OESTE HYDROLOGIC SUB-AREA
HYDROGEOLOGIC REPORT

July 2009

California State University, Fullerton
Department of Geological Sciences

OESTE HYDROLOGIC SUB-AREA HYDROGEOLOGIC REPORT

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1.0 Introduction

1.1 Location of Study Area

The Oeste Hydrologic Sub-area (also referred to as El Mirage Valley watershed) is located just north of the San Gabriel Mountains along the southern edge of the Mojave Desert, San Bernardino County, California (Figure 1: Location Map Showing Southern California and the Oeste Hydrologic Sub-area). The Oeste Hydrologic Sub-area is located approximately 25 miles (mi) [40 kilometers (km)] west of Victorville. The Oeste Hydrologic Sub-area can be accessed by Highway 18 (Palmdale Road), from Highway 395 via the city of Victorville or Highway 138 through the community of Phelan.

1.2 Adjudicated Basin Boundaries

California groundwater basins are identified based on geographical and hydrological conditions, and political boundary lines are also considered whenever practical [DWR, 1980]. The state of California is divided into 11 separate hydrologic regions [DWR, 2003]. Within these regions there are a total of 431 groundwater basins. Of the 431 groundwater basins, 24 of them are further divided into 108 sub-areas [DWR, 2003]. The El Mirage Valley groundwater basin (within the Oeste Hydrologic Sub-area) is one of 76 groundwater sub-areas of the South Lahontan Hydrologic region [DWR, 2003].

Under the “Mojave Basin Area Adjudication” [1996] the Mojave Water Agency (MWA) was designated as Watermaster for five distinct sub-areas (Figure 2: Mojave Water Agency Adjudicated Boundary). Within these sub-areas, the MWA management strategy focuses on water conservation, water supply enhancement, and water allocation. The Oeste Hydrologic Sub-area is part of the “1996 Mojave Basin Area Adjudication.”

1.3 Previous Studies

Previous studies in the Oeste Hydrologic Sub-area include geologic maps as well as investigations of the hydrogeology and paleohydrology of the region. Published studies of the water resources of the basin began with Thompson [1929] of the United Sates Geological Survey (USGS), who as part of general investigations in the Mojave Desert, conducted a survey of desert watering places in the Mojave Desert region. Within the El Mirage Valley region, Thompson gathered preliminary information on the geography, geology, and hydrology. More comprehensive hydrologic and hydrogeological assessments in the Mojave Desert region were published in the 1960’s by the Department of Water Resources (DWR) [1960, 1964, 1965, 1966, 1967] and have continued to be updated by DWR [1980, 2003, 2004] along with other agencies and groups [Subsurface Surveys, Inc., 1990; Huff et al., 2003; Stamos et al., 2001]. Previous studies in the basin are summarized in the table below (Table 1: Previous Studies of the Oeste Watershed).

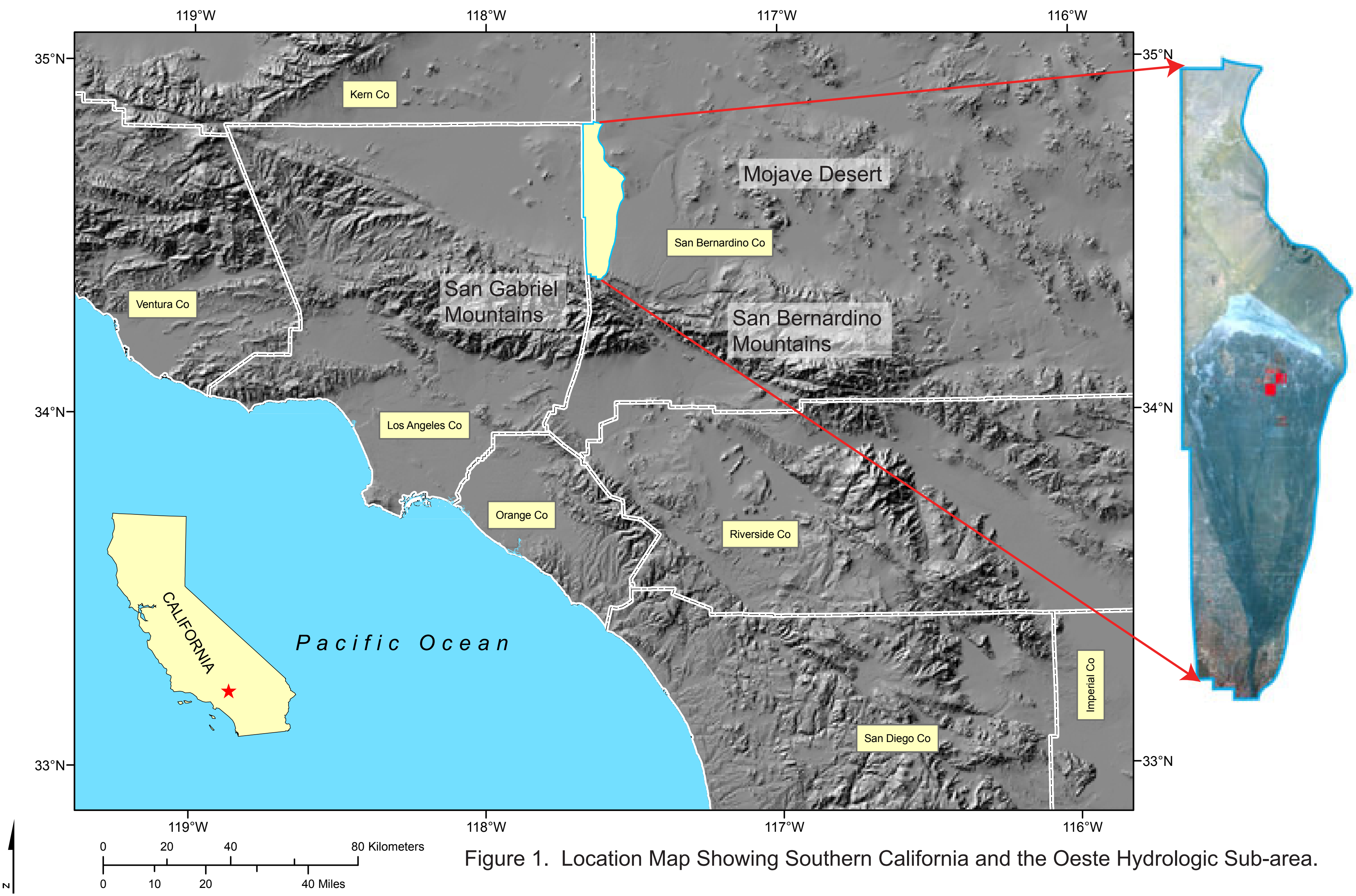
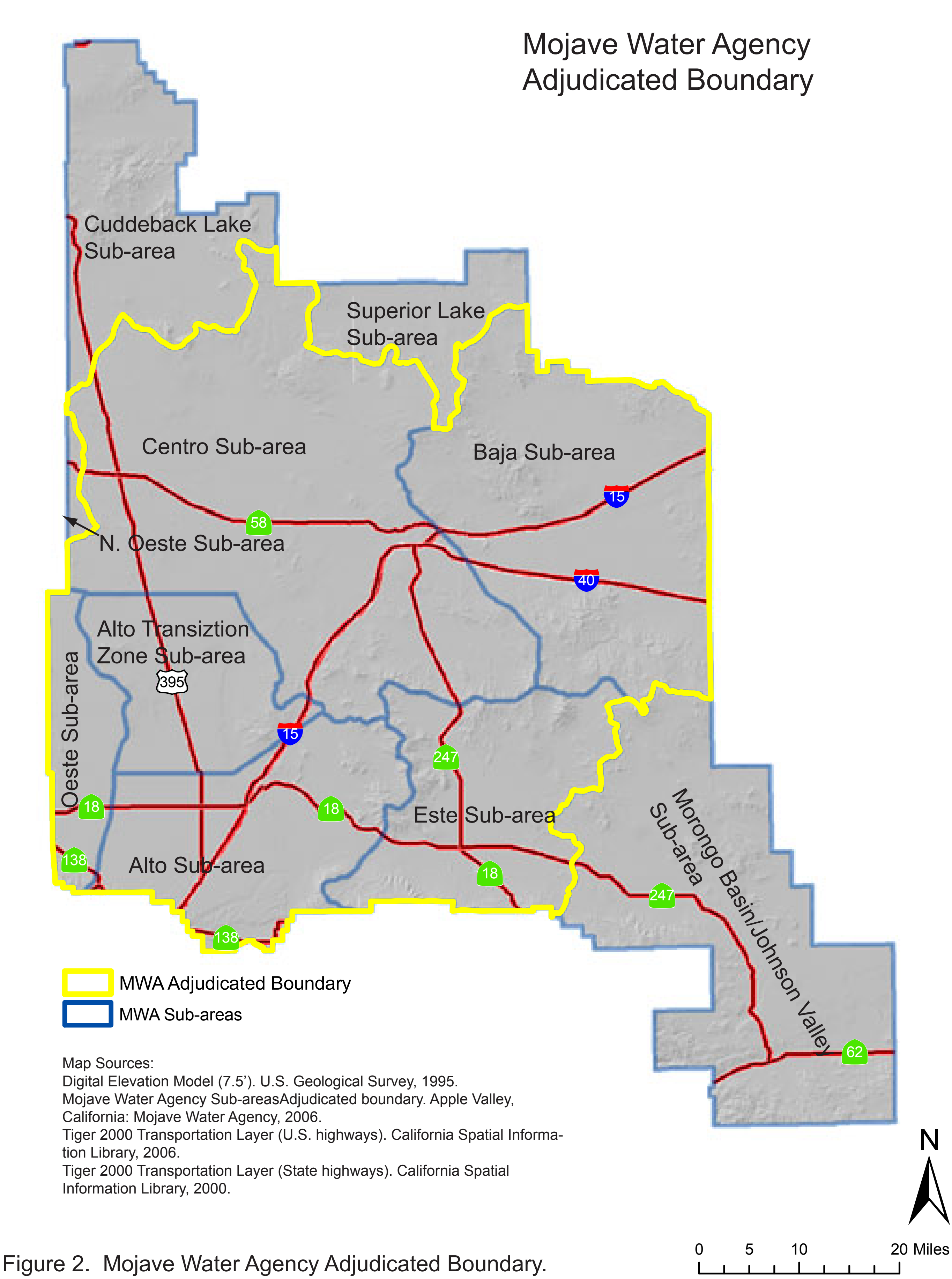


Figure 1. Location Map Showing Southern California and the Oeste Hydrologic Sub-area.



Map Sources:
Digital Elevation Model (7.5'). U.S. Geological Survey, 1995.
Mojave Water Agency Sub-areasAdjudicated boundary. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer (U.S. highways). California Spatial Information Library, 2006.
Tiger 2000 Transportation Layer (State highways). California Spatial Information Library, 2000.

Figure 2. Mojave Water Agency Adjudicated Boundary.

Table 1. Previous Studies in the Oeste Hydrologic Sub-area (El Mirage Valley watershed).

Author(s)	Topic(s)
Thompson [1929]	USGS early reconnaissance of the geographic, geologic, and hydrologic conditions of the Mojave Desert region.
Bader et al. [1958] DWR [1960, 1964, 1965, 1966, 1967, 1980, 2003, 2004]	Hydrogeologic reports for the Mojave River Basin and South Lahontan Regional Water Quality Control Board; intended to fulfill the need for reliable information on water resources.
Dibblee [1960 and 1968]	Geologic Map of Shadow Mountain quadrangle. Areal Geology Professional Paper 522.
Subsurface Surveys, Inc. [1990]	Geophysical Investigation to characterize the sub-surface geologic materials within the Mojave River Groundwater Basins
Stamos et al. [2001]	Simulation of groundwater flow in the Mojave River Basin
Morton and Miller [2003]	Geologic map San Bernardino 1:100,000 quadrangle
Huff et al. [2002]	USGS report collecting groundwater data at 85 monitoring sites constructed in the Mojave Water Agency Management area.
Bookman Edmonston [2004]	Technical study to evaluate the potential for a long-term Water Management Program between MWA and Metropolitan Water District of Southern California.
USGS [1994, 1996, 1998, 2000, 2002, 2004]	Regional water level maps.
Izbicki et al. [2000, 2005] Izbicki and Michel [2003] Izbicki [2004]	Water quality and flow throughout the upper Mojave River region.
Winfield [2000]	Master’s thesis concentrating on porosity of subsurface soils in the Oeste Hydrologic Sub-area region.

1.4 Purpose and Goals

This report provides an analysis of previously published data and new data on the geology, hydrology, hydrogeology, groundwater chemistry, geography and climate of the Oeste Hydrologic Sub-area. An awareness of the challenges in watershed management and possible solutions is imperative to the Mojave Desert region where precipitation is low and demands for freshwater are high. This attention to overall watershed issues, especially those that affect vital groundwater resources cannot be overstated. In order to address these issues, several goals have been considered for this investigation:

1. Provide basic information on the basin's geography.
2. Construct geologic cross-sections through the basin.
3. Examine surface and groundwater flow conditions.
4. Delineate the basin's aquifers (upper/lower).
5. Assess groundwater flow within the basin.
6. Determine the hydrologic budget of the basin.
7. Assess groundwater quality conditions.

2.0 Background

2.1 Physiography

The El Mirage Valley watershed boundary encloses approximately 166 mi^2 (430 km^2) ranging from an elevation of 2,833 feet (ft) [863 meters (m)] at El Mirage (dry) Lake to 8,500 ft (2,591 m) in the San Gabriel Mountains (Figure 3: Oeste Hydrologic Sub-area Physiographic Map; Table 2: El Mirage Watershed Dimensions). El Mirage Valley watershed is bordered by the Shadow Mountains to the north, Adobe Mountain and Nash Hill to the northwest, and the San Gabriel Mountains to the south.

The El Mirage Valley watershed is distinguished by a very large alluvial fan (Sheep Creek fan) descending north from the San Gabriel Mountains into El Mirage (dry) Lake. Protruding hills comprised of basement rock complex are exposed adjacent to and at the northern end of the alluvial fan. Additional low lying alluvial fans sweep southward towards El Mirage (dry) Lake from the northerly mountains. The major fan entering the Oeste Hydrologic Sub-area is the Sheep Creek fan and it is observable on Landsat (satellite) images (Figure 3: Oeste Hydrologic Sub-area Physiographic Map). This is partially due to the reflective clasts of eroded Pelona Schist derived from the adjacent San Gabriel Mountains. The Sheep Creek fan is mostly composed of debris flows entering the Oeste Hydrologic Sub-area through Sheep Creek.

Table 2. El Mirage Watershed Dimensions.

Watershed/MWA Boundary	Surface Area			Elevation Relief	
	mi^2	*km^2*	*acres*	*ft*	*m*
El Mirage Valley	166	430	106,400	7,916	2,412
Oeste Hydrologic Sub-area	164	425	105,100	5,650	1,722

2.2 Regional Climate

The southern Mojave Desert is considered "high desert." Oeste Hydrologic Sub-area has over one mile in elevation relief from El Mirage Valley center to the top of the San Gabriel Mountains. Due to this range in elevation the region is characterized by dry hot summers but with cold winters with summer maximum temperatures averaging ~95°F (35°C) and winter month maximum temperatures averaging ~35°F (2°C) [NOAA, 2005]. A maximum temperature reported for the month of July 1989 was 112°F (44°C) with a minimum temperature reported in the month of December 1990 of 1°F (-17°C) [NCDC, 2007]. In nearby Wrightwood, a maximum temperature of 96°F (35.5°C) was reported in July, 2002 and minimum temperature of 6°F (-14°C) was reported in December, 1998 [NCDC, 2007].

Precipitation within the Mojave Desert region is considered minimal (deserts are defined as arid regions that receive 10 inches (in) [25 centimeters (cm)] or less of rain per year [CALWATER, 1997] (Table 3: Precipitation for El Mirage and Wrightwood, California). Precipitation data from the El Mirage weather station indicate yearly rainfall through El Mirage Valley to be approximately 5.94 in (15.1 cm). (Figure 4: Oeste Hydrologic Sub-area Precipitation and Evapotranspriation Map). The El Mirage weather station is located south of El Mirage Rd along Malecon Dr in El Mirage Valley, CA. Precipitation increases rapidly in the small southern portion of the El Mirage Valley watershed where the San Gabriel Mountains receive greater amounts of precipitation and retain a snow pack for part of every year.

Table 3. Precipitation for El Mirage Valley, El Mirage and Wrightwood, California.

El Mirage Valley, Average Precipitation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
mm	16.5	43.2	14.5	8.9	1.5	0.28	2.5	11.9	5.6	17.5	10.9	17.5	150.9
inches	0.65	1.7	0.57	0.35	0.059	0.011	0.1	0.47	0.22	0.69	0.43	0.69	5.94
Wrightwood, Average Precipitation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
mm	202	242	213	59	25	7	2	7	26	39	82	121	1,025
inches	7.96	9.53	8.38	2.34	0.97	0.26	0.08	0.29	1.01	1.54	3.23	4.78	40.37

The Oeste Hydrologic Sub-area is located within two evapotranspiration (ETo) zones. Zone 14 (Mid-Central Valley and the Southern Sierra Nevada, Tehachapi, and High Desert Mountains) is characterized by high summer sunshine and winds. Zone 17 covers the “High Desert Valleys,” which is considered by CIMIS [2004] to be high desert near Nevada and Arizona. Groundwater resources in the Oeste Hydrologic Sub-area take on a particular resonance when one considers that the rate of water loss due to evapotranspiration is greater than annual precipitation (Figure 4: Oeste Hydrologic Sub-area Precipitation and Evapotranspiration Map).

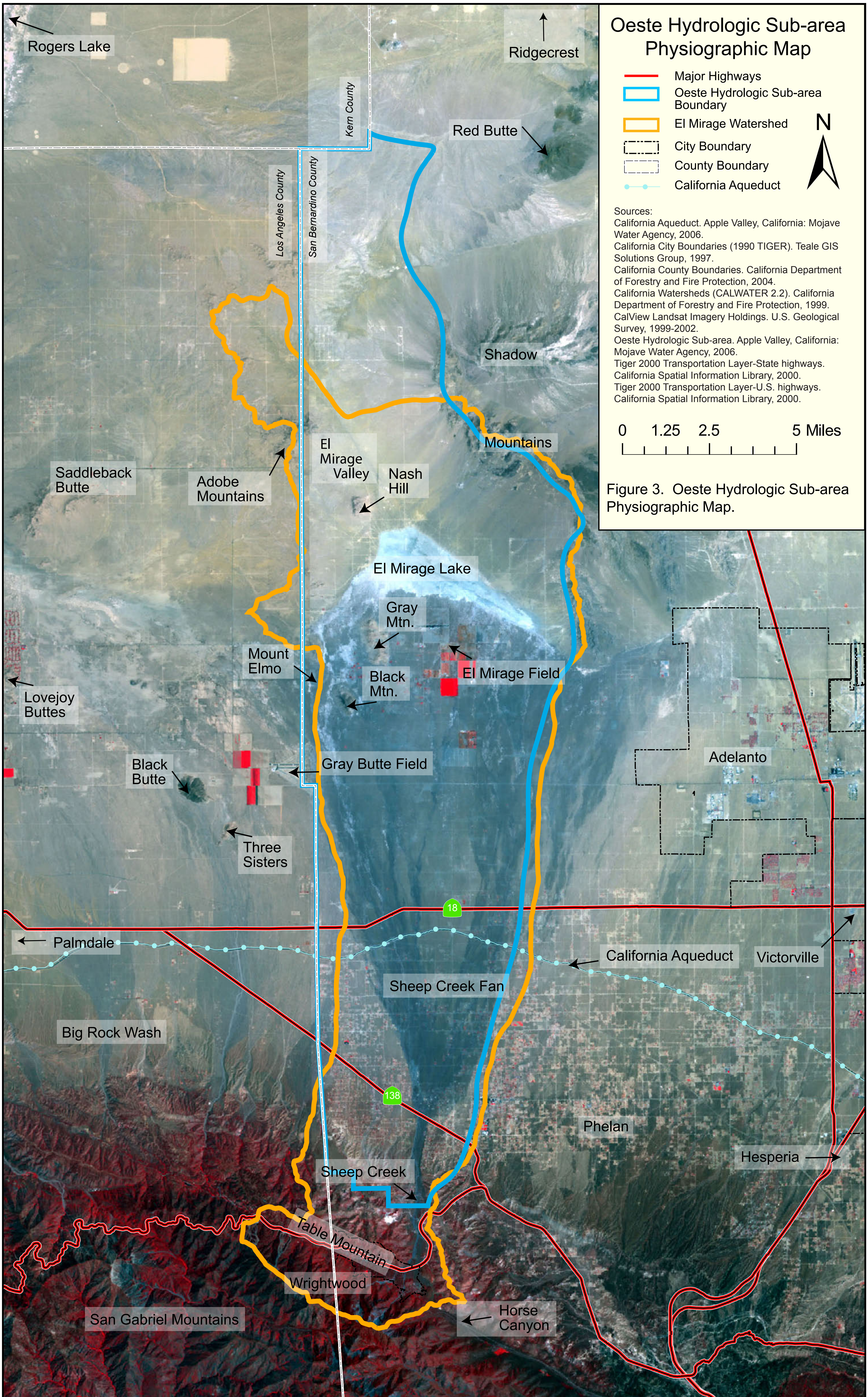


Figure 3. Oeste Hydrologic Sub-area Physiographic Map.

Oeste Hydrologic Sub-area Precipitation and Evapotranspiration Map

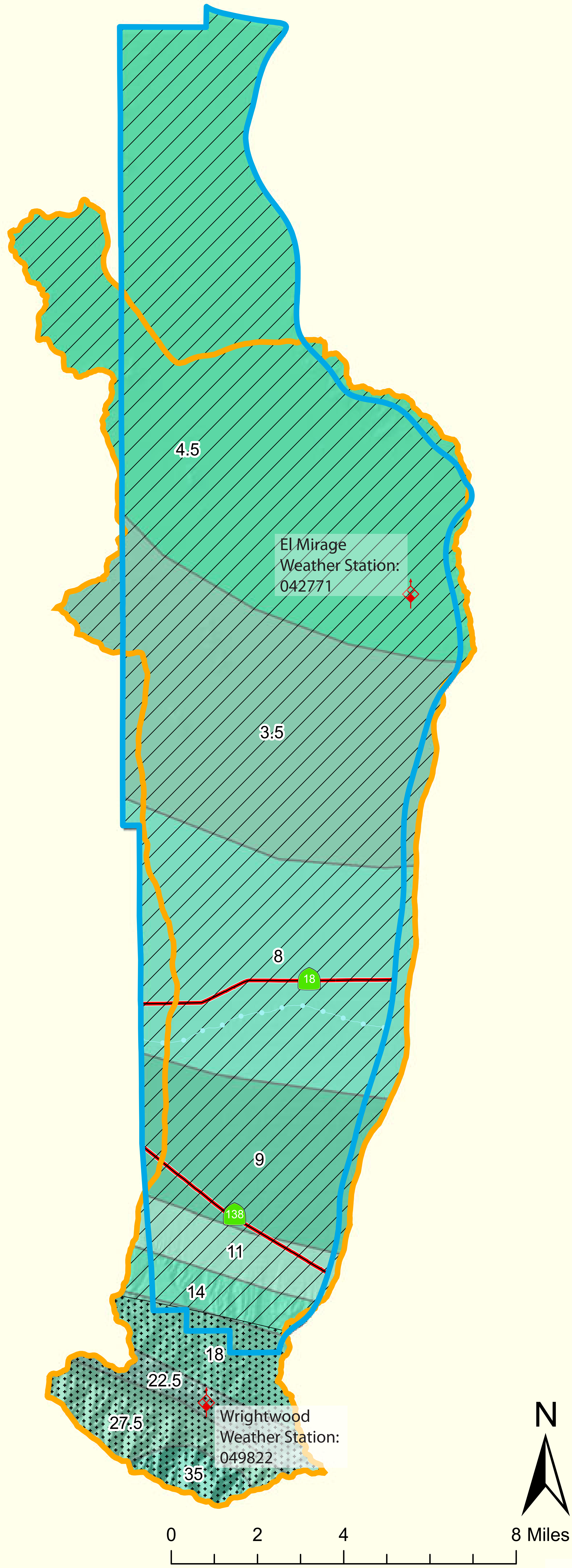
Major Highways
Oeste Hydrologic Sub-area Boundary
El Mirage Watershed
California Aqueduct

Evapotranspiration Zones

High Desert Valleys
Mid-Central Valley,Southern Sierra Nevada, Tehachapi and High Desert Mountains

Precipitation (inches)

3.5
4.5
8
9
11
14
18
22.5
27.5
35



Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
California County Boundaries (1:24,000). California Department of Forestry and Fire Protection, 2004.
California Precipitation. Teale GIS Solutions Group, 1997.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
Digital Elevation Model (7.5'). U.S. Geological Survey, 1995.
Etozones. Jones, D., Eching, S., and Snyder, R., 1997.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.

