to 4 ^{o}C until they are delivered to the laboratory.

The technician should prepare a chain of custody form that lists the samples collected with dates and times. The form will also indicate the destination laboratory, the requested analyses, and the analytical turnaround time. The form will be used to track the custody of the samples from the time they are collected until their arrival at the destination laboratory. Each time the samples change hands, the relinquishing party and the receiving party will sign and date the form.