Figure 4. Oeste Hydrologic Sub-area Precipitation and Evapotranspiration Map

2.3 Surface Water

Streams and lakes within the Oeste Hydrologic Sub-area are considered ephemeral. There are no streams that are perennial upon entering or leaving the boundary of the Oeste Hydrologic Sub-area. Some of the same streams may be considered perennial at higher elevations. Surface flow into the basin is largely derived from snow melt and storm runoff from the San Gabriel Mountains through Sheep Creek. Lesser flows drain from Table Mountain through small channels and washes that contribute to the local groundwater table or occasionally flow towards El Mirage (dry) Lake (Figure 5: Oeste Hydrologic Sub-area Groundwater Basin and Watershed Map). Water collected on the dry lake surface may evaporate and/or slowly infiltrate into the underlying semi-impermeable materials [Fife, 1977]. The estimated annual runoff into the Oeste Hydrologic Sub-area from Sheep Creek is approximately 2,200 acre-ft/yr [Izbicki et al., 2000]. This runoff is derived from the approximately 28 to 32 in (71 to 81 cm) of annual precipitation occurring in the region south of Swarthout Valley [DWR, 2003].

2.4 Vegetation

Research provided by Horne [1989] on local vegetation of the Phelan-El Mirage Valley area, to date, is the most comprehensive and the results are presented here. Native vegetation covering the majority of the Oeste Hydrologic Sub-area is considered xerophytic flora. The Joshua tree (*Yucca brevifolia*) has a dense local population particularly on the higher elevation slopes in the 3,300 ft (1,000 m) range and above [Shelford, 1963]. In local areas of higher precipitation, Pinyon Pines (*Pinus cembroides*) and California Juniper (*Juniperus californica*) consort with the Joshua tree. The Juniper and Pinyon pines segregate from the Joshua tree to form pure stands at higher and more watered elevations. The most ubiquitous of the local flora is the “Greasewood” or Creosote Bush (*Larrea tridentate*). Locally, the Creosote Bush occurs in the well drained soils of the intermountain plains. Though mostly occurring in pure stands, the Creosote Bush is often coexistent with the White Bur Sage (*Ambrosia dumosa*). Other floral occupants of the study area include the Purple Sage (*Salvia dorrii*) and Cooper’s Goldenbush (*Haplopappus cooperi*) which reside on the upper elevation slopes of the Victorville Fan. Creosote and Four-Winged saltbush (*Atriplex canescens*) are the dominant vegetation on the lower elevation slopes of the Victorville Fan. Creosote Bush and Desert Saltbush (*Atriplex polycarpa*), also known as “cattle spinach,” predominate in the lower elevations in the more alkaline soils approaching El Mirage (dry) Lake. The dominant vegetation in the lower elevations of the study area is the Creosote Bush, which is part of a diverse community of shrubs referred to as “desert scrub” in Figure 6: Oeste Hydrologic Sub-area Vegetation Map. Also evident from Figure 6 is the concentration of California and Western Juniper trees banding the southern border of the study area along the northeastern slope of the San Gabriel Mountains.

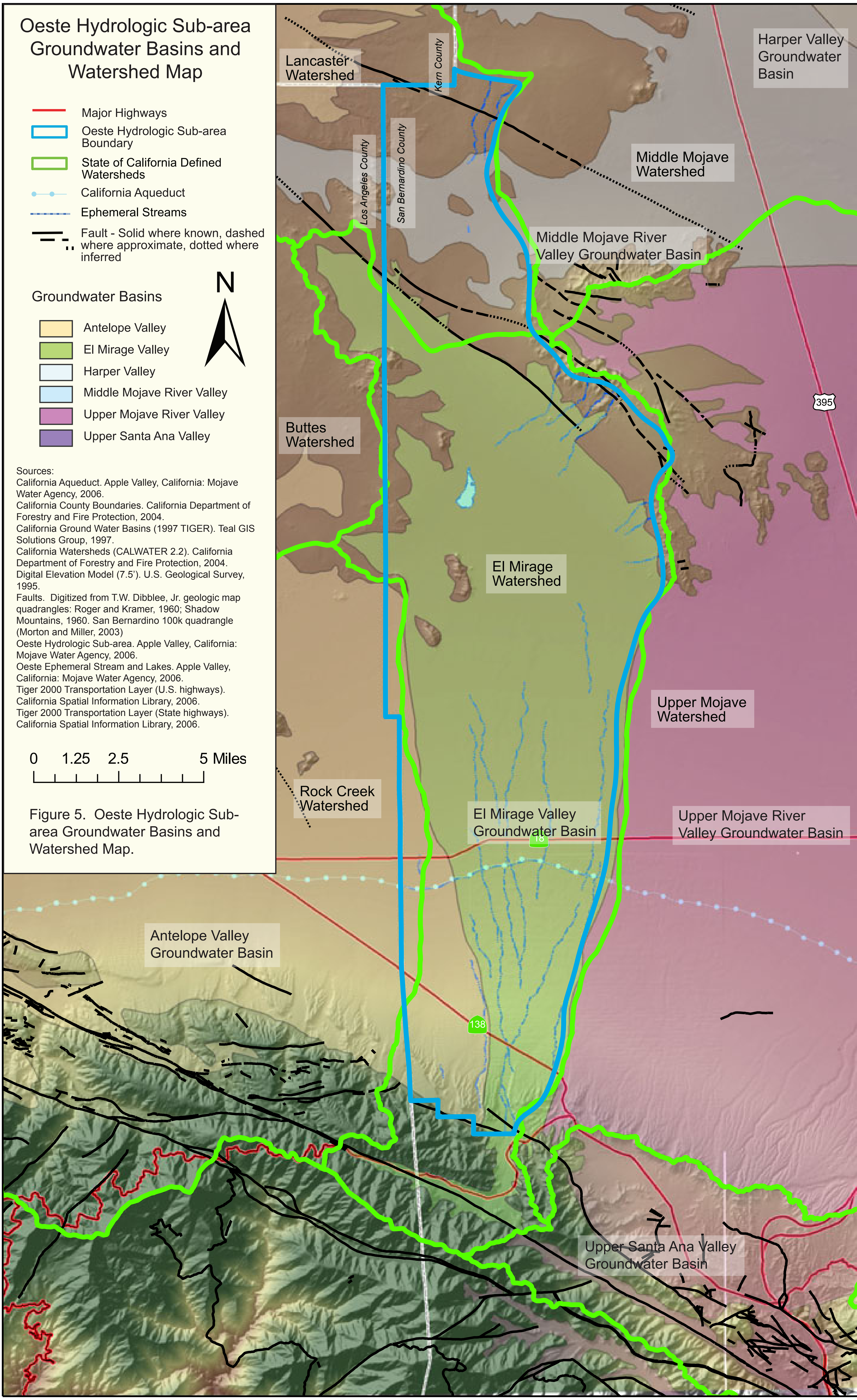


Figure 5. Oeste Hydrologic Sub-area Groundwater Basins and Watershed Map.

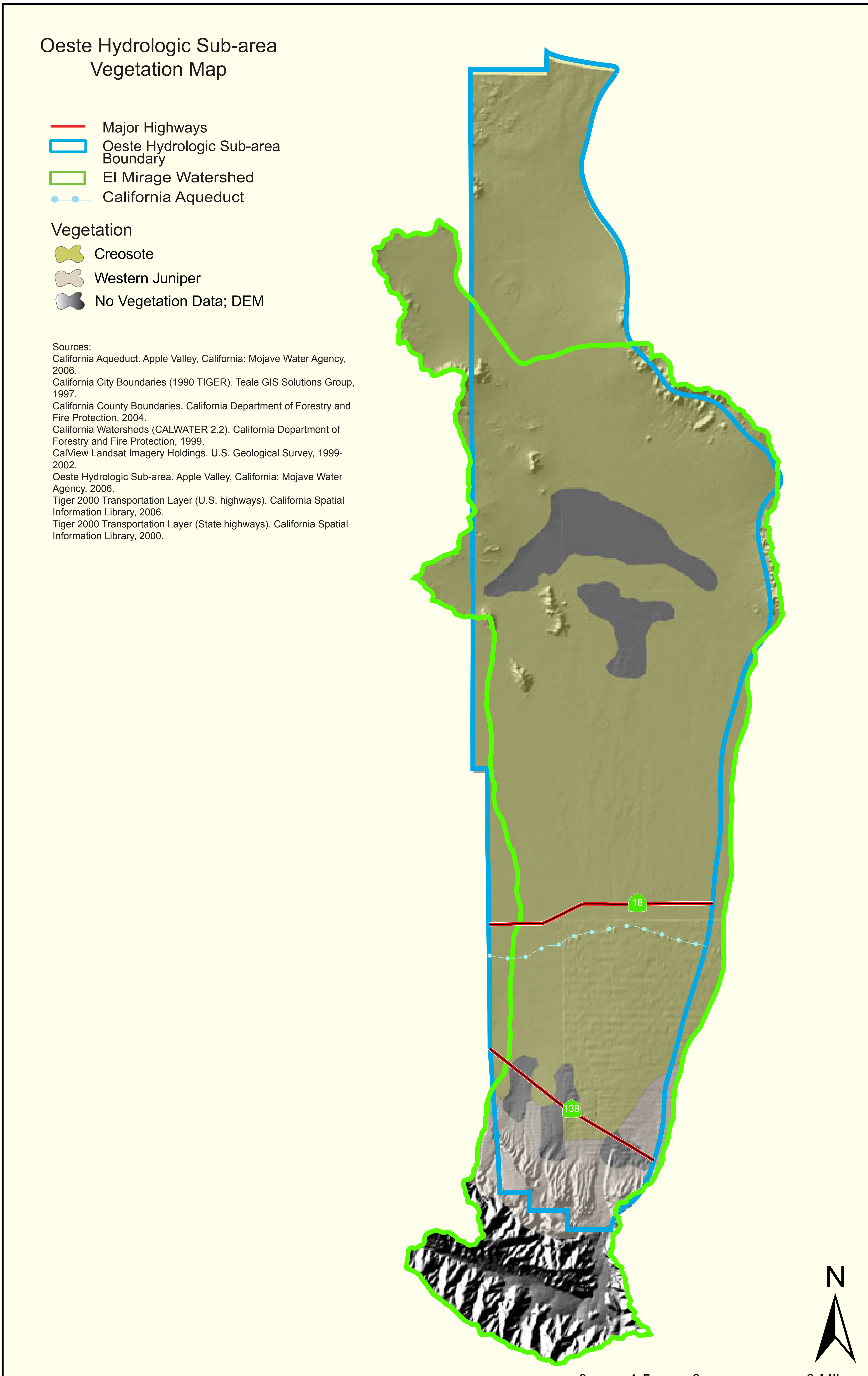


Figure 6. Oeste Hydrologic Sub-area Vegetation Map.

2.5 Demographics

2.5.1 Future Land Use Changes in the Oeste Region

Based on 2000 Census data, the Oeste Sub-area currently has a sparse population of 7,649 across the 164 square mile (264 km^2) region (Figure 7: Census 2000 Population Centers in the Oeste Hydrologic Sub-area). The most densely populated areas are centered immediately south of El Mirage (dry) Lake (the community of El Mirage) and south of Highway 18 (the communities of Phelan and Pinion Hills). Future growth in the "High Desert" and the Antelope Valley region are projected by the Southern California Association of Governments (SCAG) [SCAG, no date] and indicate the majority of growth within the Oeste Sub-area will occur south of Highway 18 in the Phelan and Pinion Hills area. Populations are expected to triple in these areas by 2030 (assuming year 2000 populations) to over 35,000. Populations in the community of El Mirage area are projected to stay at current numbers (approximately 1,000).

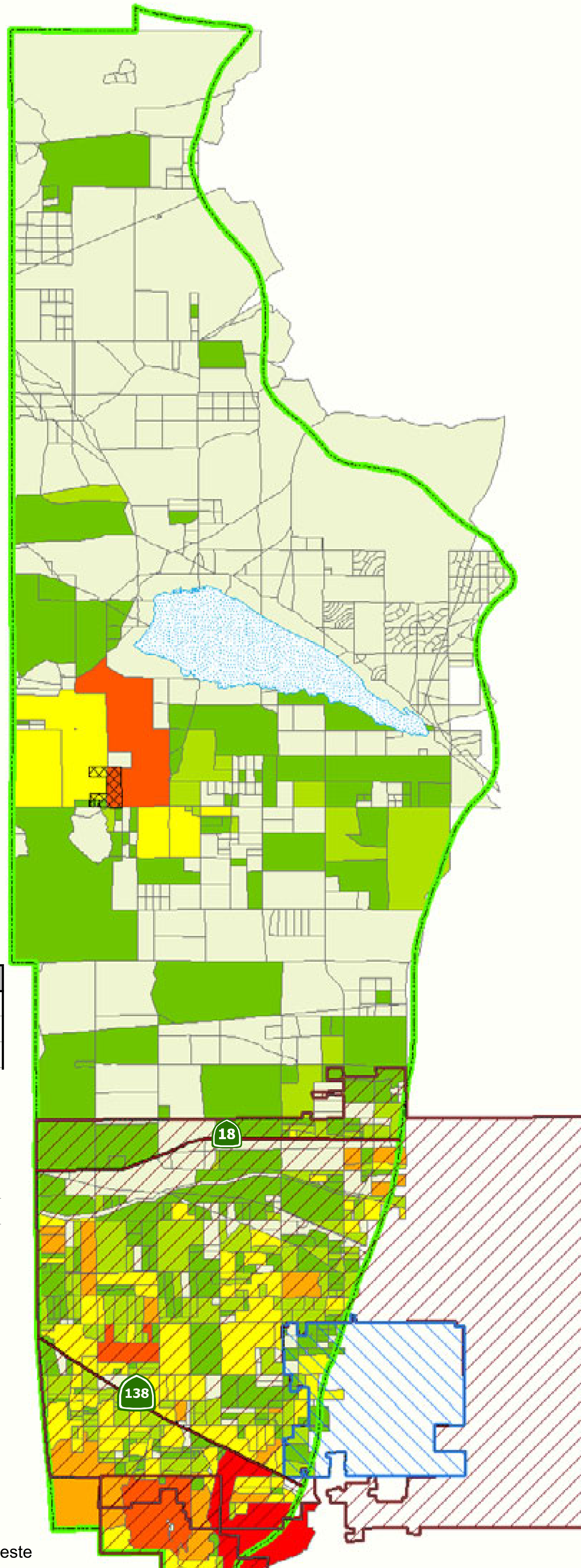
Based on SCAG projections, population in eastern Antelope Valley (adjacent to the western border of the Oeste Sub-area), is expected to see very little growth through 2030. Most of the future growth is expected in the Lancaster and Palmdale areas located in the central Antelope Valley. The population of Lake Los Angeles, located 9 miles (14.5 km) east of the eastern Oeste Sub-area border, is expected to double to approximately 21,000 by the year 2030 and constitutes the highest anticipated growth area in Los Angeles County. Other smaller communities in eastern Antelope Valley are expected to see little to no growth through 2030 (Figure 8: Population Projections Oeste Sub-area and Eastern Los Angeles County 2000 to 2030).

2.5.2 Historic Land Use in the Oeste Region

The Oeste Hydrologic Sub-area has been host to many peoples and industries throughout recorded history. More notable peoples include the Serrano Indians, Spanish missionaries, Mormon colonists, and homesteaders like the Wright family, for whom the town of Wrightwood is named [Wrightwood California, 2006]. Some of the historical industries of the region include cattle ranching, gold mining, as well as apple and alfalfa farming.

Phelan, Piñon Hills, and El Mirage are unincorporated communities concentrated within the Oeste Hydrologic Sub-area (Figure 3: Oeste Hydrologic Sub-area Physiographic Map). Phelan is part of the larger Victor Valley which is expected to reach 250 % to 2,000% growth in some areas by the year 2030 [Bookman and Edmonston, 2004]. Though access to population and local history information for unincorporated areas is limited, the growth of Victor Valley is a good indicator for the eventual growth of these smaller communities. To protect their autonomy, Phelan and Piñon Hills are attempting to form a community service district which, at a minimum

Census 2000 Population Centers in the Oeste Subarea



Water Companies

- Chamisal Mutual Water Company
- County Service Area 70L
- Sheep Creek Water Company

Population (Census 2000)

- 0
- 1 - 10
- 11 - 25
- 26 - 50
- 51 - 100
- 101 - 150
- 151 - 250

Water Company	Population
CSA 70L	6575
Sheep Creek	218
Chamisal Mutual	67*

*based on airphoto count 2.3 persons/household

Total in Oeste Subarea	7649
Total within water companies	6860
Total outside water companies	789

N

0 1 2 4 Miles

Figure 7. Census 2000 Popoulation Centers in the Oeste Hydrologic Sub-area.

Population Projections
Oeste Subarea and Eastern Los Angeles County
2000 to 2030

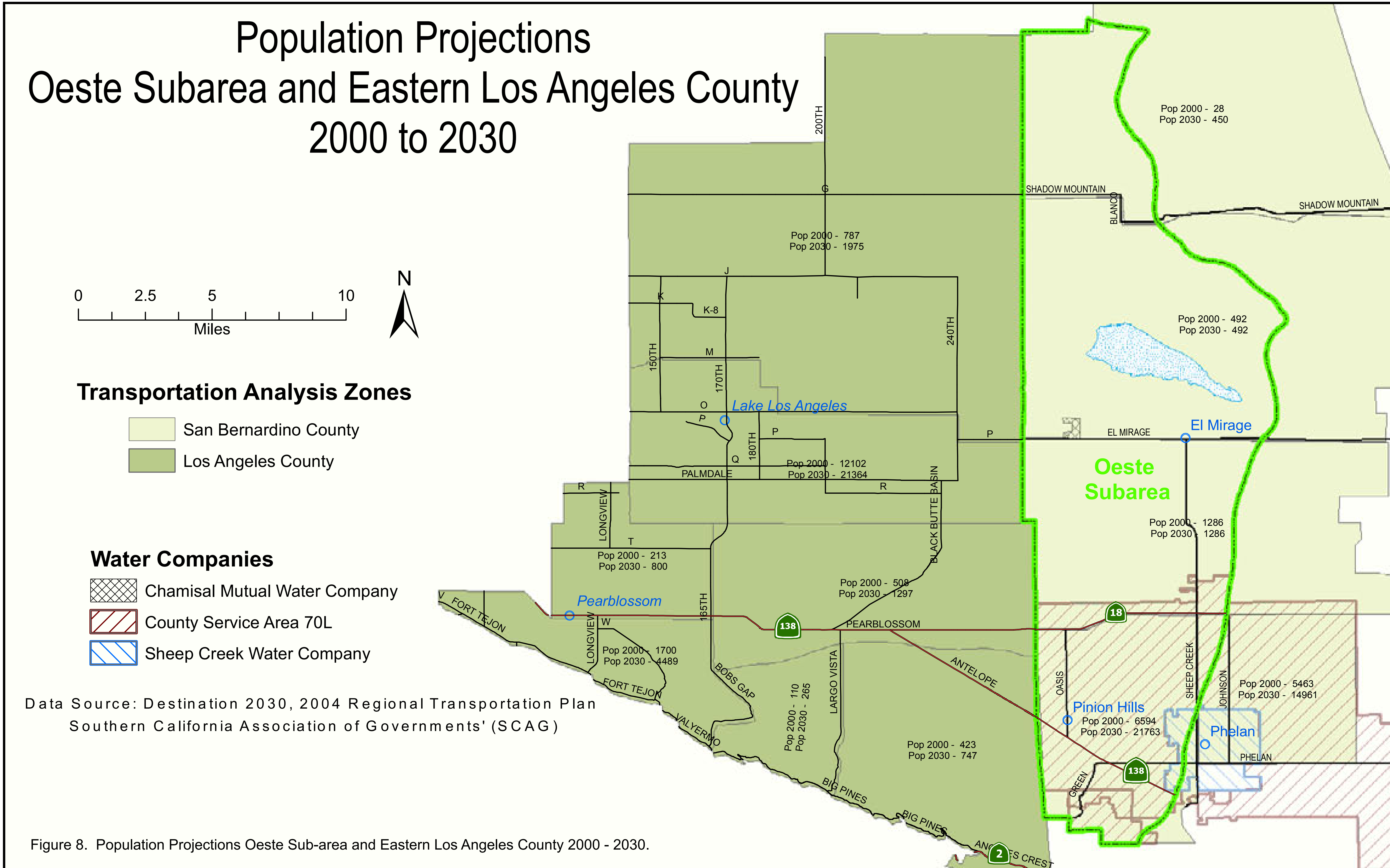


Figure 8. Population Projections Oeste Sub-area and Eastern Los Angeles County 2000 - 2030.

will allow them to clearly define their borders and discourage encroachment of nearby city entities [Morrissette, 2006]. Although it doesn't lie within the Oeste Hydrologic Sub-area boundary, the town of Wrightwood does lie within the El Mirage Valley watershed and is part of what is deemed the "Tri-community", Wrightwood, Phelan, and Piñon Hills. These burgeoning communities display diverse character and accommodate industry from agriculture to high technology [California Department of Conservation, 2002]. For example, the Ducommun AeroStructures Company produces aircraft parts for civilian and military aircraft [Ducommun AeroStructures, 2006]. Dairy farming and alfalfa farming are also thriving industries within the Oeste Hydrologic Sub-area.

3.0 Geology

3.1 Methods

The subsurface geology of the El Mirage Valley groundwater basin was interpreted using geologic maps, all applicable driller's water well logs, oil well logs, USGS monitoring well data and geophysical work [Subsurface Surveys, Inc., 1990]. Subsurface Surveys, Inc. [1990] developed a gravity model of the basin's basement geometry. Based on pertinent well information and location, some wells were logged with a MGX II Portable Logger with MGX II Console Gamma Ray. Gamma ray logging is a useful tool in measuring the natural radioactivity of materials. It is particularly helpful in differentiating between gravels, sands, and clays [Schlumberger, 1972]. Coupled with well descriptions and geology, gamma logs provide additional aid in correlating stratigraphic units between wells.

3.2 Subsurface Geology

Bedrock within the El Mirage Valley area is predominantly granitic. Two composite plutonic complexes were mapped by Martin and Walker [1995] in the Shadow Mountains, El Mirage Valley, and Adobe Mountain areas. Granitic rocks in the Shadow Mountains range from felsic granite to mafic rocks and include gabbro, with roof pendant metamorphic rocks comprised mostly of marble, schist, and quartzite. Basement rock in the southern portion of the basin is composed of two distinct rock sequences divided by the San Andreas Fault. South of the fault (Swarthout Valley), rocks are predominantly composed of Pelona Schist, a gray to green chlorite-actinolite and muscovite schist. North of the San Andreas Fault are the basement rocks of Table Mountain. These include Mesozoic granites and gneisses and marbles of Pre-Mesozoic age. Pediments northeast of El Mirage (dry) Lake are underlain by compositionally uniform medium- to coarse-grained biotite-hornblende granodiorite [Dibble, 1960; Miller and Bedford, 2000].

El Mirage Valley is formed between the Shadow Mountains on the northeast and Adobe Mountain on the northwest. The exposures of Adobe Mountain appear to continue, in the shallow subsurface as a pediment westward to the area of Lovejoy Buttes and Black Butte where they are then completely buried by alluvium in a westerly direction to the edge of the mountain front west of Pearland. The gravity map of Mabey [1960] shows this broad subsurface basement ridge as well. Contour lines on the gravity data indicate that the basement may deepen in a broad subsurface valley southeastward from El Mirage (dry) Lake towards the east-west elongate depression shown about 6 miles (10 km) north of Cajon Pass. West of the Oeste Hydrologic Sub-area, a narrow basement trough deepens southeastward from the Lovejoy Buttes subsurface ridge and south of Black Butte. This depression most likely controls deep groundwater movement and may be the location of a fault that is shown in DWR [1965] and on Mabey's [1960] gravity map (Plate 10 in Mabey, 1960).

The geomorphology and depositional history of El Mirage Valley is the result of the interaction between the Transverse Ranges, namely the San Gabriel Mountains to the south and a desert semi-bolson to the north. El Mirage Valley is the semi-bolson formed between the Adobe and Shadow Mountains. Very young alluvial deposits comprise the Sheep Creek fan and the fan consists mostly of Pelona Schist debris [Horne, 1989]. Eolian sand is also widespread on the fan [Miller and Bedford, 2000]. Underlying these younger sediments are deposits exposed in the in-facing bluffs and San Gabriel Mountains that have been described as, from oldest to youngest respectively: the Phelan Peak Formation, the Harold Formation, the Shoemaker Gravel and the Older alluvium of Noble [1953], Foster [1980], and Weldon [1984]. The geology depicted in Plate 2 Generalized Geology and Bedrock/Alluvium Map, is based on mapping done by [Dibblee, 1967; Miller and Bedford, 2000; Morton and Miller, 2003]. The surficial and subsurface distribution of both the basement rocks and Cenozoic sedimentary deposits are shown on cross-sections A through E (Plate(s) 3a, 3b, and 3c). In addition, a short cross-section (Plate 3a Generalized Geology Cross-section A-A') was developed across the narrow channel of Sheep Creek to illustrate the loose stream alluvium and groundwater elevations in the recharge area of the basin.

3.2.1 Phelan Peak Formation

The Phelan Peak Formation (Tpp) of Weldon [1984] were previously termed "the western facies of the Crowder Formation" by Foster [1980] who considered them to be of latest Tertiary age (2 – 4 million years ago (Ma). However, the Crowder Formation has since been shown to be a mid-Tertiary formation based on fossils found near Highway 138 in Cajon Pass by Reynolds [1991]. Weldon [1984] determined the sediments to be younger than the Crowder Formation (17 - 19 Ma) with the time of deposition ranging from 1.4 - 4.1 Ma [Weldon 1984; 1986]. The unit is further broken down into Pliocene aged rocks (Tpp) and Pliocene and Pleistocene units $Tpp_{1\text{-}3}$. Only Tpp and Tpp_3 are exposed within this report's study area.

The lithology of the older Phelan Peak Formation deposits (Tpp) consists of Pliocene aged arkosic sandstone with thin beds of clayey and silty sandstone and feldspathic conglomerate [Foster, 1980; Weldon 1984]. The younger Phelan Peak ($QTpp_3$) consists of claystone and siltstone containing lesser sandy zones in which sand is either disseminated or restricted to beds. Phelan Peak also includes argillic paleosols and carbonate-cemented layers [Weldon, 1984]. The clasts, which include, granitic, volcanic, and a variety of metamorphic rocks, are derived from the nearby basement rocks and from older sedimentary rocks. Most significantly, the Phelan Peak Formation contains no rock fragments of Pelona Schist. The age significance of this is that debris forming these deposits was being derived 3 to 4 Ma from the area of Table Mountain and not the Hinterland mountains south of the San Andreas Fault where Pelona Schist is abundantly exposed today. Phelan Peak deposits are grouped together as shown in Plate 2: Generalized Geology and Bedrock/Alluvium Map.

3.2.2 Harold Formation

The Harold Formation lies unconformably above the Phelan Peak Formation and grades upward into the Shoemaker Gravel. The formation was first defined by Noble [1953] as fine-to coarse grained sediments locally cemented with calcite and exposed at Harold siding in the hills 0.6 mi (1 km) southwest of the San Andreas fault and 1 mi (1.5 km) southeast of the town of Harold. The Harold Formation is composed of arkosic conglomeratic sandstone and arkosic sandstone, with discontinuous carbonate cemented layers. The clasts are composed of Pelona Schist and other metamorphic rocks that are sub-rounded to moderately rounded [Foster, 1980; Miller and Bedford, 2000]. The Harold Formation is Pleistocene in age and is about 490 ft (150 m) thick at the mountain front where Sheep Creek debouches into the El Mirage Valley and Sheep Creek Fan [Miller and Bedford, 2000].

3.2.3 Shoemaker Gravel

The Shoemaker Gravel was named by Noble [1953] for exposures of a boulder polymict conglomerate in Shoemaker Canyon near Valyermo. The Shoemaker Gravel is composed of conglomerate, lithic arkosic conglomerate and lithic arkosic sandstone. The clasts range in size from pebbles to meter sized boulders, and are typically rounded to sub-rounded. Clast composition includes a large variety of granitic rocks including Lowe granodiorite, gneiss, and Pelona Schist [Foster, 1980; Miller and Bedford, 2000]. The Shoemaker Gravel is unconformably overlain by very old Quaternary fanglomerate deposits (Qvof). Foster [1980] suggests that the Harold Formation and Shoemaker Gravel formed as an upward coarsening alluvial fan reflecting the initial Pleistocene uplift of the San Gabriel Mountains.

3.2.4 Very old alluvial fan deposits (Older Alluvium of Noble)

Middle to early Pleistocene alluvial fan deposits are comprised of moderately to well consolidated deposits of silt, sand, and gravel. These deposits were named and mapped by Noble [1953] for exposures above the Shoemaker Gravel along the trace of the mountain front in the Pearland and Valyermo areas. Grain size is mostly medium- to very-coarse sand and ranges from sparsely to highly conglomeratic. These deposits also contain an abundance of Pelona Schist clasts [Miller and Bedford, 2000].

3.2.5 Old Alluvial Fan deposits

The late to middle Pleistocene (Qof) fans consist of massive to poorly bedded, sand to boulder alluvium. In the distal fan region, approximately 4.5 to 5 mi (7 to 8 km) north of the San Gabriel Mountain front, the deposits become primarily clays as observed in well 5N/7W-24D2. Within this well, clay is present from a depth of 260 ft (80 m) to the bottom of the well at 700 ft (213 m). These fans are moderately consolidated and highly dissected where exposed [Miller and Bedford, 2000].

3.2.6 Young Alluvial Fan Deposits

Young unconsolidated alluvium derived from the San Gabriel Mountains overlies all older deposits to a depth of several hundred feet in a wedge that thickens towards El Mirage (dry) Lake. Intermixed with the young alluvial fan deposits derived from the San Gabriel Mountains are other alluvial fan deposits that were derived contemporaneously from the Shadow Mountains, Adobe Mountain, Gray Mountain, and Black Mountain. However, within this overall sequence of coarse alluvial deposits is a thick section of brown sandy clay that extends in the subsurface over an area of approximately 35 mi^2 (90 km^2). These clay deposits reportedly underlie a large area in the vicinity of El Mirage (dry) Lake and act as an aquiclude separating a perched groundwater aquifer from a deep groundwater aquifer [Stamos et al., 2001]. The clay zone is thickest southwards from the eastern portion of El Mirage (dry) Lake in a westward turning arc that ends about 3.7 mi (6 km) south of El Mirage (dry) Lake near Black Mountain. It is continuous from about 100 ft (30 m) depth to 300 ft (90 m), though in places the clay will be separated by sand and gravel lenses that range from 10 to 16 ft (3 to 5 m) thick. North of Black Mountain in the western portion of El Mirage Valley and south of El Mirage (dry) Lake, the clay is mostly confined to shallower depths. Here groundwater wells are shallower and the clay occurs from the surface to a depth of no more than about 115 ft (35 m). Farther northwest, particularly north of Gray Mountain and along the west perimeter of El Mirage (dry) Lake, there are many groundwater wells with no clay mentioned in the well records,. This thick subsurface clay sequence extends southward about 2 mi (3 km) to well 5N/7W-04M01 and is not mentioned in records from wells located further south.

3.2.7 El Mirage (dry) Lake

El Mirage (dry) Lake is composed of extensive surficial brown clay deposits and is present at the distal end of the Sheep Creek Fan as a low spot before the land surface rises into the Adobe and Shadow Mountains. The deeper clay deposits represent former lake deposits that have been slowly covered by the Sheep Creek Fan deposits to the south.

3.3 Faulting

Main faults that dissect the groundwater basin are located north of Mirage Valley (Mirage Valley fault) and near Wrightwood within Swarthout Valley (San Andreas fault). The Llano fault is a seven km long northwest trending reverse fault near the San Gabriel mountain front west of the Oeste Sub-area. The San Andreas Fault is an active strike-slip fault [SCEC, No date]. A more northerly oriented and isolated structure has been proposed by Dibblee [1960] and DWR [1966], which is corroborated with gravity linear lows from Mabey [1960] and Subsurface Survey, Inc. [1990]. The structure extends from near Lovejoy Buttes to just north of the mouth of Sheep Creek.

3.3.1 Mirage Valley Fault

Faults dissecting the Shadow Mountains include the northwest trending Mirage Valley fault along the southern boundary of the mountains and several parallel faults or splays cutting the range. The fault extends from the area near Roger's Lake and continues southeast through the granitic terrain exposed in the hills and pediment at upper Mirage Valley, but dies out southeastward as it intersects the metasedimentary rocks of the southeastern Shadow Mountains. The fault is considered to be Late Pleistocene in age and exhibits normal movement down to the south at its mapped ends with right lateral motion on the central segment [Jennings, 1994].

3.3.2 Llano Fault

The Llano fault which is described as Holocene(?) or possibly active, is present near the town of Pearblossom [Jennings, 1994]. The fault is mapped at the surface for about 4 miles (7 km) and is located 6 miles (10 km) east of Pearblossom and 6 miles (10 km) northeast of the San Gabriel Mountains where Big Rock Creek flows onto the desert floor. The fault is shown to be a reverse fault with the north block down and the fault plane inclined to the southwest [SCEC, No date]

3.3.2 Concealed and Queried Faults

Dibblee [1960] mapped a questionable concealed fault striking linearly N30°W along the southwest side of Black Butte to the area just west of Three Sisters Butte in the Shadow Mountains 15' quadrangle (Plate 2: Generalized Geology and Bedrock/Alluvium Map). DWR [1965] continues this structure to the northwest past Lovejoy Buttes and the structure is parallel to the gravity lineament shown by Mabey [1960, Plate 10]. If continued in a southeast direction, the proposed fault would align with a small fault shown on Mabey's gravity map and Dibblee's geologic map of the Mojave Desert [Mabey, 1960 and Dibblee, 1960]. This structure would project into the Sheep Creek drainage area, however, mapping by Foster [1980] shows that such a structure does not break the Pleistocene sequence along the Table Mountain range front (Plate 2: Generalized Geology and Bedrock/Alluvium Map).

3.3.3 San Andreas Fault

The most significant structure in the Oeste Hydrologic Sub-area is the active right-lateral strike-slip San Andreas Fault cutting through Swarthout Valley [SCEC, No date]. Sieh [1978] has demonstrated that this fault has had multiple large magnitude earthquakes in historical times. Large earthquakes of this nature have been shown to alter groundwater conditions [Townley and Allen, 1939]. Although the fault is covered by faulted young alluvium within the small area of the El Mirage Valley watershed, groundwater is only affected in a minor way. Most of the recharge flows as surface water into Sheep Creek and through the faulted alluvium.

4.0 Groundwater

4.1 Aquifer Boundaries

The El Mirage Valley groundwater basin is bordered on the west by the Antelope Valley groundwater basin, to the north by the Middle Mojave River Valley groundwater basin, and to the east by the Upper Mojave River Valley groundwater basin (Figure 5: Oeste Hydrologic Sub-area Groundwater Basins and Watershed Map). These groundwater basins typically follow watershed boundaries, but in some cases are geopolitical boundaries. This is best represented by the boundary between the Antelope Valley, El Mirage Valley, and Upper Mojave River Valley groundwater basins. The regional aquifer in each of these groundwater basins is probably extensive across all of the defined boundaries [Horne, 1989; Stamos et al., 2001].

4.1.1 Antelope Valley Groundwater Basin

The Antelope Valley groundwater basin is bounded by the Garlock fault zone to the northwest, the San Andreas Fault zone to the southwest, and by a drainage divide to the north through the low hills, ridges, and buttes that separate it from the Freemont Valley groundwater basin [DWR, 2004]. The eastern portion of the Antelope Valley groundwater basin is directly adjacent to the El Mirage Valley groundwater basin.

Lacustrine clay beds form deposits approaching a thickness of 400 ft (122 m) and comprise a zone of low permeability separating groundwater into an upper and lower aquifer. The upper aquifer is unconfined and provides the primary groundwater source for the Antelope Valley [DWR, 2004]. The lower aquifer is semi-confined where overlain by the lacustrine and upper aquifer deposits [Leighton and Phillips 2003].

Recharge to the Antelope Valley groundwater basin is primarily from surface water runoff infiltrating from the surrounding San Gabriel Mountains and foothills. The majority of the runoff is contributed by Big Rock Wash which rapidly percolates through alluvial fan systems [DWR, 2004].

Before development, the primary source of groundwater discharge from the Antelope Valley groundwater basin was through evapotranspiration and springs. Urban and agricultural groundwater development is now the primary source of discharge from the Antelope Valley groundwater basin [Leighton and Phillips 2003].

4.1.2 El Mirage Valley Groundwater Basin

The El Mirage Valley groundwater basin has two principle groundwater aquifers [Smith and Pimentel, 2000; Izbicki, et al., 2003]. A lower regional aquifer extends from the southern portion of Sheep Creek to El Mirage (dry) Lake in the north. This aquifer extends from the Los Angeles county line in the west to the community of Phelan in the east (Figure 5: Oeste Hydrologic Sub-area Groundwater Basins and Watershed Map). The lower, regional aquifer is primarily being used by the larger water consumers in the north and is the primary aquifer for several municipal groups [Sheep Creek Water Company and the County of San Bernardino]. The upper perched aquifer is isolated near the dry lake area and is typically less then 250 ft (75 m) in depth [Horne, 1989]. However, in several places, the depth of the perched layer may be deeper and is interbedded with sands, silts, and gravels (Plate 3c: Generalized Geology Cross-section D-D’, E-E’, Insert A and Insert B). The upper perched aquifer is principally used by single family dwellings and small businesses. DWR [2003] reports well yields averaging 230 gallons/minute (gpm) and a high of 1,000 (gpm). It is not clear in the DWR [2003] report if these yields are derived from the perched (less than 250 ft (75 m)) or regional aquifer, although the regional aquifer seems more likely.

4.2 Groundwater Flow

4.2.1 Methods

Water level data from the USGS National Water Information System [NWIS, 2006] and Department of Water Resources [DWR, 2006] were compiled to create a groundwater level database for the region in and around the Oeste Hydrologic Sub-area. Based on these data and Smith and Pimentel, (2000), the Oeste Hydrologic Sub-area is divided into an upper (perched) and lower (regional) aquifer system. Groundwater level data was separated by aquifer and a series of hydrographs were created (Appendix A-1: Groundwater Hydrographs). The hydrographs were then used to determine which multiple time-steps (periods of time) contained enough spatially diverse data to create reasonable groundwater elevation contour maps. Groundwater gradients were then calculated from the groundwater elevation contour maps (Table 4: Gradient Sloping towards Central Oeste Hydrologic Sub-area). Because the flow direction is not directly down the axis of the basin, but rather radiating out from Sheep Creek Wash and ultimately crossing into the adjacent Alto Hydrologic Sub-area, only one gradient line was used for the actual flow. This was also demonstrated with the USGS Mojave River groundwater model [Hardt, 1971; Stamos et al., 2001], where a no-flow boundary at the Oeste-Alto boundary was simulated.

Table 4: Gradient Sloping towards Central Oeste Hydrologic Sub-area.

Method / Period	1956-57	2000	2002	2004
Calculated from contour map (ft/ft)	0.0056	0.0038	0.0033	0.0038

4.2.2 Groundwater Level Data

A total of 187 groundwater wells were evaluated for this study (Figure 9: Oeste Hydrologic Sub-area Location of Wells); 152 wells in the Oeste Hydrologic Sub-area and 35 wells in the Alto Hydrologic Sub-area. Data for all 187 wells are from the NWIS and DWR, as well as from MWA, County Service Area 70L, and Sheep Creek Water Company databases. Records from these wells represent 1,624 individual data points from 1916 through 2005. Groundwater elevations ranged from a low of 1,922 ft (586 m) above mean sea level (AMSL) to a high of 4,692 (1,430 m) AMSL.

At the time of this report, no groundwater data was available for the Antelope Valley groundwater basin. However, considering the basin geometry and the flow patterns, flow across the county line from Oeste Hydrologic Sub-area to Los Angeles County appears to be minimal (Figure 10: Oeste Hydrologic Sub-area Regional Aquifer Groundwater Elevation Contour Map, 2004; Figure 11: El Mirage Clay Zone Groundwater Elevation Contour Map, 2004). Based on the contour maps it is unknown if water is flowing from Antelope Valley groundwater basin and into the El Mirage Valley groundwater basin. Contour maps prepared by USGS for 1915 and Spring 1996 indicate groundwater movement is to the northwest near Big Rock creek, and away from El Mirage Valley (Leighton and Phillips 2003). Water levels declined between 1915 and 1996 but the contours indicate that the direction of groundwater flow has not changed. Since pumping in both El Mirage and Antelope increased significantly between 1915 and 1996, it seems unlikely that water supplies in Antelope are influenced by pumping in El Mirage. There is a lack of water level data in area between Antelope and El Mirage and consequently further work will be needed to verify and confirm the relationship between Antelope and El Mirage.

4.2.3 Hydraulic Conductivity

The ranges in hydraulic conductivities were obtained from a variety of sources (Table 5: Source and Information on Varying Hydraulic Conductivity Values) [Horne, 1989; Winfield, 2000; Stamos et al., 2001]. These values constitute the range of expected hydraulic conductivities for undifferentiated alluvium, partly-cemented sandstone, and weathered fractured gravelly sandstones. Although flow in and between the Antelope Valley, El Mirage Valley, and Upper Mojave River Valley groundwater basins can be calculated, many assumptions must be made regarding the basin's geometry and the hydraulic conductivities of the aquifers. These assumptions have forced a more complete groundwater flow model to be constructed by Mojave Water Agency [MWA, in progress].

Table 5: Source and Information on Varying Hydraulic Conductivity Values.

Source	Hydraulic Conductivity (K) (ft/day)	Aquifer Thickness ft (m)	Notes on source
Horne [1989]	NA	2,500 (760 m)	-
Winfield [2000]	-	-	Porosity range from 29 – 42%.
Stamos et al. [2001]	0.8 – 11.6	700 (213 m)	This value was used as an average for the storage coefficient.

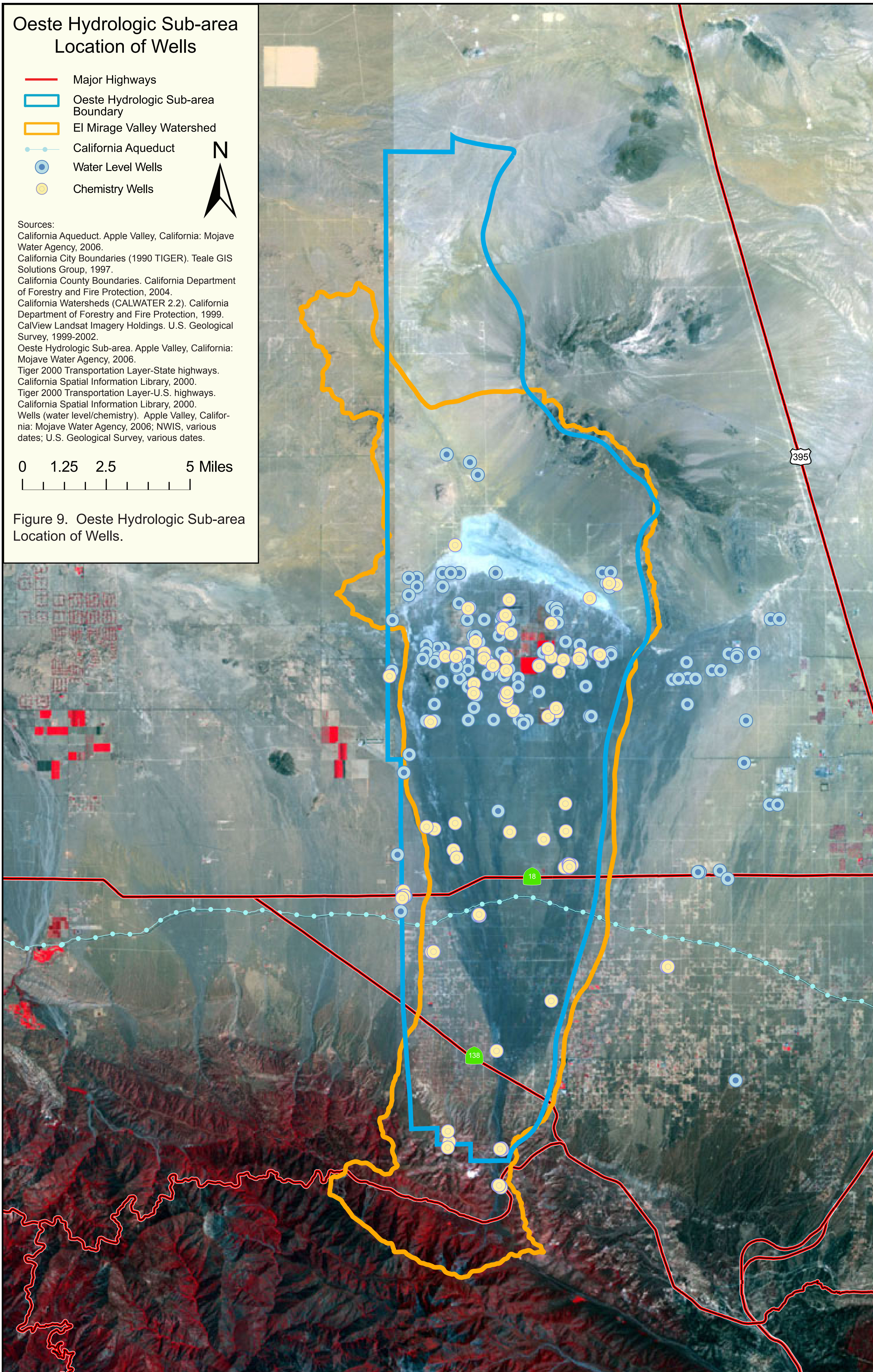


Figure 9. Oeste Hydrologic Sub-area Location of Wells.

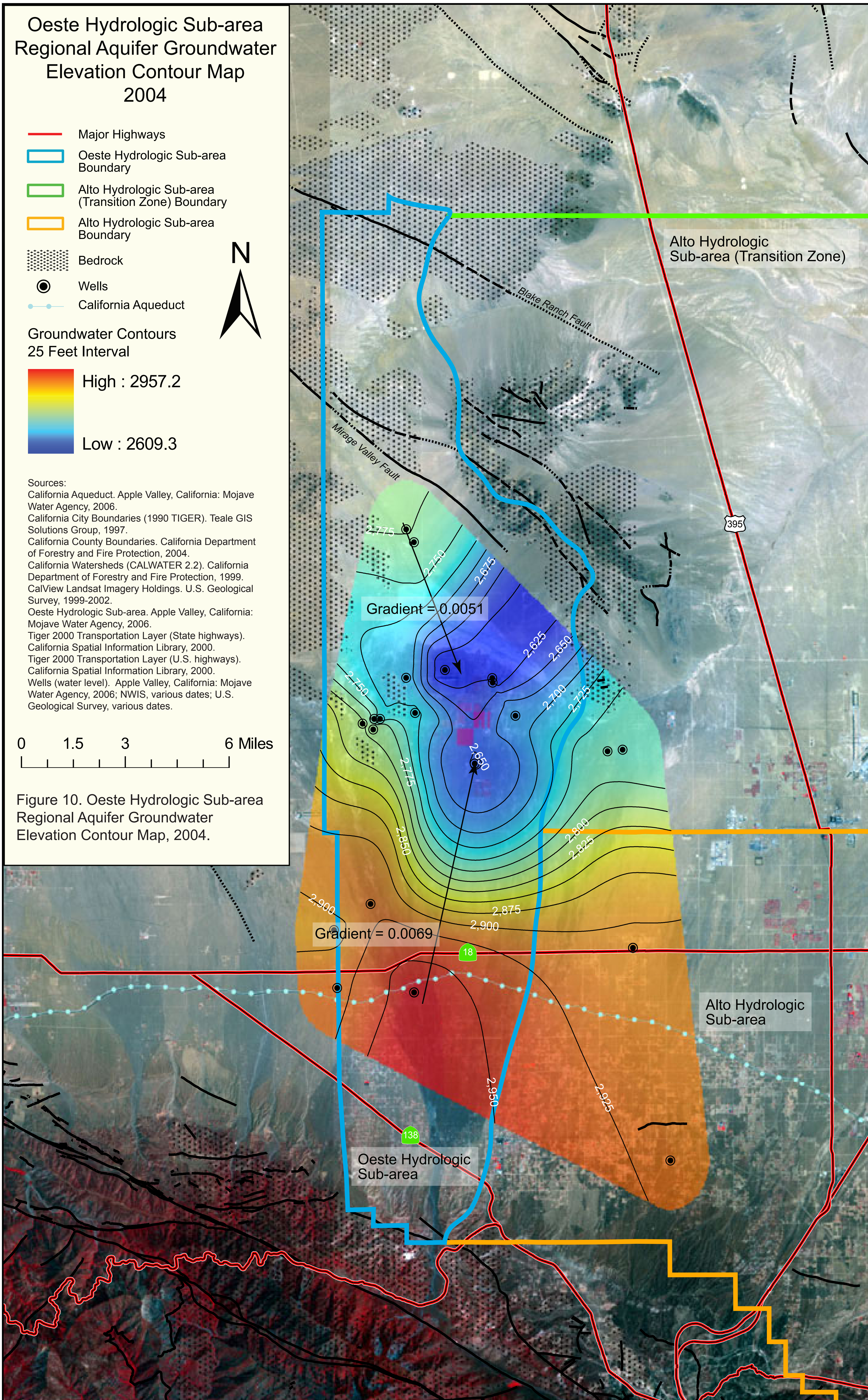


Figure 10. Oeste Hydrologic Sub-area Regional Aquifer Groundwater Elevation Contour Map, 2004.

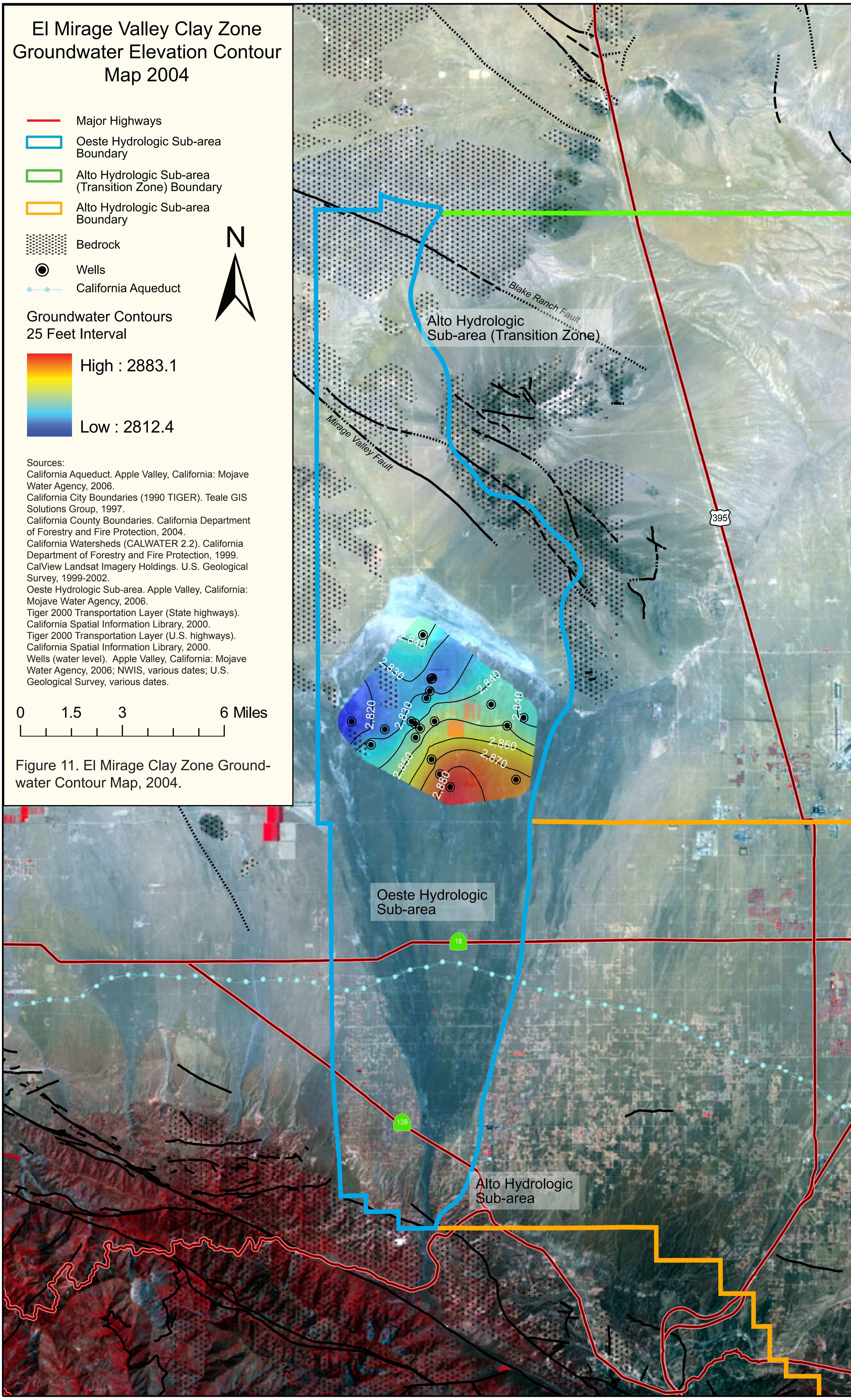


Figure 11. El Mirage Clay Zone Groundwater Contour Map, 2004.

4.3 Hydrograph Analysis

Groundwater hydrographs were created for all 187 wells within the study area (Appendix A-1: Groundwater Hydrographs; Figure 9: Oeste Hydrologic Sub-area Location of Wells). Based on the hydrographs, there appears to be little variation in groundwater levels for the regional (lower) aquifer system across the entire El Mirage Valley groundwater basin. Any fluctuations in groundwater levels are attributable to seasonal effects (particularly wet or dry years). The groundwater data and geologic cross-sections were used to distinguish between the El Mirage Valley and Upper Mojave River Valley groundwater basins. The hydrographs suggest relatively stable groundwater conditions with only minor fluctuations. The analysis used groundwater levels from 179 wells for the period of 1990 to the present and from eight wells from the period from 1994 to the present. These figures show that water levels have been stable with only minor [< 10 ft (3 m)] fluctuations over the past 15 years. There is however, a very slight downward trend in groundwater levels (Appendix A-1: Groundwater Hydrographs) that may require additional monitoring in the future.

4.4 Groundwater Flow Out of Sheep Creek

Groundwater flow out of Sheep Creek wash is the primary source of drinking water for the communities of Phelan and Adelanto. Sheep Creek Water Company, on average, pumps 500 + acre-ft/yr of groundwater near the mouth of Sheep Creek wash [GeoConsultants Inc., 2005]. Groundwater flow from Sheep Creek originates from the San Gabriel Mountains, in the southern portion of the El Mirage Valley watershed. Horne [1989] calculates that based on average rainfall within this portion of the watershed, approximately 7,147 acre-ft/yr of recoverable water exists as subsurface flow. This is significantly higher than the DWR [1967] value of 3,300 acre-ft/yr. Further research will be required to constrain subsurface flow estimates through this area.

4.4.1 Sheep Creek Wash Groundwater Flow Analysis

A simplified flow analysis from Sheep Creek wash to the El Mirage Valley groundwater basin was also conducted for this report. Utilizing several sources of information [Sheep Creek Water Company data; DWR, 1967; Horne, 1989; GeoConsultants, 2005], a generalized cross-section was constructed (Plate 3c: Generalized Geology Cross-section D-D', E-E', Insert A and Insert B). Aquifer hydraulic conductivities coupled with the cross-sectional area were used to calculate ranges of subsurface flow from the Sheep Creek wash. Based on these simplified calculations, flow values from Sheep Creek wash range from a low of 1,340 (acre-ft/yr) to a high of 24,000 (acre-ft/yr) (Table 6: Range of Yearly Discharge Values acre-ft/year). The high seems unreasonable based on the hydrographs used for this study and the lack of large changes in storage. The more reasonable range is 1,340 – 8,000 acre-ft/year [DWR, 1967; Horne, 1989].

Table 6: Range of Yearly Discharge Values (acre-ft/yr)*.

Discharge (Q) (acre-ft/yr)		**Hydraulic Conductivity (K) (ft/day)**			
		50	**100**	**150**	**300**
Thickness (b) (ft)	**100**	1,340	2,700	4,000	8,000
	200	2,680	5,400	8,000	16,000
	300	4,000	8,000	12,000	24,000

*Based on a Gradient of 0.04 ft/ft [Winfield, 2000].

4.5 Groundwater Production and Usage

Historically, groundwater production in the Oeste Sub-area has primarily been for agricultural purposes. Over the last 20 years, housing development and municipal production in the region has increased and has replaced agricultural production. Farming in the "High Desert" has slowed over the last few decades and agricultural activities are expected to follow current downward trends in the Oeste Sub-area. Dairy will most likely remain stable as long as the two active dairy operations (Meadowbrook and Hettinga) choose to remain in operation. Industrial uses may increase slightly over time but currently do not make up a material amount of production in the basin. Municipal production is expected to increase over time to serve the rapidly growing communities of Pinon Hills and Phelan. Domestic uses [adjudicated domestic purveyors and non-adjudicated domestic producers (minimal producers)] are expected to increase slightly over time but will most likely be greatly outpaced by municipal demands.

The USGS estimated groundwater production in the region to be approximately 2,200 acre-ft/yr from the period between 1931 and 1990. Based on USGS estimates, less than 1,000 acre-ft/yr was produced from the Oeste Sub-area from 1931 to the mid-1950's. Since the mid-1950's, groundwater production steadily increased due to more agricultural activities, and new additional municipal demand. Annual groundwater production in the Oeste Sub-area peaked in the early 1990's at approximately 7,500 acre-ft/yr and subsequently declined to approximately 5,000 acre-ft/yr.

Table 7 below (Groundwater Production in the Oeste Sub-area) shows monitored groundwater production in the Oeste Sub-area from 1993 to 2006. Production data is provided by the Mojave Basin Area Watermaster. Figures 13, 14 and 15 show areas and volumes of groundwater production for major producers (>10 acre-ft groundwater production per year) for water years 1993-94, 1999-2000 and 2005-06, respectively (Figure 12: 1993-1994 Water Production and Population Centers in the Oeste Sub-area; Figure 13: 1990-2000 Water Production and Population Centers in the Oeste Sub-area; and Figure 14: 2005-2006 Water Production and Population Centers in the Oeste Sub-area). The majority of minimal producers (untracked groundwater producers <10 acre-ft/yr, generally consisting of small domestic users) are located in the community of El Mirage.

Table 7. Groundwater Production in the Oeste Sub-area (acre-ft/yr).

	Agriculture	Dairy	Small Domestic	Industrial	Municipal	Minimal Producer*	Total
1993-1994	4,073	395	154	8	2,184	220	7,034
1994-1995	3,089	489	34	7	2,004	223	5,846
1995-1996	3,569	376	36	7	2,375	226	6,589
1996-1997	3,563	420	28	8	2,384	229	6,632
1997-1998	2,042	1,005	19	7	2,151	232	5,456
1998-1999	1,853	624	23	9	2,626	235	5,370
1999-2000	1,740	492	24	10	2,651	238	5,155
2000-2001	1,314	511	23	9	2,584	241	4,682
2001-2002	1,651	571	83	10	2,849	244	5,408
2002-2003	1,427	511	28	11	2,703	247	4,927
2003-2004	1,639	544	18	12	2,991	250	5,454
2004-2005	1,695	329	11	12	2,645	253	4,945
2005-2006	1,425	644	16	13	2,805	256	5,159

*Estimated untracked production (small domestic).

4.6 Land Subsidence

Land Subsidence is a gradual settling or sinking of the ground surface with little or no horizontal movement and typically accompanied by fissuring. The pore spaces within an aquifer are supported by a combination of the aquifer's granular skeleton (sedimentary grains) and the fluid pressure exerted by groundwater [Meinzer, 1928]. Subsidence occurs when large amounts of groundwater are withdrawn, which causes compression of the aquifer due to the weight of the overlying sediments. This compression results in an irreversible reduction of pore space within the aquifer. In groundwater basins like El Mirage, where the aquifer system includes fine-grained unconsolidated sediments, subsidence can occur when there are extensive groundwater level declines.

A Global Positioning System (GPS) survey conducted in 1998 by Sneed et al. [2003], coupled with historical ground elevations (back to 1944) were used to determine land subsidence in the Oeste Hydrologic Sub-area. From the GPS data, measurements indicate that between 1995 and 1999, as much as 0.16 ft (50 mm) of subsidence occurred. Sneed et al. [2003] suggest that the pre-consolidated stress of the aquifer may have been exceeded during periods of increased groundwater production and that aquifer compaction is complete in these areas. This observation is supported by only two water level readings, where a decline of 8 ft (2.4 m) was recorded. MWA and the USGS will continue to monitor land subsidence within the El Mirage area.

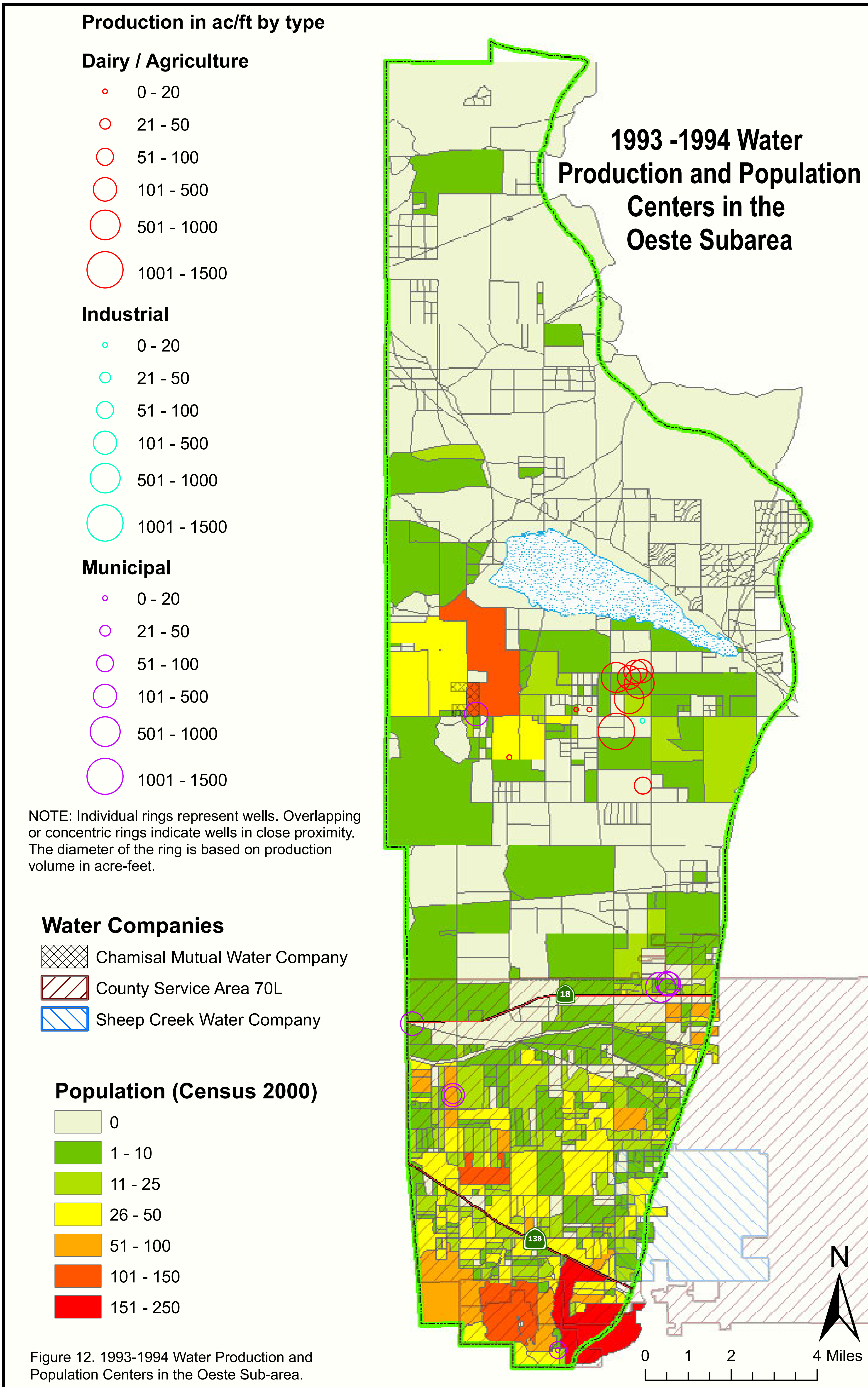


Figure 12. 1993-1994 Water Production and Population Centers in the Oeste Sub-area.

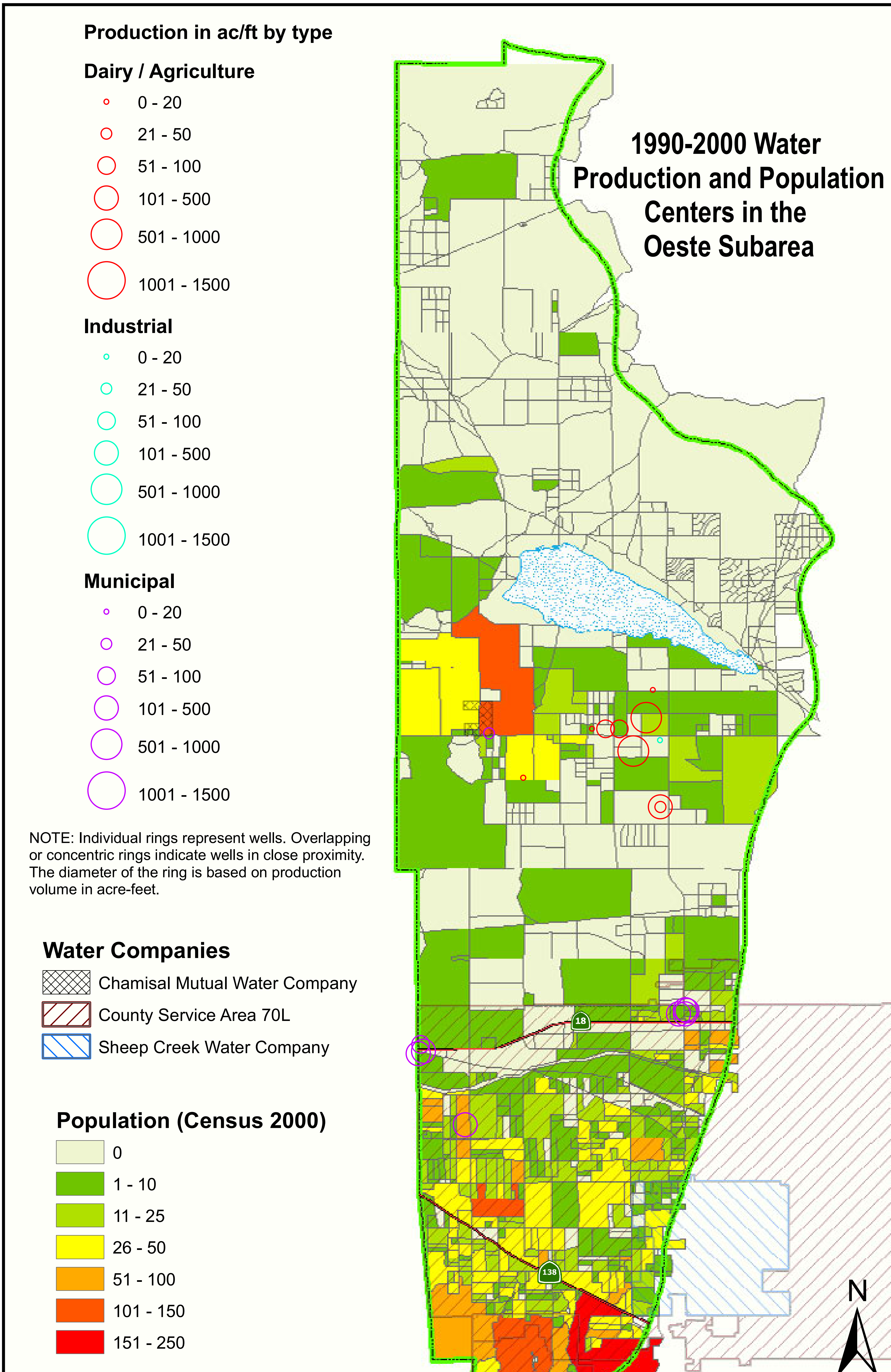


Figure 13. 1990-2000 Water Production and Population Centers in the Oeste Sub-area.

Oeste Hydrologic Sub-area Precipitation and Evapotranspiration Map

Major Highways
Oeste Hydrologic Sub-area Boundary
El Mirage Watershed
California Aqueduct

Evapotranspiration Zones

High Desert Valleys
Mid-Central Valley, Southern Sierra Nevada, Tehachapi and High Desert Mountains

Precipitation (inches)

3.5
4.5
8
9
11
14
18
22.5
27.5
35

Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
California County Boundaries (1:24,000). California Department of Forestry and Fire Protection, 2004.
California Precipitation. Teale GIS Solutions Group, 1997.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
Digital Elevation Model (7.5'). U.S. Geological Survey, 1995.
Etozones. Jones, D., Eching, S., and Snyder, R., 1997.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.

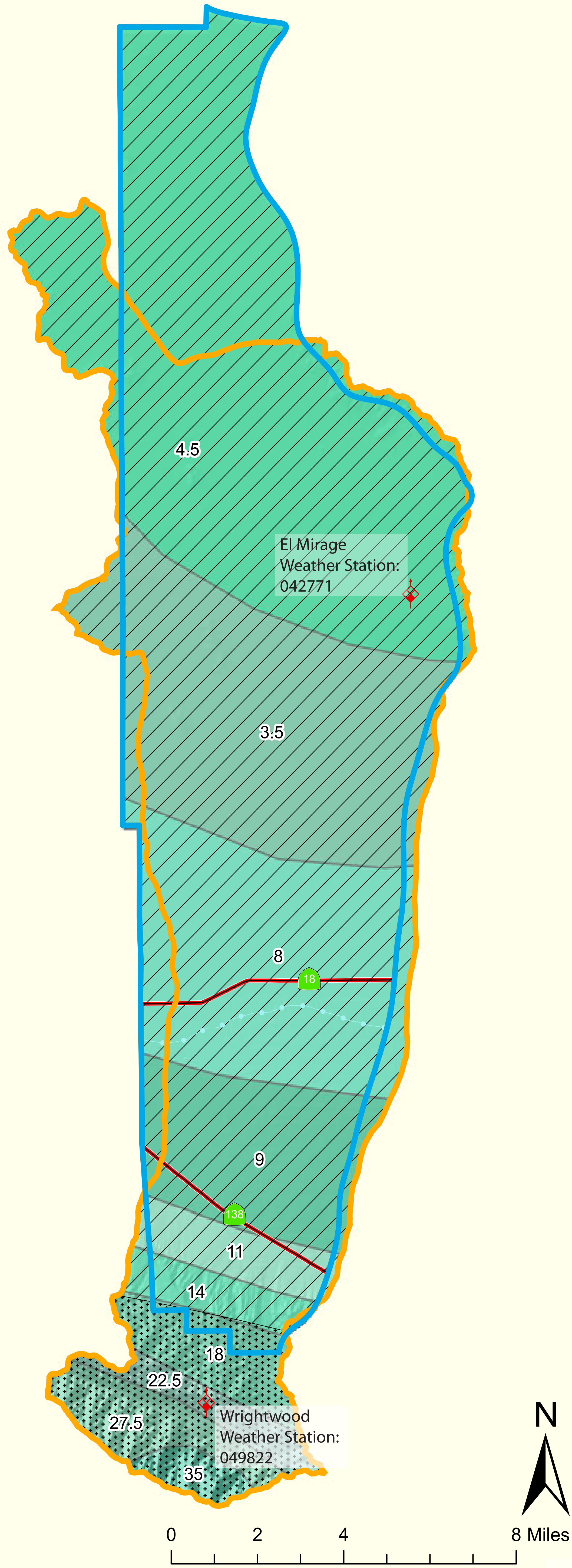


Figure 4. Oeste Hydrologic Sub-area Precipitation and Evapotranspiration Map

4.7 Water Budget Analysis

Analysis of general water budgets yields insight to the hydrologic system at work within a specific region. Water budgets take into consideration various parameters, including soil characteristics, weather (precipitation, temperature, and evapotranspiration), surface waters, infiltration, groundwater flow, and groundwater production. To calculate a budget for the study site, it is necessary to combine past region-wide water budgets with known site-specific parameters.

Water budgets for the Oeste Hydrologic Sub-area were calculated using a general water budget equation (Table 8: Water Budget Equations). Based on the relatively stable groundwater levels, it is assumed that there has been little change in storage within the study area (inflow generally equals outflow). Precipitation contributions to groundwater and recharge (return flow) are not well understood across the entire Oeste Hydrologic Sub-area and are sensitive variables in water budget calculations. Also, perennial overland inflow (Sheep Creek) and outflow was considered insignificant in the Oeste Hydrologic Sub-area water budget. This is due to the lack of stream gauging data as well as the fact surface water rapidly infiltrates into the Sheep Creek wash. Primary recharge to the basin is considered to be through flow (under flow) through the Sheep Creek wash area. This report focuses on water budget calculations presented by other researchers and groups. In some cases, only some of the water budget inputs and outputs are calculated. Groundwater recharge was calculated by GeoConsultants [2005] to represent 15% of the annual direct precipitation. The remaining 85% was assumed to be lost to evapotranspiration (ETo). Of the calculated runoff, 20% is assumed to be contributing to deep percolation [GeoConsultants Inc., 2005]. The USGS [Stamos, et. al., 2001] calculated the only water input into the Oeste Sub-area as mountain front recharge at approximately 1,940 acre-ft/yr. The Mojave Basin Area Watermaster assumes 1,500 acre-ft/yr of input as ungauged surface water inflow.

Hydrograph analysis suggests that water levels have only fluctuated slightly over the past 15 years with a slight trend downwards. Since the hydrograph analysis illustrates little change in storage, the amount of groundwater input to the system must be close to those of the output or possibly slightly less. Therefore, the excess water calculated by Horne [1989] must over estimate the input to the groundwater system or represent the excess water that flows from the Oeste Hydrologic Sub-area and into adjacent hydrologic regions.

Table 8: Water Budget Equations.

Inflow = Outflow ± changes in storage **Inflow:** interflow, precipitation, return flow, and overland inflow **Outflow:** through flow, evaporation, transpiration, surface runoff, infiltration, overland outflow, and pumping

Source: Fetter [2001]. For definition of above terms see section 9.0

Table 9: Oeste Hydrologic Sub-area watershed groundwater inputs.

Annual Average (acre-ft)	[DWR, 1967]	[Horne, 1989]	[GeoConsultants, 2005][1]	[Stamos, et. al., 2001][2]	[Mojave Basin Area Watermaster][3]
Surface inflow	-	3,300	1,085	-	1,500
Subsurface inflow	1,100	7,147	-	2,990	-
Precipitation	-	3,654	7	-	-
Imported water	-	-	-	-	-
Total	**NA**	**14,101**	**1,092**	**2,990**	**1,500**

[1] Based on Sheep Creek Water Company well field only.
[2] 1931-1990 average
[3] 2004-05 water year

Table 10: Oeste Hydrologic Sub-area watershed groundwater outputs.

Annual Average (acre-ft)	[DWR, 1967]	[Horne, 1989]	[GeoConsultants, 2005][1]	[Stamos, et. al., 2001][4]	[Mojave Basin Area Watermaster][5]
Surface outflow	-	-	5,424	-	-
Subsurface outflow	250	1,700	560[2]	2,392	350
Consumptive use	-	4,300	532[3]	2,196	2,700
Total	**NA**	**6,000**	**-**	**4,588**	**3,050**

[1] Based on Sheep Creek Water Company well field area.
[2] Calculated from Sheep Creek Water Company annual recharge minus annual withdrawal.
[3] Based on Sheep Creek Water Company well field withdrawals only.
[4] 1931-1990 average
[5] 2004-05 water year

Table 11: Oeste Hydrologic Sub-area Groundwater Budget Calculations.

Annual Average (acre-ft)	[Horne, 1989]	[Stamos, et. al., 2001[[1]	[Mojave Basin Area Watermaster][2]
Total input	14,101	2,990	1,500
Total output	6,000	4,588	3,050
Total Water Budget	**+8,101**	**(1,598)**	**(1,550)**

[1] 1931-1990 average
[2] 2004-05 water year

Based on a review of available water budget data prepared by others, it appears that the majority of researchers conclude that the annual average water supply to the Oeste Sub-area is most likely between 1,000 to 3,000 acre-ft/yr. The best contemporary estimates of water being removed from the system [Stamos, et. al., 2001 and the Mojave Basin Area Watermaster], estimate an annual budget deficit of approximately 1,600 acre-ft/yr. These estimates appear reasonable when compared to water levels in the region which show a gradual downward trend. More work is needed to establish an actual basin safe yield for the sub-area although based on current water budget estimates, annual volumes groundwater that can be totally consumptively used in the Oeste sub-area without mining the basin will most like fall somewhere in the lower portion of the range of 1,500 to 3,000 acre-ft/yr.

5.0 Water Chemistry

5.1 General Water Chemistry

Groundwater is just one part of the water cycle. In areas such as the Oeste Hydrologic Sub-area, where surface waters are limited and not considered a major source of fresh water, groundwater becomes the only source of water. Groundwater is utilized for drinking, irrigation, and mining among many other uses. The chemical characteristics of these waters is a major concern for both public and private sectors, such as the MWA and the USGS, and is the focus of this section. MWA is constantly updating their database of groundwater chemistries and are incorporating sampled wells into their "Key Well Program."

5.1.1 Water Residence Time and Pathways

Two physical factors are particularly important to the chemical composition of water: the residence time and the pathways or routes along which water moves through the hydrologic system. Residence time (contact time between groundwater and sediments) in a particular environment allows more time for reactions to occur between water and the materials in the environment. Subsurface sediments can filter out many impurities in the groundwater supply as well as changing the chemical composition of the groundwater. Water pathways also play an important role in the chemical composition of water. These pathways determine which materials water contacts during its passage through the hydrologic system. In general, water that follows along shallow pathways tend to contact more weathered and typically less reactive materials than waters that move along deeper pathways. Therefore, the travel time of groundwater and the pathways along which the water moves can strongly affect the chemical composition of the sampled groundwater. Water quality within the basin was evaluated based on a lower, more regional aquifer and a perched or shallow groundwater system surrounding EL Mirage (dry) Lake.

5.1.2 Water Quality Standards

Water quality standards are designed to protect the public. Standards are developed based on the intended use of the water (drinking, agriculture, industrial use, etc.). National Primary Drinking Water Regulations (NPDWR's or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. National Secondary Drinking Water Regulations (NSDWR's or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (taste, odor, or color) in drinking water. United States Environmental Protection Agency (USEPA) recommends secondary standards to water systems but does not require public water systems to comply. However, individual states may choose to adopt them as enforceable standards. Table 12 (Drinking Water Quality Standards) refers to the standards for various chemical ions, physical water quality, and contaminants [State of California Department of Health Services (CDHS), 2006]. Contaminants which are not currently subject to any proposed or promulgated national primary drinking water regulation (NPDWR), are known or anticipated to occur in public water systems, and may require regulations under Safe Drinking Water Act are known as unregulated contaminants.

Table 12: Primary Drinking Water Quality Standards.

MCLs, DLRs, and PHGs for Regulated Drinking Water Contaminants

Units are in milligrams per liter (mg/L), unless otherwise noted.
MCL (Maximum Contaminant Limit)
DLR (Detection Limits for purpose of Reporting)
PHG (Public Health Goal)

Contaminant	**MCL**	**DLR**	**PHG**	**Date of PHG**
Chemicals with MCLs in 22 CCR §64431—Inorganic Chemicals				
Arsenic - The federal MCL is 0.010 mg/L	0.01	0.002	0.000004	2006
Chromium, Total - OEHHA withdrew the 1999 0.0025-mg/L PHG in November 2001	0.05	0.01	withdrawn	1999
Chromium-6 **-** MCL to be established - currently regulated under the total chromium MCL	--	0.001	--	--
Nitrate (as NO_3)	45	2	45	1997

Source: California Department of Health Services (CDHS), Division of Drinking Water and Environmental Management – Updated December 22, 2006.

Table 12a: Secondary Drinking Water Quality Standards.

Constituent	Secondary MCL (mg/L) Recommended	Secondary MCL (mg/L) Upper	Secondary MCL (mg/L) Short Term
Chloride (Cl^-)	250	500	600
Sulfate (SO_4^{2+})	250	500	600
Total Dissolved Solids (TDS)	500	1,000	1,500

Source: CDHS [2003].

5.2 Ion Water Chemistry

Many chemical compounds dissolve within water. Electrolytes, which dissolve in distilled water, increase conductivity and form electrically charged particles called ions. An ion can be defined as an electrically charged atom or group of atoms in solution. Because the solution as a whole is electrically neutral, there are two types of ions: one negative charge and one positive charge. Anions are negatively charged ions and cations are positively charged ions. When a molecule dissociates (ionizes) in water, the total charge before and after the reaction must be the same. This condition is called electroneutrality. A reaction not in equilibrium will adjust itself under stress until equilibrium is re-established. Changing the temperature, pressure, or concentration of a constituent in a compound will change its equilibrium and cause a reaction(s) to return the solution to equilibrium. Many impurities exist, however, as ions in natural waters (i.e., cations such as magnesium, sodium, and calcium; anions such as chloride, sulfate, and nitrate) these electrically charged dissolved particles make water a good conductor of electricity. Conversely, pure water has high electrical resistance, which is frequently used as a measure of its purity. A series of chemistry star diagrams for major cations and anions for selected wells in the Oeste Hydrologic Sub-area is displayed on Plate 4 (Plate 4: Groundwater Chemistry for specific wells located throughout the Oeste Hydrologic Sub-area). Water chemistry is also shown for the lower regional aquifer chemistry as it is spatially mapped (Plate 5: Regional Groundwater Chemistry). Plate 6, illustrates the groundwater quality of the shallow water wells within the central El Mirage Valley area (Plate 6: El Mirage Clay Zone Generalized Water Quality). For a listing of water chemistry results see Appendix B-3: Star Diagrams.

5.2.1 Magnesium

Magnesium is not a regulated constituent by either the USEPA or State of California. In spite of the higher solubility of most of its compounds, the magnesium content in fresh water is generally below that of calcium.

The average regional lower aquifer magnesium concentration in the Oeste Hydrologic Sub-area is **15.16 mg/L**. The highest groundwater concentrations appear to be where Sheep Creek exits the mountains. As groundwater moves north towards the center of the basin, magnesium levels decline. Slightly higher concentrated water appears to be drawn into the Oeste Sub-area from the east due to the heavy agricultural pumping.

5.2.2 Sodium

Sodium is not a regulated constituent in drinking water by both the USEPA and State of California. Risks of high sodium intake include possible high blood pressure in susceptible individuals. Anthropogenic sources of excess sodium are primarily from septic systems.

The average regional lower aquifer sodium concentration in the Oeste Hydrologic Sub-area is **69.95 mg/L**. Generally, sodium is high towards El Mirage (dry) Lake. High regional aquifer concentrations exist near the northeastern portion of the basin and appear to be associated with the El Mirage Dry Lake. The upper perched aquifer shows readings of sodium ranging from a low of **1.22 mg/L** to a high of **94.10 mg/L**.

5.2.3 Calcium

Calcium is not a regulated constituent by either the USEPA or State of California for drinking water. Calcium enters in the groundwater through rock weathering, atmospheric precipitation, as cyclic salt from seawater, or from industrial emissions. It is also a common constituent in soil fertilizer.

The average regional lower aquifer calcium concentration in the Oeste Hydrologic Sub-area is **65.92 mg/L**. Groundwater exiting the mountains at Sheep Creek tends to have slightly elevated concentrations of calcium (above 100 mg/L). Concentrations are generally lower towards the central portion of the basin; except, it appears that elevated calcium concentrated water is being drawn into the basin from the east. The upper perched aquifer has calcium concentrations ranging from a low of **9.41 mg/L** to a high of **54.0 mg/L**.

5.2.4 Chloride

Secondary MCL (mg/L) Recommended	Secondary MCL (mg/L) Upper	Secondary MCL (mg/L) Short Term	Noticeable effects above the Secondary MCL
250	500	600	Salty taste

Source: CDHS [2003].

Chloride is regulated as a secondary contaminant in drinking water by the USEPA and State of California. The secondary maximum contaminant limit (Secondary MCL) for chloride is **250 mg/L**. Risks or effects include high blood pressure, salty taste, corroded pipes, blackening of fixtures and appliances, and pitting of stainless steel. Sources for contamination include fertilizers, animal sewage, septic systems, and industrial wastes. A small portion of chloride found in drinking water is derived from the weathering of rocks.

The average regional lower aquifer chloride concentration in the Oeste Hydrologic Sub-area is **20.24 mg/L**. Elevated concentration (>100 mg/L) are located around El Mirage (dry) lake, whereas the remaining portion of the basin is generally under **25 mg/L**.

5.2.5 Sulfate

Secondary MCL (mg/L) Recommended	Secondary MCL (mg/L) Upper	Secondary MCL (mg/L) Short Term	Noticeable effects above the Secondary MCL
250	500	600	Salty taste

Source: CDHS [2003].

Sulfate is regulated as a secondary contaminant in drinking water by the USEPA and State of California. The Secondary MCL for sulfate is **250 mg/L**. Risks or effects include bitter, medicinal taste, scaly deposits, corrosion, laxative effects, and "rotten-egg" odor. Sources include animal sewage, septic systems, sewage, industrial waste, natural deposits, or salts. Considerable amounts of sulfates are derived from anthropogenic air-pollution. Sulfate is only a minor constituent in igneous rocks.

The average regional lower aquifer sulfate concentration in the Oeste Hydrologic Sub-area is **198.78 mg/L**. The highest concentrations are near El Mirage (dry) Lake with concentrations over **600 mg/L**. The higher concentrated waters are located in the northeastern and northwestern portion of the study area. The upper perched aquifer shows sulfate readings ranging from **14.7 mg/L** to **229.0 mg/L**.

5.2.6 Nitrate (as NO_3)

Primary MCL (mg/L)	Public Health Goal (mg/L)	Potential health effects from ingestion of water	Sources of contaminant in drinking water
45	45	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill, and if untreated, may die. Symptoms include shortness of breath and "blue-baby" syndrome.	Runoff from fertilizer use, leaching from septic tanks, sewage, and erosion of natural deposits.

Source: CDHS [2006].

Nitrate (as NO_3) has a primary maximum contaminant level (Primary MCL) of **45 mg/L** for drinking water. Risks or effects associated with high levels of nitrate (as NO_3) include methemoglobinemia or "blue baby" syndrome in infants. Sources include livestock facilities, septic systems, manure lagoons, fertilizers, household waste-water, and natural deposits. Nitrate is also defined as fertilizer consisting of sodium nitrate or potassium nitrate.

The average regional lower aquifer nitrate (as NO_3) concentration in the Oeste Hydrologic Sub-area is **7.35 mg/L**. Nitrate (as NO_3) concentrations are all below the regulated primary MCL of **45 mg/L**. The highest nitrate (as NO_3) concentration is **20.0 mg/L** near the southern portion of the basin. The upper perched aquifer, where one would assume would have the highest readings actually resulted in lower readings of **0.3** to **4.70 mg/L** with an average of only **1.72 mg/L**.

5.3 Miscellaneous Water Chemistry

5.3.1 Arsenic

Primary MCL (mg/L)	Public Health Goal (mg/L)	Potential health effects from ingestion of water	Sources of contaminant in drinking water
0.01 (10.0 µg/L)	0.000004 (0.004 µg/L)	Skin damage or problems with circulatory systems, and may have increased risk of cancer.	Erosion of natural deposits, runoff from orchards, runoff from glass and electronics production wastes.

Source: CDHS [2006].

Arsenic is regulated as a primary contaminant in drinking water. Currently the primary MCL for arsenic is **0.01 mg/L (10.0 µg/L)**. Arsenic comes from the erosion of natural deposits, runoff from orchards, and runoff from glass and electronics production. Potential health risks associated with arsenic include skin damage, circulatory system problems and an increased risk of cancer.

The average regional lower aquifer arsenic concentration in the Oeste Hydrologic Sub-area is **0.00383 mg/L (3.83 µg/L)**. Based on the regional groundwater chemistry the only location that has elevated arsenic is in the very central portion of the basin, however this is still below the MCL of **10.0 µg/L**. The upper perched aquifer shows arsenic readings ranging from **1.0 µg/L** to **5.20 µg/L** with an average of **2.43 µg/L**.

5.3.2 Chromium

Primary MCL (mg/L) for Chromium (total)	Potential health effects from ingestion of water	Sources of contaminant in drinking water
0.05 (50.0 µg/L)	Allergic dermatitis.	Discharge from plating facilities, steel and pulp mills and erosion of natural deposits.

Source: CDHS [2006].

Chromium (total) is regulated as a primary contaminant in drinking water. Currently the primary MCL for chromium (total) is **0.05 mg/L (50.0 µg/L)**. Chromium (total) is a metal found in natural ore deposits. Chromium (total) is mostly used in metal alloys such as stainless steel, protective coatings on metal, magnetic tape and pigments for paints, cement, paper, rubber, composition floor covering, and wood preservatives.

The average regional lower aquifer chromium (total) concentration in the Oeste Hydrologic Sub-area is **0.021 mg/L (21.0 µg/L)**. During the 2006 water quality sampling event conducted as part of this study, chromium VI was detected in 12 of the 21 wells sampled. Detected concentrations ranged from **0.0013 mg/L to 0.01 mg/L (1.3 µg/L to 10.0 µg/L)**. The USGS has documented naturally occurring chromium VI in alluvial aquifers of the western Mojave Desert at concentrations up to **0.06 mg/L (60.0 µg/L)** [Ball and Izbicki, 2004; Khachikian et al., 2004; NWIS 2006].

The CDHS currently regulates chromium VI under the chromium (total) primary MCL of **0.05 mg/L (50 µg/L)** (http://www.dhs.ca.gov/ps/ddwem/chemicals/Chromium6/default.htm). California Health & Safety Code Section 116365.5 required DHS to adopt a MCL for chromium VI by January 1, 2004. California Health & Safety Code Section 116365(a) requires establishment of an MCL at a level as close to the public health goal (PHG) established for the contaminant as is technically and economically feasible. According to DHS, a MCL for chromium VI has not been established because a PHG for chromium VI is not yet available. Chromium VI concentrations in the Oeste Sub-area should be monitored and re-evaluated upon establishment of a MCL for chromium VI.

5.3.3 Total Dissolved Solids

Secondary MCL (mg/L) Recommended	Secondary MCL (mg/L) Upper	Secondary MCL (mg/L) Short Term	Noticeable effects above the Secondary MCL
500	1,000	1,500	Hardness, deposits, colored water, staining, and salty taste.

Source: CDHS [2003].

Total dissolved solids (TDS) is regulated as a secondary contaminant. The Secondary MCL for TDS is **500 mg/L**. A high TDS results in hard, salty, colored water that stains and produces deposits on or in pipes and faucets.

The average regional lower aquifer TDS concentration in the Oeste Hydrologic Sub-area is **435 mg/L**. The majority of the basin has waters that are above **300 mg/L** and less than **500 mg/L**. Groundwater exiting the mountains near Sheep Creek has TDS concentrations ranging from **400 to 600 mg/L**. The El Mirage dry lake region has the highest reported TDS readings which are in excess of **1,000 mg/L** (twice that of the Secondary MCL of **500 mg/L**). The upper perched aquifer shows TDS concentrations ranging from a low of **46.9 mg/L** to a high of **1,190.0 mg/L**.

6.0 Conclusions

6.1 Geology

1. The geomorphology and depositional history of El Mirage Valley is the result of the interaction between the Transverse Ranges, namely the San Gabriel Mountains to the south and a desert semi-bolson to the north. El Mirage Valley is the semi-bolson formed between the Adobe and Shadow Mountains. Very young alluvial deposits comprise the Sheep Creek fan and the fan consists mostly of Pelona Schist debris [Horne, 1989]. Eolian sand is also widespread on the fan [Miller and Bedford, 2000]. Underlying these younger sediments are deposits exposed in the in-facing bluffs and San Gabriel Mountains that have been described as, from oldest to youngest respectively: the Phelan Peak Formation, the Harold Formation, the Shoemaker Gravel and the Older alluvium of Noble [1953], Foster [1980], and Weldon [1984].

2. Underlying El Mirage (dry) Lake and extending southwards into the subsurface for some 19,000+ feet (6 km) is a thick clay sequence with disconnected but extensive interbeds of sand and gravel. These lenses are primary sources of perched or semi-confined groundwater in the area around El Mirage (dry) Lake.

3. The main faults that cut the El Mirage Valley groundwater basin are the Mirage Valley fault and cutting the Swarthout Valley is the San Andreas Fault. A more northerly oriented and isolated structure has been proposed by Dibblee [1960] and DWR [1966], which is corroborated with gravity linear lows of Mabey [1960] and Subsurface Survey, Inc. [1990]. The structure extends from near Lovejoy Buttes to just north of the mouth of Sheep Creek.

6.2 Groundwater

1. Historical groundwater flow direction for the Oeste Hydrologic Sub-area is from the southern proximal portion of Sheep Creek wash fan to the northern central portion of Oeste Hydrologic Sub-area. However, due to the Sheep Creek wash fan morphology, a portion of flow exits the Oeste Hydrologic Sub-area and flows into the Alto Hydrologic Sub-area to the northeast. Further groundwater may be moving from other canyons and small streams from the west into El Mirage valley. However, more detailed studies will need to be completed to prove or disprove this hypothesis.

2. The upper perched aquifer is isolated near the dry lake area and is typically less then 250 ft (75 m) in depth [Horne, 1989]. However, in several places, the depth of the perched layer may be deeper and is interbedded with sands, silts, and gravels. The upper perched aquifer is principally used by single family dwellings and small businesses. Agricultural interests tend to tap into the lower confined aquifer in the vicinity of the dry lake area.

3. The groundwater gradient between the Oeste and Alto Hydrologic Sub-areas is less than 0.0043 ft/ft. Based on the depth to water and gradient calculations, the flow across the Oeste/Alto Hydrologic Sub-area boundary appears to have been relatively the same throughout

the past 10+ years. Groundwater flow direction is complicated by the large alluvial fan complex. Generally, groundwater flow is towards the north, with a component moving towards and into the Alto Hydrologic Sub-area.

4. Groundwater levels have been relatively stable across the Oeste Hydrologic Sub-area with only minor fluctuations over the past 15 years (since 1990). This demonstrates that usage and recharge have not experienced any significant major change over the past 15 years. The groundwater gradients have however increased towards the central portion of the Oeste Hydrologic Sub-area (near the community of El Mirage). This appears to be due to increased pumping of groundwater in this area creating a cone of depression. This area of concentrated groundwater pumping and corresponding groundwater level drawdown (approximately 1 foot/year) has resulted in groundwater flow towards this pumping depression, including water from the Adelanto area towards El Mirage.

5. Groundwater levels within the upper perched zone of the central portion of El Mirage Valley have also experienced slight drops in overall water levels over the past 40 years. In some wells this has been significant (greater than 8 feet (2.4 m)) [Sneed et al., 2003], whereas several areas have seen little decrease and even in one case a slight rise in water levels (hydrograph analysis, section 4.3).

6. Based upon work of others [DWR, 1967; Stamos et al., 2001; Mojave Basin Area Watermaster] a reasonable range would be 1,000 – 3,000 acre-ft/year with the remainder of groundwater recharge being made up of return flow and subsurface flow of groundwater from other sources in the San Gabriel Mountains. Stamos, et. al., [2001] and the Mojave Basin Area Watermaster estimate an annual budget deficit of approximately 1,600 acre-ft/yr. These estimates appear reasonable when compared to water levels in the region which show a gradual downward trend. More work is needed to establish an actual basin safe yield for the sub-area although based on current water budget estimates, annual volumes groundwater that can be totally consumptively used in the Oeste sub-area without mining the basin will most like fall somewhere in the lower portion of the range of 1,500 to 3,000 acre-ft/yr.

7. Based on 2000 Census data, the Oeste Sub-area currently has a sparse population of 7,649 across the 164 square mile (424 km^2) region. Based on SCAG projections, future growth within the Oeste Sub-area will occur south of Highway 18 in the Phelan and Pinion Hills area. Populations in the Phelan and Pinion Hills area are expected to triple by 2030. Populations in the community of El Mirage area are projected to stay at current numbers (less than 1,000). Further population in eastern Antelope Valley (adjacent to the western border of the Oeste Sub-area), is expected to see very little growth through 2030. The population of Lake Los Angeles, located 9 miles (15 km) east of the eastern Oeste Sub-area border, is expected double to approximately 21,000 by the year 2030 and constitutes the highest anticipated growth area adjacent to the Oeste Sub-area in Los Angeles County.

8. The USGS estimated groundwater production in the region to be approximately 2,200 acre-ft/yr from the period between 1931 and 1990. Based on USGS estimates, less than 1,000 acre-ft/yr was produced from the Oeste Sub-area from 1931 to the mid-1950's. From the mid-1950's, groundwater production steadily increased due to increased agricultural activities and

later, increased municipal demand. Annual groundwater production in the Oeste Sub-area peaked in the early 1990's at approximately 7,500 acre-ft/yr and subsequently declined to approximately 5,000 acre-ft/yr.

9. Simple water budget calculations have been prepared by multiple entities within the Oeste sub-area over the past several decades. In general, water budget analyses indicate an average annual deficit of approximately 1,600 acre-ft/yr. Hydrograph analysis of the regional aquifer system indicates that water budget estimates appear reasonable when compared to water levels in the region which show a gradual downward trend. Based on water budget and hydrograph analysis, a safe annual volume of groundwater that can be consumptively used on an annual basis in the Oeste Sub-area is most likely in the lower portion of the range of 1,500 to 3,000 acre-ft/yr.

6.3 Water Quality

1. Water quality throughout the lower regional aquifer in the Oeste Hydrologic Sub-area is generally of good quality. Several locations have experienced a small degradation in water quality over time, mainly those near the El Mirage (dry) Lake. Elevated arsenic levels (**1.2 mg/l**) near the dry lake are higher in concentration than the present MCL (**0.010 mg/L**). The source appears to be natural weathering processes of the Pelona schist, but further research will be needed to completely verify the source.

2. The upper perched aquifer waters are generally of poorer quality than that of the deeper regional aquifer. This is in part due to recharge from the agricultural activities and association with the El Mirage (dry) Lake. Although most of the analyzed ions in the upper perched aquifer show elevated concentrations, the waters still meet state and federal drinking water quality standards. The only exception is arsenic. Arsenic is elevated in several wells along the northeastern edge of the perched aquifer. Variations in water quality may also be attributed to the possibility that groundwater is moving from Los Angeles county and into the Oeste Hydrologic Sub-area lower regional aquifer. This should be further evaluated as part of any future groundwater monitoring program. Other Potential issues may be associated with sampling protocols and should also be re-evaluated as part of future key well program.

6.4 Un-resolved Issues for Future Research

1. Future geophysical work will be needed to focus on determining the depth to and shape of bedrock throughout the Oeste Hydrologic Sub-area.

2. Better delineation and characterization of the confining unit that separates the Oeste Hydrologic Sub-area into an upper unconfined aquifer and a lower regional confined aquifer.

3. More new data is needed to better determine groundwater movement across the western and eastern boundaries of the Oeste Hydrologic Sub-area. This consists of new monitoring wells around sub-area borders and long term monitoring.

4. Future groundwater recharge from adjacent mountains should focus on infiltration and runoff capacities of soils and bedrock fractures in the southern portion of the Oeste Hydrologic Sub-area. This work should also identify spring water contribution to the groundwater system.

5. Return flow (groundwater recharge) from agricultural activities. Irrigation practices have vastly improved since the 1900's. With improved irrigation practices comes more efficient use of water. However, the return flow associated with these practices is not fully understood. Understanding the quantity of return flow will provide a better understanding of the overall groundwater budget. This will also allow for a better prediction of groundwater quality in the Oeste Hydrologic Sub-area.

6. A key well program will need to be established and maintained in order to further delineate groundwater quality and water level and chemistry changes. This will help with overall management of the basin.

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9.0 Glossary of Terms

abandoned well – A well that has been permanently disconnected and filled. Most US states have regulations or guidelines for abandoned well to ensure that contamination cannot move from the surface in the aquifer.

absorption - The process by which substances in gaseous, liquid, or solid form dissolve or mix with other substances.

acidic - The condition of water or soil that contains a sufficient amount of acid substances to lower the pH below 7.0.

acre-foot (acre-ft) - The volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot. Equal to 325,851 gallons or 1,233 cubic meters.

adsorption - The attraction and adhesion of ions from an aqueous solution to the surface.

Advanced treatment – A level of wastewater treatment more stringent than secondary treatment; requires an 85-percent reduction in conventional pollutant concentration or a significant reduction in non-conventional pollutants. Sometimes called tertiary treatment.

advection - The transport of dissolved constituents (i.e., solutes), particulate/colloidal matter, and/or heat by flowing groundwater. Generally, advection is considered synonymous with forced convection.

aeolian (eolian) - Windblown, carried and deposited by wind.

aeration – A process which promotes biological degradation of organic matter in water. The process may be passive (as when waste is exposed to air), or active (as when a mixing or bubbling device introduces the air).

aerobic - Bacteria or processes active only in the presence of molecular oxygen.

agricultural pollution – Farming wastes, including runoff and leaching of pesticides and fertilizers; erosion and dust from plowing; improper disposal of animal manure and carcasses; crop residues, and debris.

alkalinity - The total measurable bases (OH, HCO_3, CO_3) in a volume of water; a measure of a material's capacity to neutralize acids; pH > 7.

alluvial - Pertaining to, or composed of, alluvium or deposited by a stream or running water.

alluvium - A general term for clay, silt, sand and gravel, or similar unconsolidated material deposited by a river as a sorted or semi-sorted sediment in the bed of the river or on its floodplain.

anaerobic - Bacteria or processes active only in the absence of molecular oxygen.

anoxic - Conditions where O2 is absent or present in very low concentrations.

anthropogenic – Created, caused, or induced by human actions.

aqueous solubility – The maximum concentration of a chemical that will dissolve in pure water at a reference temperature

aqueous - 1. Relating to, similar to, containing, or dissolved in water. **2.** Formed from matter deposited by water, as certain sedimentary rocks.

aquiclude - A geologic formation which may contain water (sometimes in appreciable quantities), but is incapable of transmitting significant quantities under ordinary field conditions.

aquifer - A consolidated or unconsolidated geologic unit (material, stratum, or formation) or set of connected units that yields a significant quantity of water of suitable quality to wells or springs in economically usable amounts. Typically is an unconsolidated deposit, or sandstone, limestone or granite

- **confined (or artesian)** - An aquifer that that is immediately overlain by a low-permeability unit (confining layer). A confined aquifer does not have a water table.
- **leaky** - An aquifer that receives recharge via cross-formational flow through confining layers.
- **perched** - A local, unconfined aquifer at a higher elevation than the regional unconfined
- **unconfined (or water-table)** - The upper surface of the aquifer is the water table. Water-table aquifers are directly overlain by an unsaturated zone of a surface water body.
- **aquifer system** - Intercalated permeable and poorly permeable materials that comprise two or more permeable units separated by aquitards which impede vertical groundwater movement but do not affect the regional hydraulic continuity of the system.

aquifer storage - The ability of the aquifer to store water in interconnected pores and fractures. Aquifer storage is quantified by a values referred to as storativity and specific yield.

aquifer system - Two or more permeable units separated at least locally by confining units that impede groundwater movement but do not greatly affect the regional hydraulic continuity of the system.

aquifer test - A test to determine hydraulic properties of an aquifer.

aquifuge - A geologic material, stratum, or formation that neither contains nor transmits water (i.e., has zero or negligible permeability and porosity).

aquitard - A semi-pervious geologic formation, which can store water but transmits water at an overflow rate compared to the aquifer.

area of influence – Area surrounding pumping or recharging within which the water table or potentiometric surface has been changed due to the well's pumping or recharge; Alco called zone of influence

arroyo - A ephemeral streambed of arid and semiarid areas typically with a coarse bed-load sediments and steep channel walls.

artesian aquifer - Commonly used expression, generally synonymous with (but less favored term than confined aquifer. The term "artesian" takes its name from the basin of Artois in France. In the common usage, this implies the existence of flowing wells, but all flowing wells are not artesian nor do all artesian wells flow.

artesian – Hydrostratigraphically confined. In the common usage, this implies the existence of flowing well, but all flowing wells are not artesian nor do all artesian wells flow.

artesian well - A well deriving its water from a confined ("artesian") aquifer.

artificial recharge - The process by which water can be injected or added to an aquifer. Dug basins, wells, or the spread of water across the land surface are all means of artificial recharge.

attenuation – The process of reducing a quantity of a solute or colloid in a groundwater system

available soil moisture - The portion of water in a soil that can be readily absorbed by plant roots. It is the amount of water released between in situ field capacity and the permanent wilting point.

average linear velocity – The specific discharge (darcian velocity) divided by the effective porosity. The average linear velocity is an estimate of the mean rate that water molecules flow.

Background level – 1. The concentration of a substance in an environmental media (air, water, or soil) that occurs naturally or is not the result of human activities. **2.** In exposure assessment, the concentration of a substance in a defined control area, during a fixed period of time before, during, or after a data-gathering operation.

banking - A system for recording qualified air emission reductions for later use in bubble, offset, or netting transactions. (See: emissions trading.)

basalt - A dark colored, extrusive igneous (lava) rock. Basalt is differentiated from other igneous rocks by its chemical composition. The basalt of the Eastern Snake River Plain is thought to have intermittently flowed from numerous vents across the Plain over long periods of time.

baseflow – Part of a stream discharge not attributable to direct runoff from precipitation or snowmelt, usually sustained by groundwater discharging into the stream.

basin - An aquifer or aquifer system whose boundaries are defined by surface-water divides, topographic barriers, or a structural basin and in which the aquifers are isolated from adjacent aquifers.

bedrock - A general term for the rock formation, usually solid, that underlies soil or other unconsolidated materials.

biological contaminants – Living organisms or derivatives (e.g. viruses, bacteria, fungi, mammal, and bird antigens) that can cause harmful health effects when inhaled, swallowed, or otherwise taken into the body.

bolson - extensive, saucer shaped alluvial filled basin almost or entirely surrounded by mountains (per Glossary of Geology)

build-up – The potentiometric surface (or the water table) rise in the vicinity of recharge. It is the vertical distance between the initial and the new potentiometric surface (or the water table in the case of an unconfined aquifer) at a given point.

caliche - A geological formation often found in the Southwestern United States that can be as hard as rock but more closely resembles very dry layered clay which becomes sticky when wet.

cap - A layer of clay, or other impermeable material installed over the top of a closed landfill to prevent entry of rainwater and minimize leachate.

capillarity - The action by which water is raised (or lowered) relative to the water surface because of interaction between the water molecules and the solids of the porous medium. Capillarity can also refer to the movement of a fluid through a porous medium due to this interaction; this is also called imbibition.

capillary fringe - The zone immediately above the water table within which the water is drawn by capillary forces (fluid is under tension). The capillary fringe is saturated, and it is considered to be part of the unsaturated zone.

carbonate - A sediment formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron.

carbonate rock - A rock consisting chiefly of carbonate minerals, such as limestone and dolomite.

clastic - Pertaining to a rock or sediment composed principally of broken fragments that are derived from pre-existing rocks or minerals, and that have been transported some distance from their places of origin.

clay - Soil particles with < 0.004 mm effective diameter.

clay soil - Soil material containing more than 40 percent clay, less than 45 percent sand, and less than 40 percent silt.

coarse - The term used to denote sand and gravel. The use of bentonite in the drilling fluid is recommended when boring in this type of soil conditions.

combined sewer overflows – Discharge of a mixture of storm water and domestic waste when the flow capacity of a sewer system is exceeded during rainstorms.

community water system - A public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

compaction - The processes by which sediment is densified (reduction of porosity or increase in bulk density caused by an increase in the compressive or total stress). In soil mechanics this term is limited to processes involving the expulsion of air from the voids.

conductance - A rapid method of estimating the dissolved solids content of water supply by determining the capacity of a water sample to carry an electrical current. Conductivity is a measure of the ability of a solution to carry and electrical current.

conductivity - A measure of the ability of a solution to carry an electrical current.

cone of depression - A depression in the groundwater table (or potentiometric surface) that has the shape of an inverted cone and develops around a discharge well.

cone of influence - The depression, roughly conical in shape, produced in a water table by the pumping of water from a well.

confined aquifer - An aquifer whose upper, and perhaps lower boundary is defined by a layer of natural material that does not transmit water readily, and retards the vertical movement of water. When a well is installed in a confined aquifer, the water level in the well rises above the top of the aquifer.

confining layer - Geological material through which significant quantities of water can not move, and is located below unconfined aquifers, above and below confined aquifers. Also known as a confining bed.

confining unit - A hydro geologic unit of relatively low hydraulic conductivity, bounding one or more aquifers. (See: aquitard, aquifuge, and aquiclude.)

conjunctive management - Managing surface and ground water as a single system.

consolidation - The reduction of porosity or increase in bulk density caused by an increase in the effective stress, typically concomitant with a decrease in the fluid pressure and the expulsion of water from the voids. In some usages, consolidation is considered synonymous with lithification.

- **primary consolidation** - Decrease in the void ratio (e) as a function of change in the effective stress (σ)

- **secondary consolidation** - Decrease in void ratio (e) as a function of time at a given effective stress (σ)

consumptive use – That part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.

contaminant – A toxic substance in the ground water.

contamination - The degradation of natural water quality as a result of man's activities. There is no implication of any specific limits, since the degree of permissible contamination depends upon the intended end use of the water.

cross contamination - The movement of underground contaminants from one level or area to another due to invasive subsurface activities.

cubic feet per second (cfs) – A rate of flow in streams and rivers. It is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One “cfs” is equal to 7.48 gallons of water flowing each second. As an example, if your car’s gas tank is 2 feet by 1 foot by 1 foot (2 cubic feet), then gas flowing at a rate of 1 cubic foot/second would fill the tank in two seconds.

Darcy's Law – The discharge of water through a unit area of porous medium is directly proportional to the hydraulic gradient normal to the area.

deep percolation - Water that moves downward through the soil profile below the root zone and cannot be used by plants

depression storage - Water stored in surface depressions and therefore not contributing to surface runoff.

detection limit - The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

dike - A low wall that can act as a barrier to prevent a spill from spreading.

dimictic - Lakes and reservoirs that freeze over and normally go through two stratifications and two mixing cycles a year.

direct runoff - Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.

discharge – The release or extraction of water from an aquifer. Typical mechanisms of natural discharge are evapotranspiration by phreatophytes, springs, and drains to surface water bodies. Pumping is a man-caused discharge.

- **mean discharge** - Arithmetic mean of discharges over a given time period.
- **instantaneous discharge** - The discharge at a given instant of time.

discharge, instantaneous – The discharge at a given instant of time

discharge, mean – Arithmetic mean of discharges over a given time period.

discharge area - An area in which groundwater is discharged to the land surface, surface.

dispersion length or dispersivity – The factor which, when multiplied by the average linear velocity estimates the coefficient of hydrodynamic dispersion; either longitudinal or transverse

dissolved oxygen (DO) - The oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced waste treatments are generally designed to ensure adequate DO in waste-receiving waters.

dissolved solids - Disintegrated organic and inorganic material in water. Excessive amounts make water unfit to drink or use in industrial processes.

divide – A topographic high (or ridge) separating surface watershed (catchments). A groundwater divide is an elevated area, line, or ridge of the potentiometric surface separating different groundwater flow systems.

domestic water use – Water used for household purposes, such as drinking, food preparation, bathing, washing clothes, dishes, animals, plumbing, and water lawns and gardens. About 85% of domestic water is delivered to homes by public supply facility, such as a county water department. About 15% of the U.S. population supplies their own water mainly from wells.

Double (or dual) porosity – When two porosities may be associated with a hydrogeological system. An example is a porous rock with a fracture set and primary porosity; such a system may then have two characteristic porosities – one for the fractures and one for the porous matrix. Implied in this definition is that significant flow rates are present in both the fractures and the matrix.

down-gradient - The direction that groundwater flows; similar to "downstream" for surface water.

drainage basin - The area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel.

drawdown - 1. The drop in the water table or level of water in the ground when water is being pumped from a well. **2.** The amount of water used from a tank or reservoir. **3.** The drop in the water level of a tank or reservoir.

drinking water equivalent level – Protective level of exposure related to potentially non-carcinogenic effects of chemicals that are also known to cause cancer.

drought - A prolonged period of low (lower than average) rainfall.

effective grain size (d10) – The grain size corresponding to the 10% finer by weight on the grain-size distribution curve.

effective porosity – The interconnected pore space through which fluids can pass; expressed as a percent of bulk volume. Part of the total porosity will be occupied by static fluid being held to mineral surface by surface tension; so effective porosity will be less than total porosity.

effluent - Wastewater, treated or untreated, that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

effluent stream – 1. A surface stream that flows out of a lake or any branch of a larger stream. **2.** A stream that intersects and receives its water from the water table.

Eh - A measure of the oxidation-reduction state of a solution.

EPA - The Environmental Protection Agency. The federal authority responsible for enforcing the various laws dealing with environmental standards.

ephemeral stream – A stream which flows only briefly after rainfall events.

equipotential line - A line in a two-dimensional groundwater flow field along which the total hydraulic head (the groundwater potential) is constant.

erosion - The wearing away of land surface by wind or water, intensified by land-clearing practices related to farming, residential or industrial development, road building, or logging.

evaporite - A rock or material caused by the precipitation of minerals formed from evaporation of a body of water.

evapotranspiration - The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil; generally measured in $[L^3 /t/ L^2]$.

- **evapotranspiration, actual** - The evaporation that actually occurred under given climatic and soil-moisture conditions.
- **evapotranspiration, potential** - The evaporation that would occur under given conditions if there were unlimited soil moisture.

extraction well - A discharge well used to remove groundwater or air.

fault - A fracture which has experienced translation or movement of the fracture walls parallel to the plane of the fracture.

- **normal fault** - A fault in which the hanging (upper) wall moves down with respect to the foot (lower) wall.
- **reverse fault** - A fault in which the hanging (upper) wall moves up with respect to the foot (lower) wall.
- **strike-slip fault** - A fault in which the movement parallel to the plane of the fracture is parallel to the land (horizontal) surface.

field capacity - The amount of water a soil can hold under natural conditions by capillarity and the suction of plant roots. If the water content is greater than the field capacity then gravitational flow can occur.

flow rate – The rate expressed in gallons – or liters-per hour at which a fluid escapes from a hole or fissure in a tank. Such measurements are also made of liquid waste, effluent, and surface water movement.

formation - A body of rock strata that consists of a certain lithology or combination of lithologies.

fractured formation – A fractured porous medium in which flow rates in the matrix can be assumed to be negligible. Compared with a purely fractured medium and a double porosity medium.

fracture trace – Visible on aerial photographs, fracture traces are natural linear-drainage, soil-tonal, and topographic alignments that are probably the surface manifestation of underlying zones of fractures.

fresh water – Water with a salinity <1000 mg/l of dissolved solids; drinkable or potable water is implied.

friable - Easily crumbled. Friable is used in description of soils and drill cuttings.

geophysical log – A detailed description of all underground features (depth, thickness, type of formation) discovered during the drilling of a well. Also called "geological log."

gravel - Soil or rock particles with an effective grain diameter between 2.0 and 64 mm.

gray water - Domestic wastewater composed of wash water from kitchen, bathroom, and laundry sinks, tubs, and washers.

groundwater - The water contained in interconnected pores below the water table in an unconfined aquifer or in a confined aquifer.

groundwater barrier - Rock, artificial material, or geologic structures with a relatively low permeability that occurs (or is placed) below ground surface, where it impedes the movement of groundwater and thus causes a pronounced difference in the heads on opposite sides of the barrier.

groundwater basin - General term used to define a groundwater flow system that has defined boundaries and may include more than one aquifer underlain by permeable materials that are capable of storing or furnishing a significant water supply. The basin includes both the surface area and the permeable materials beneath it.

groundwater discharge - Ground water entering near coastal waters which has been contaminated by landfill leachate, deep well injection of hazardous wastes, septic tanks, etc.

groundwater barrier - Rock or artificial material with a relatively low permeability that occurs (or is placed) below ground surface, where it impedes the movement of groundwater and thus causes a pronounced difference in the heads on opposite sides of the barrier.

groundwater basin - General term used to define a groundwater flow system that has defined boundaries and may include more than one aquifer underlain by permeable materials that are capable of storing or furnishing a significant water supply. The basin includes both the surface area and the permeable materials beneath it.

groundwater divide - Ridge in the water table, or potentiometric surface, from which groundwater moves away at right angles in both directions. Line of highest hydraulic head in the water table or potentiometric surface.

groundwater flow - The movement of water through openings in sediment and rock that occurs in the zone of saturation.

groundwater mound - Raised area in a water table or other potentiometric surface, created by groundwater recharge.

groundwater recharge - Process of water addition to the saturated zone, or the volume of water added by this process.

hardness - A water-quality indication of the concentration of alkaline salts in water, mainly calcium and magnesium. If the water you use is “hard" then more soap, detergent or shampoo is necessary to raise a lather.

hard water - Alkaline water containing dissolved salts that interfere with some industrial processes and prevent soap from sudsing.

hardness (of water) - The increased quantity of soap required to produce a lather. It is computed as the sum of the polyvalent ion equivalents and typically expressed as an equivalent concentration of CaCO3.

headwater(s) - 1. The source and upper reaches of a stream; also the upper reaches of a reservoir. **2.** The water upstream from a structure or point on a stream. **3.** Small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstream river and main tributaries.

homogeneity - Characteristic of a medium in which material properties are identical throughout. Though heterogeneity or non-uniformity is the characteristic of most aquifers, assumed homogeneity, with some other additional assumptions, allows use of analytical models as a valuable tool for approximate analyses of groundwater movement.

hydraulic barrier - Modifications to a groundwater flow system that restrict or impede movement of contaminants.

hydraulic conductivity (K) - The volume of fluid that flows through a unit area of porous medium for a unit hydraulic gradient normal to that area.

hydraulic diffusivity - The ratio of hydraulic conductivity (K) to specific storage (Ss) or the ration of transmissivity (T) to storativity (S).

hydraulic gradient (I or ∇h) - In general, the direction of groundwater flow due to changes in the depth of the water table.

hydraulic head (h) - Height above a datum plane (such as mean sea level) of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system. Equal to the distance between the water level in a well and the datum plane.

hydraulic radius (R) - The cross-sectional area of a stream, conduit, or fracture divided by its wetted perimeter.

hydrochemical facies - How the groundwater chemistry changes over space. Typically, the facies reflect the major ionic constituents.

hydrocompaction - Volume decrease and density increase caused as moisture-deficient sediments compact as they become wetted.

hydrogeologic - Those factors that deal with subsurface waters and related geologic aspects of surface waters.

hydrogeology - The geology of groundwater, with particular emphasis on the chemistry and movement of water. These factors, along with related geologic aspects of surface waters are *hydrogeologic* factors.

hydrograph - A chart depicting either discharge or water level as a function of time.

hydrologic unit - A geographic area representing all or part of a surface drainage basin or a distinct hydrologic feature. In the U. S. these units have 8-digit identification numbers.

hydrology - 1. The study of the waters of the Earth (or other planetary bodies). **2.** A distinct geoscience interactive on a wide range of spatial and temporal scales with the oceanic, atmospheric, and solid earth sciences as well as with many biological sciences.

hydrological cycle - The cyclic transfer of water vapor from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, lakes, and ultimately into the oceans.

hydrostratigraphic unit - A formation, part of a formation, or group of formations of significant lateral extent which compose a unit of reasonably distinct (similar) hydrogeologic parameters and responses.

impermeable - Not easily penetrated. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water.

impermeable layer - An area in the subsurface that has zero air flow. Limits the range of influence of the extraction wells in SVE systems.

infiltration - The downward entry of water into soil or rock.

infiltration capacity - The maximum rate at which a soil at a given condition can absorb rain as it falls.

infiltration gallery - A sub-surface groundwater collection system, typically shallow in depth, constructed with open-jointed or perforated pipes that discharge collected water into a watertight chamber from which the water is pumped to treatment facilities and into the distribution system. Usually located close to streams or ponds.

infiltration rate - Rate at which soil or rock under specified conditions absorbs falling rain, melting snow, or surface water; expressed in depth of water per unit time. Also, the maximum rate at which water can enter soil or rock under specific conditions, including the presence of an excess of water; expressed in units of velocity.

influent stream - A stream that contributes water to the zone of saturation.

injection well - Refers to a well constructed for the purpose of injecting water or air directly into the ground.

interflow - Water which infiltrates the land surface and flows into a stream but never recharges the local water table.

intermittent stream - A stream which does not flow all year long.

intrinsic permeability - Pertaining to the relative ease with which a porous medium can transmit a liquid under a hydraulic or potential gradient. It is a property of the porous medium and is independent of the nature of the liquid or the potential field.

isotope - A variation of an element that has the same atomic number of protons but a different weight because of the number of neutrons. Various isotopes of the same element may have different radioactive behaviors; some are highly unstable.

isotropy - The condition in which the properties of interest (generally hydraulic properties of the aquifer) are the same in all directions.

lacustrine - Relating to processes occurring in a lake.

leachate - Water that collects contaminants as it trickles through wastes, pesticides or fertilizers. Leaching may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, ground water, or soil.

leaching - The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or contaminants are washed into a lower layer of soil or are dissolved and carried away by water.

leakage - Flow of water from one hydrogeologic unit to another. This may be natural, as through a somewhat permeable confining layer, or anthropogenic, as through an uncased well. It may also be the natural loss of water from artificial structures, as a result of hydrostatic pressure.

leaky aquifer - An artesian or water table aquifer that loses or gains water through adjacent semi-permeable confining units.

lithology - Mineralogy, grain size, texture, and other physical properties of granular soil, sediment, or rock.

losing stream - A stream or reach of a stream that is losing water by seepage into the ground. Also known as an influent stream.

matrix - Solid framework of a porous material or system.

maximum contaminant level (MCL) - The designation given by the U.S. Environmental Protection Agency (EPA) to water-quality standards promulgated under the Safe Drinking Water Act. The MCL is the greatest amount of a contaminant that can be present in drinking water without causing a risk to human health.

maximum contaminant level goal (MCLG) – Under the Safe Drinking Water Act, a non-enforceable concentration of a drinking water contaminant, set at the level at which no known or anticipated adverse effects on human health occur and which allows an adequate safety margin. The MCLG is usually the starting point for determining the regulated.

maximum residual disinfectant level (MRDL) - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

maximum residual disinfectant level goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs' do not reflect the benefits of the use of disinfectants to control microbial contaminants.

milligram (mg) - One-thousandth of a gram.

milligrams per liter (mg/l) - A unit of the concentration of a constituent in water or wastewater. It represents 0.001 gram of a constituent in 1 liter of water. It is approximately equal to one part per million (ppm).

million gallons per day (Mgd) - A rate of flow of water equal to 133,680.56 cubic feet per day, or 1.5472 cubic feet per second, or 3.0689 acre-feet per day. A flow of one million gallons per day for one year equals 1,120 acre-feet (365 million gallons).

mitigation - Measures taken to reduce adverse impacts to the environment.

monitoring well - 1. A well used to obtain water quality samples or measure groundwater levels and is usually larger diameter than a piezometer and is typically screened or slotted throughout the thickness of the aquifer. Also referred to as an "observation well".

non-point sources - Diffuse pollution sources (i.e. without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants are generally carried off the land by storm water. Common non-point sources are agriculture, forestry, urban, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.

non-potable - Water that is unsafe or unpalatable to drink because it contains pollutants, contaminants, minerals, or infective agents.

orographic lifting - Lifting of air caused by its passage up and over mountains or other sloping terrain. Clouds that form in this lifting process are called orographic clouds.

outfall - The place where a sewer, drain, or stream discharges; the outlet or structure through which reclaimed water or treated effluent is finally discharged to a receiving water body.

overdraft - The pumping of water from a groundwater basin or aquifer in excess of the supply flowing into the basin; results in a depletion or "mining" of the groundwater in the basin.

overland flow - The flow of water over the land surface created by direct precipitation.

oxygen demand - The need for molecular oxygen to meet the needs of biological and chemical processes in water. Even though very little oxygen will dissolve in water, it is extremely important in biological and chemical processes.

particle size - The diameter, in millimeters, of suspended sediment or bed material. Particle-size classifications are:

- Clay - 0.0000094 - 0.00016 inch (0.00024-0.004 mm)
- Silt - 0.00016 - 0.0024 inch (0.004—0.062 mm)
- Sand - 0.0024 - 0.079 inch (0.062 - 2.0 mm)
- Gravel - 0.079 - 2.52 inch (2.0 - 64.0 mm)

pediment - a broad flat rock floored erosion surface (per Glossary of Geology)

perched water table - The top of a zone of saturation that bottoms on an impermeable horizon above the level of the general water table in the area. It is generally near the surface.

percolating water - Water that passes through rocks or soil under the force of gravity.

percolation - Downward movement of water through the unsaturated zone; also defined as the downward flow of water in saturated or nearly saturated porous media at hydraulic gradients of 1.0 or less. The act of water seeping or filtering through the soil without a definite channel.

permeability - The ease with which a porous medium can transmit water or other fluids.

- **permeability, effective** - Observed permeability of a porous medium to one fluid phase, under conditions of physical interaction between the phase and other fluid phases present.
-

  permeability, intrinsic - Relative ease with which a porous medium can transmit a fluid under a potential gradient, as a property of the medium itself. Property of a medium expressing the relative ease with which fluids can pass through it.

- **relative permeability (kr)** - The permeability of the medium for a specific fluid relative to the intrinsic permeability ($k_r < k$) for a porous medium containing more than a single fluid phase (e.g., air and water or oil, gas, and water).

permeability coefficient - Rate of flow of water through a unit cross-sectional area under a unit hydraulic gradient at the prevailing temperature (field permeability coefficient), or adjusted to 15 degrees C.

pH - An expression of the intensity of the basic or acid condition of a liquid; may range from 0 to 14, where 0 is the most acid and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.

phosphates - Certain chemical compounds containing phosphorus. Phosphogypsum Piles (Stacks): principal byproduct generated in production of phosphoric acid from phosphate rock. These “stacks” may generate radioactive radon gas.

phreatic water - Synonymous with the zone of saturation.

playa - A dry (ephemeral) lake bed. Common in semiarid areas.

plume - A three-dimensional body of fluid emanating from a point source or point sources with a chemistry or physical composition differing from the ambient groundwater, atmosphere, or surface water body.

point-source pollution - Water pollution coming from a single point, such as a sewage-outflow pipe.

pollution - When the contaminant concentration levels restrict the potential use of groundwater.

porosity - 1. Ratio of the total volume of voids to the total volume of a porous medium. **2.** The percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected. Porosity may be primary, formed during deposition or cementation of the material, or secondary formed after deposition or cementation, such as fractures.

- **effective porosity** - The interconnected porosity which contributes to groundwater flow. Often used synonymously with specific yield although the two terms are not synonymous.

- **primary** – Inter-granular porosity formed during the deposition of the sediment or from vesicles in igneous rocks

- **secondary** - Porosity formed after the rock is lithified by either dissolution or fracturing.

potable water - Water of a quality suitable for human consumption.

precipitation - **1. W**ater condensing from the atmosphere and falling in drops or particles (e.g., snow, hail, sleet) to the land surface. **2.** Formation of a solid from dissolved or suspended matter.

preliminary wastewater treatment - Removal of wastewater constituents such as rags, sticks, floatables, grit, and grease that may cause maintenance or operational problems with the treatment operations, processes and ancilliary systems.

potentiometric surface - The surface to which water in an aquifer can rise by hydrostatic pressure.

prior appropriation doctrine - The system for allocating water to private individuals used in most western states. The doctrine of Prior Appropriation was in common use throughout the arid west as early settlers and miners began to develop the land. The prior appropriation doctrine is based on the concept of "First in Time, First in Right." The first person to take a quantity of water and put it to beneficial use has a higher priority of right than a subsequent user. The rights can be lost through non-use; they can also be sold or transferred apart from the land. Contrasts with riparian water rights.

PRPs - Potential responsible parties. Waste generators who are responsible for the ultimate fate of toxic wastes. Includes property owners, industries, government agencies, etc. The current federal laws make the PRPs liable in perpetuity for these wastes.

pumping test - A test that is conducted to determine aquifer or well characteristics. A test made by pumping a well for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the well and the hydraulic characteristics of the aquifer. Also called aquifer test.

radius of influence - The radial distance from the center of a well bore to the point where there is no lowering of the water table or potentiometric surface (the edge of its cone of depression). The radial distance from an extraction well that has adequate air flow for effective removal of contaminants when a vacuum is applied to the extraction well.

rain shadow – A region of low precipitation because it is located on the leeward (windward) side of a mountain range. As a moist air mass rises to the top of a mountain range, it cools, water vapor condenses as rain, and most of the moisture is lost. Thus on the windward side (or leeward side) it is dry, often an arid desert.

recharge - The process by which water is added to the groundwater system or, more precisely, enters the phreatic zone. Can be expressed as a rate (i.e., in/yr) or a volume.

recharge area - An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.

recharge basin - A basin or pit excavated to provide a means of allowing water to soak into the ground at rates exceeding those that would occur naturally.

recharge boundary - An aquifer system boundary that adds water to the aquifer. Streams and lakes are typical recharge boundaries.

recharge rate - The quantity of water per unit of time that replenishes or refills an aquifer.

redox potential - The oxidation state of a solution.

reservoir - **1.** An impoundment of surface water behind a dam; **2.** A porous and permeable subsurface formation or part of a formation containing a natural, individual, and separate accumulation of hydrocarbons (oil or gas).

return flow - That part of irrigation water that is not consumed by evapotranspiration and that returns to its source or another body of water.

safe water - Water that does not contain harmful bacteria, toxic materials, or chemicals, and is considered safe for drinking even if it may have taste, odor, color, and certain mineral problems.

safe yield - The amount of naturally occurring groundwater that can be withdrawn from an aquifer on a sustained basis without impairing the native groundwater quality or lowering water levels.

saline water - Water that contains significant amounts of dissolved salts. Salinity is defined as:
• Fresh water - Less than 1,000 ppm
• Slightly saline water - From 1,000 ppm to 3,000 ppm
• Moderately saline water - From 3,000 ppm to 10,000 ppm
• Highly saline water - From 10,000 ppm to 35,000 ppm

salts - Minerals that water picks up as it passes through the air, over and under the ground, or from households and industry.

sand - Soil or rock particles with an effective grain diameter between 0.62 and 2.0 mm.

saprolite - A soft, clay-rich, thoroughly decomposed rock formed in place by chemical weathering of igneous or metamorphic rock. Forms in humid, tropical, or subtropical climates.

saturated zone - The area below the water table where all open spaces are filled with water under pressure equal to or greater than that of the atmosphere. Generically is considered equivalent to the phreatic zone.

saturation - When all the pores are filled with water. The ratio of the volume of a single fluid in the pores, to pore volume expressed, as a percentage or a fraction.

secondary drinking water regulations - Non-enforceable regulations applying to public water systems and specifying the maximum contamination levels that, in the judgment of EPA, are required to protect the public welfare. These regulations apply to any contaminants that may adversely affect the odor or appearance of such water and consequently may cause people served by the system to discontinue its use.

sediment - Usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.

sedimentary rock - Rock formed of sediment, and specifically: **1.** Sandstone and shale, formed of fragments of other rock transported from their sources and deposited in water; and **2.** Rocks formed by or from secretions of organisms, such as most limestone. Many sedimentary rocks show distinct layering, which is the result of different types of sediment being deposited in succession.

seepage - Percolation of water through the soil from unlined canals, ditches, laterals, watercourses, or water storage facilities.

semi-arid - Pertaining to climatic conditions in which the precipitation, although slight, is sufficient for growth of short sparse grass. A semiarid climate is sometimes referred to as a steppe climate.

semi-confined aquifer - An aquifer partially confined by soil layers of low permeability through which recharge and discharge can still occur.

silt - Sedimentary materials composed of fine or intermediate-sized mineral particles.

soft water - Any water that does not contain a significant amount of dissolved minerals such as salts of calcium or magnesium.

soil moisture - The water contained in the pore space of the unsaturated zone.

specific storage (Ss) - The volume of water released per unit volume of aquifer for a unit decrease in hydraulic head [L^{-1}].

specific yield (S_y) - The volume of water that a saturated porous medium can yield by gravity drainage divided by the volume of the porous medium.

spring - Ground water seeping out of the earth where the water table intersects the ground surface.

static water depth - The vertical distance from the centerline of the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.

static water level - The level of water in a well that is not being affected by the withdrawal of groundwater.

storage - Water contained within an aquifer or within a surface-water reservoir.

storage coefficient - The amount of water released from or taken into storage per porous medium column with a unit surface area per unit change in head.

storativity (S) - The volume of water released per unit area of aquifer for a unit decline in head. In a confined aquifer, S is essentially the specific storage (Ss) times aquifer thickness; in an unconfined aquifer, S is essentially equal to the specific yield.

stratigraphy - Study of the formation, composition, and sequence of sediments, whether consolidated or not.

stream - A flowing body of water which is generally confined to a specific channel or channels.

- **effluent stream** - A steam which is receiving base flow.
- **ephemeral stream** - A stream which flows only briefly after rainfall events.
- **gaining stream** - A stream which increases in discharge along its channel because of groundwater inflow.
- **influent stream** - A stream with its water flowing into the groundwater system.
- **intermittent stream** - A stream which typically does not flow all year long.
- **losing stream** - A stream which loses discharge along its channel.
- **perennial stream** - A stream which flows all year long.
- **sinking steam** - A stream which loses discharge because its water is infiltrating into the ground.

subsidence - The vertical movement of the surface, although small-scale horizontal movements may be present. This sinking or settlement of the land surface can be caused by a number of processes, including production of fluids, solution, compaction, or cooling of magmatic bodies.

Sub-watershed - Topographic perimeter of the catchment area of a stream tributary. Sulfur Dioxide (SO2): A pungent, colorless, gas formed primarily by the combustion of fossil fuels; becomes a pollutant when present in large amounts.

suspended solids (SS) - Small particles of solid pollutants that float on the surface of, or are suspended in, sewage or other liquids. They resist removal by conventional means.

tertiary wastewater treatment - Removal of residual suspended solids (after secondary treatment), usually by granular medium filtration or microscreens. Disinfections is also typically a part of tertiary treatment. Nutrient removal is often included in this definition.

throughflow - The lateral movement of water in an unsaturated zone during and immediately after a precipitation event. The water from throughflow seeps out at the base of slopes and then flows across the ground surface as return flow, ultimately reaching a stream or lake.

total dissolved phosphorous - The total phosphorous content of all material that will pass through a filter, which is determined as orthophosphate without prior digestion or hydrolysis. Also called soluble P or ortho P.

total dissolved solids (TDS) - All material that passes the standard glass river filter; now called total filterable residue. Term is used to reflect salinity.

total suspended solids (TSS) - A measure of the suspended solids in wastewater, effluent, or water bodies, determined by tests for "total suspended non-filterable solids." (See: suspended solids.) Total Suspended Particles (TSP): A method of monitoring airborne particulate matter by total weight.

transmissivity (T) - Rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths. Transmissivity is related to Hydraulic Conductivity by the relationship: $T = Kb$, where T = Transmissivity, K = Hydraulic Conductivity and b = the saturated thickness of the aquifer.

transpiration - The process by which water vapor is lost to the atmosphere from living plants. The term can also be applied to the quantity of water thus dissipated. Transportation Control Measures (TCMs): Steps taken by a locality to reduce vehicular emission and improve air quality by reducing or changing the flow of traffic; e.g. bus and HOV lanes, carpooling and other forms of ride-sharing, public transit, bicycle lanes.

turbidity - A measure of water cloudiness caused by suspended solids.

unconfined - Refers to an aquifer which has a water table and implies direct contact of from the water table to the atmosphere (through the vadose zone).

unconfined aquifer - An aquifer in which the water table is at or near atmosphere pressure; the aquifer may or may not be saturated to the top of the aquifer.

underflow - The flow of ground water in the alluvial materials beneath and immediately adjacent to a stream and flowing in the same general direction as the stream. Note: this term is commonly misused as a term for inter-basin groundwater flow or for a regional component of flow.

underground sources of drinking water – Aquifers currently are being used as a source of drinking water or those capable of supplying a public water system.

unsaturated - The condition when the porosity is not filled with water.

unsaturated zone - Generically, is considered equivalent to the vadose zone. This is the zone above the water table and the saturated portion of the capillary fringe where the pores are generally filled with both liquid water and air.

urban runoff - Storm water from city streets and adjacent domestic or commercial properties that carries pollutants of various kinds into the sewer systems and receiving waters.

vadose zone - The zone between land surface and the water table within which the moisture content is less than saturation (except in the capillary fringe) and pressure is less than atmospheric. Soil pore space also typically contains air or other gases. The capillary fringe is included in the vadose zone. (See: Unsaturated Zone.)

vadose water - Water above the water table; the water has a pressure less than atmospheric.

water quality - a term used to describe the chemical, physical, and biological characteristics of water usually in respect to its suitability for a particular purpose.

water quality standards - State-adopted and EPA-approved ambient standards for water bodies. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses.

watershed - The land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds, like the Mississippi River basin contain thousands of smaller watersheds.

water table - Upper surface of a zone of saturation, where that surface is not formed by a confining unit; water pressure in the porous medium is equal to atmospheric pressure. The surface between the vadose zone and the groundwater; that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

water table aquifer - An aquifer whose upper boundary is the water table; also known as an unconfined aquifer.

water use - Water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrologic cycle and includes elements such as water withdrawal from surface and groundwater sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and in-stream uses; such as using water to produce hydroelectric power.

water well - An excavation where the intended use is for location, acquisition, development, or artificial recharge of ground water.

watershed - All land and water within the confines of a drainage divide.

watershed area - A topographic area within a line drawn connecting the highest points uphill of a drinking water intake into which overland flow drains.

well (water) - 1. An artificial excavation put down by any method for the purposes of withdrawing water from the underground aquifers. When the well extends the entire thickness of the aquifer and constructed to withdraw water from that thickness, it is said to be fully penetrating. **2.** A bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies.

well, fully penetrating - A well drilled to the bottom of an aquifer, constructed in such a way that it withdraws water from the entire thickness of the aquifer.

well efficiency - The ratio of the drawdown in the formation adjacent to the well divided by the drawdown in the well.

well field - An area containing two or more wells supplying a public water supply system.

well head - The physical structure, facility, or devise at the land surface from or through which groundwater flows or is pumped from the subsurface.

well interference - The condition occurring when the area of influence of a water well (the cone of depression) overlaps that of a neighboring well or wells, as when the wells are pumping from the same aquifer.

well monitoring - Measurement by on-site instruments or laboratory methods of well water quality and levels.

well screen - A filtering device used to permit the flow of liquid or air but prevents the passage of sediments or backfill particles.

well yield - The discharge of well at (nearly) steady flow [L3t-1].

wilting point - The soil moisture below which a type of plant can no longer extract water from the soil. The plant then suffers turgor loss (it wilts).

withdrawal - Water removed from a ground or surface-water source for use.

yield – Generically, the amount of water pumped from a well (or bore). In Australia, there is a narrower definition - the maximum sustainable pumping rate such that the drawdown in a well after 24 hours does not exceed a specified percentage (typically ~2%) of the column of water above the base of the aquifer. This assumes that the well is fully penetrating and screened over all permeable intervals of the aquifer. The units of yield are volume per time [L3 t].

zone of capture - Area surrounding a pumping well that encompasses all areas of features that supply groundwater recharge to the well.

zone of contribution (ZOC) - The area surrounding a pumping well that encompasses all areas or features that supply groundwater recharge to the well.

zone of influence (ZOI) - The area surrounding a pumping well within which the water table or potentiometric surfaces have been changed due to groundwater withdrawal.

zone of transport (ZOT) - The area surrounding a pumping well, bounded by an isochrone and/or isoconcentration contour, through which a contaminant may travel and reach the well.

10.0 Figure References

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11.0 Appendices

Appendix A – Water Level Data and Plots
- A-1 Monitoring Well Data Plots
- A-2 Groundwater Elevation Contour Maps and Data

Appendix B – Water Quality Standards and Chemistry Data
- B-1 EPA National Primary Drinking Water Standards and USEPA VS CDHS Maximum Contaminant Levels and Regulation Dates for Drinking Water Contaminants
- B-2 Water Chemistry Data Sheets
- B-3 Star Diagrams

Appendix C – Well Information
- C-1 Well Logs

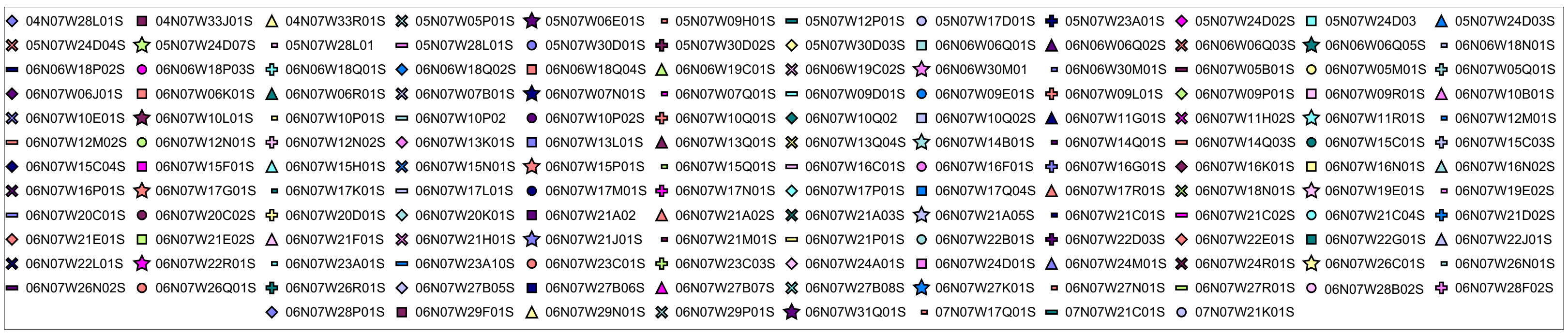
Appendix D – Plates

Appendix A – Water Level Data and Plots

A-1 Groundwater Hydrographs

A-2 Groundwater Elevation Contour Maps

A-1 Monitoring Well Data Plots



Legend for Oeste groundwater hydrographs from 1915 to present.

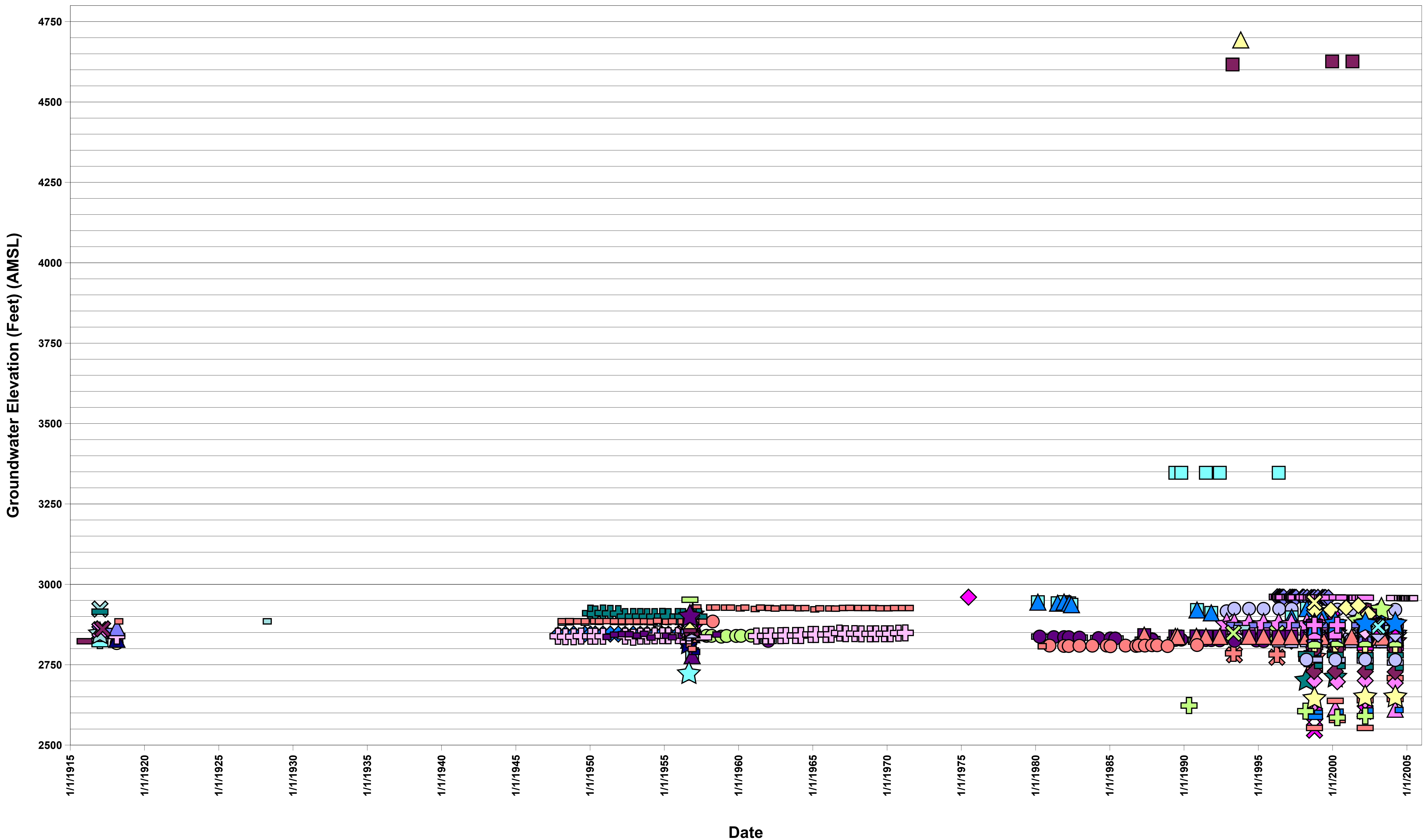


Figure 3c: Oeste groundwater hydrographs from 1915 to present.

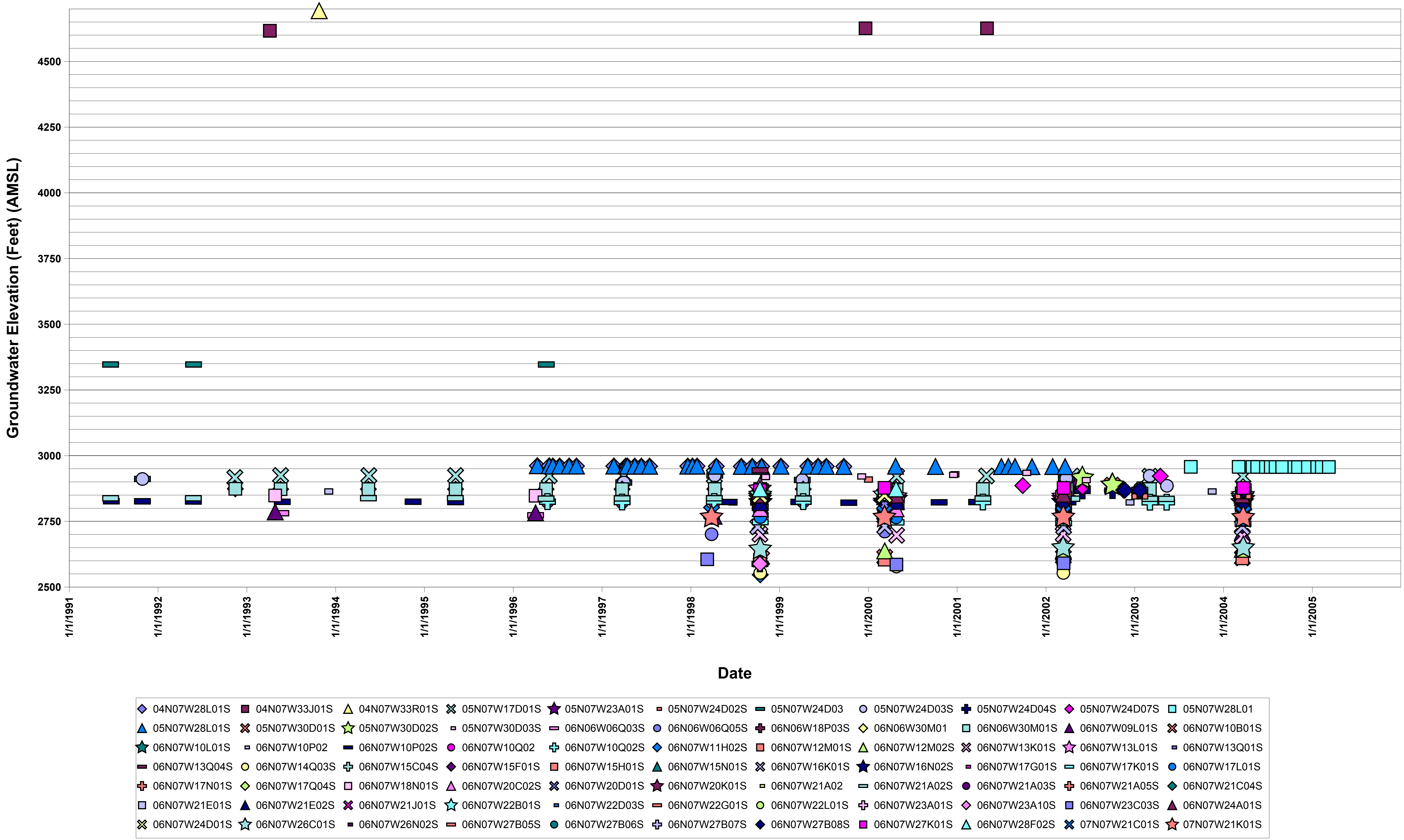
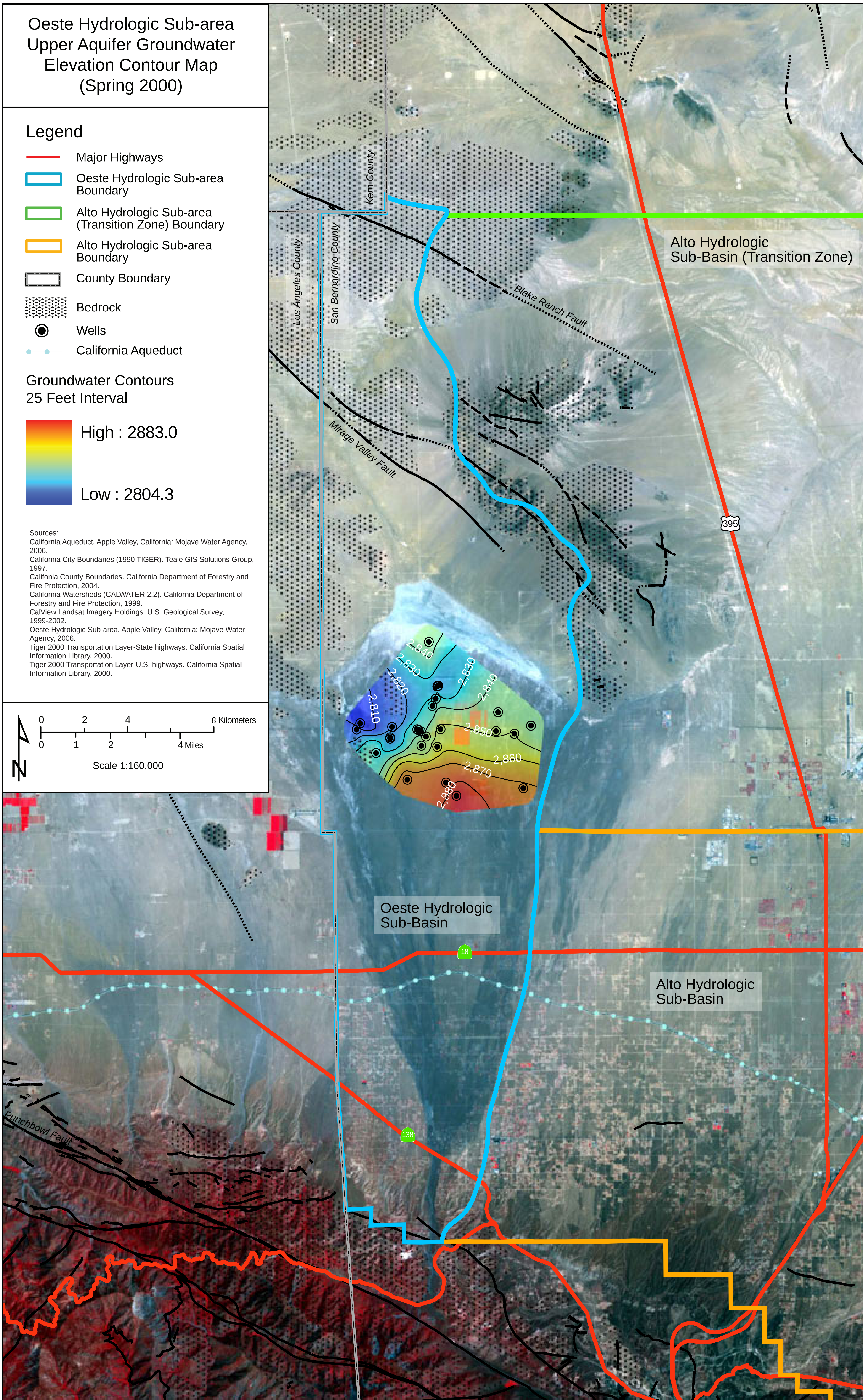


Figure 4c: Oeste groundwater hydrographs from 1990 to present.

A-2 Groundwater Elevation Contour Maps and Data



Oeste Hydrologic Sub-area
Upper Aquifer Groundwater
Elevation Contour Map
(Spring 2000)
Legend
Major Highways
Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
County Boundary
Bedrock
Wells
California Aqueduct
Groundwater Contours
25 Feet Interval
High : 2883.0
Low : 2804.3
Sources:
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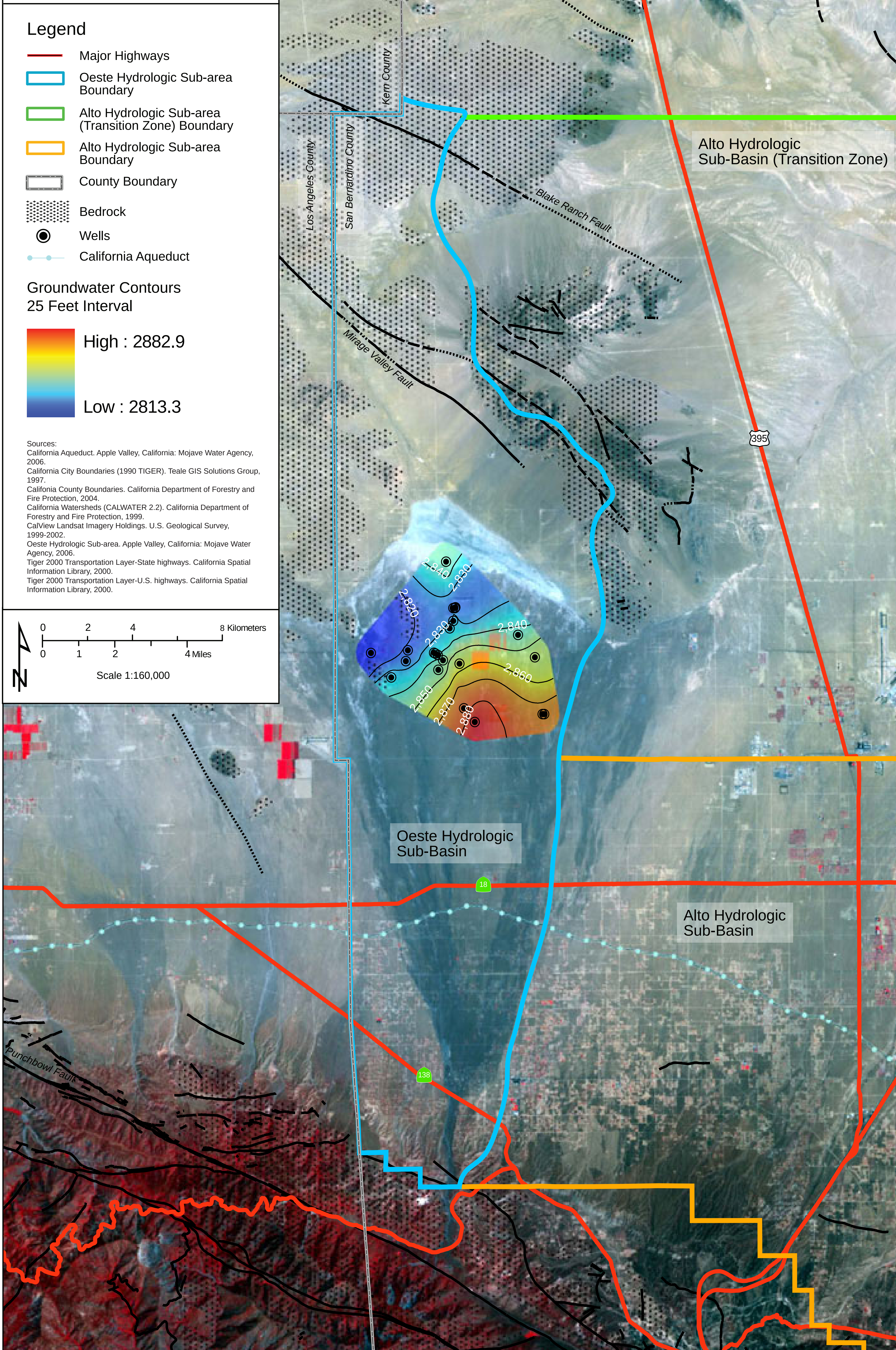
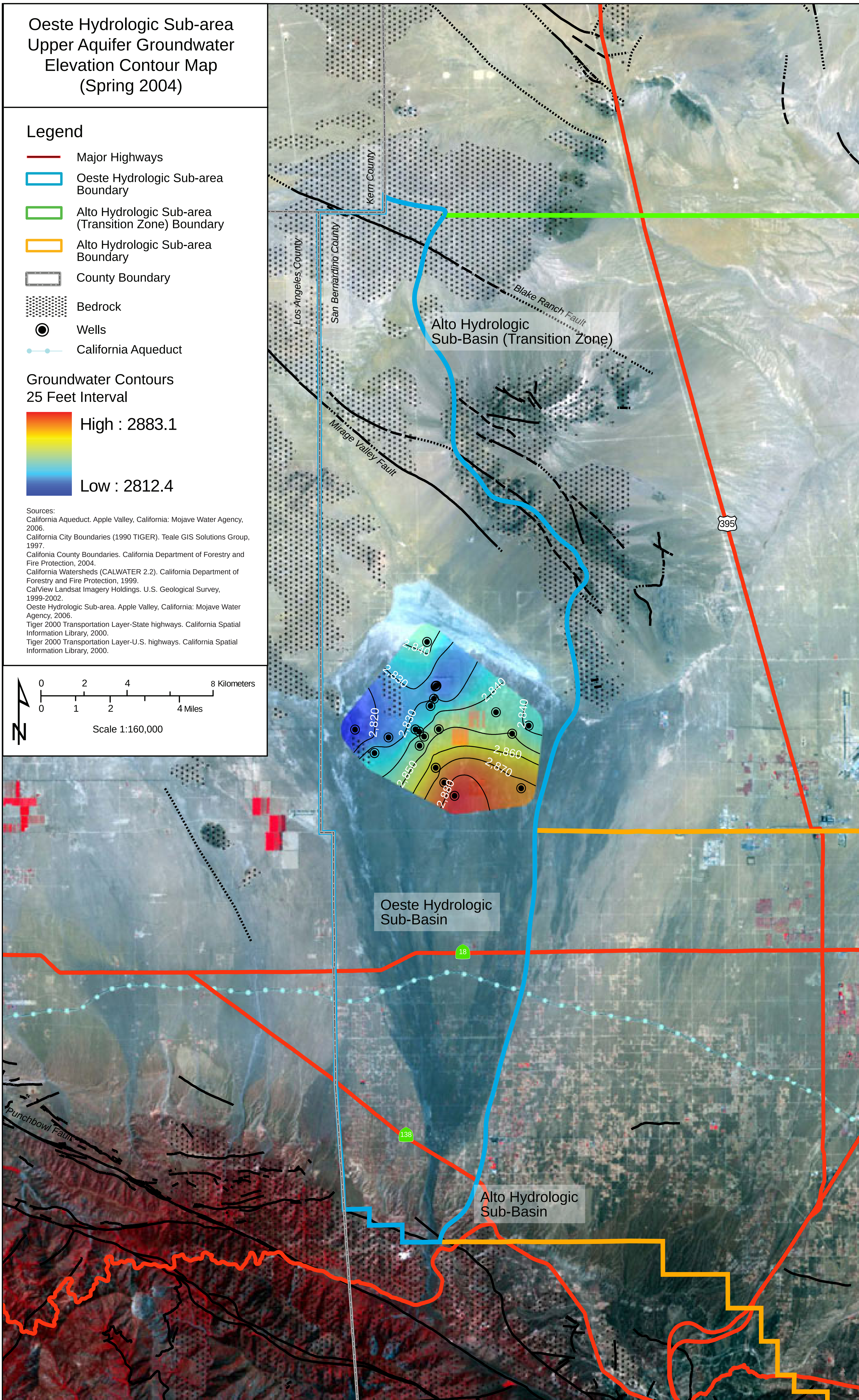
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.
0 2 4 8 Kilometers
0 1 2 4 Miles
N
Scale 1:160,000
Kern County
San Bernardino County
Los Angeles County
Blake Ranch Fault
Mirage Valley Fault
Punchbowl Fault
Alto Hydrologic
Sub-Basin (Transition Zone)
395
2,840
2,830
2,820
2,810
2,850
2,860
2,870
2,880
Oeste Hydrologic
Sub-Basin
18
138
Alto Hydrologic
Sub-Basin

Oeste Hydrologic Sub-area Upper Aquifer Groundwater Elevation Contour Map (Spring 2002)





Oeste Hydrologic Sub-area
Upper Aquifer Groundwater
Elevation Contour Map
(Spring 2004)
Legend
Major Highways
Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
County Boundary
Bedrock
Wells
California Aqueduct
Groundwater Contours
25 Feet Interval
High : 2883.1
Low : 2812.4
Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
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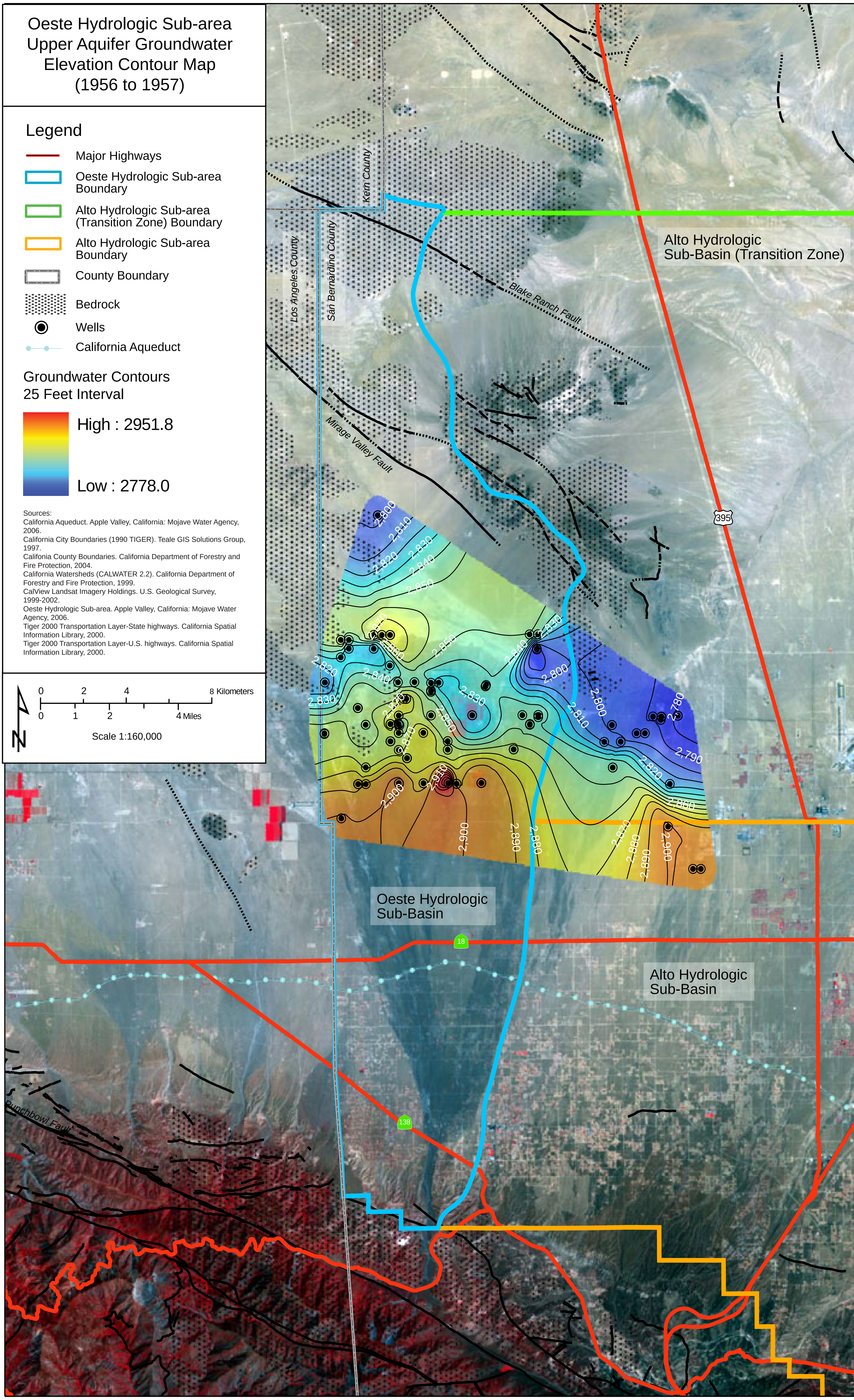
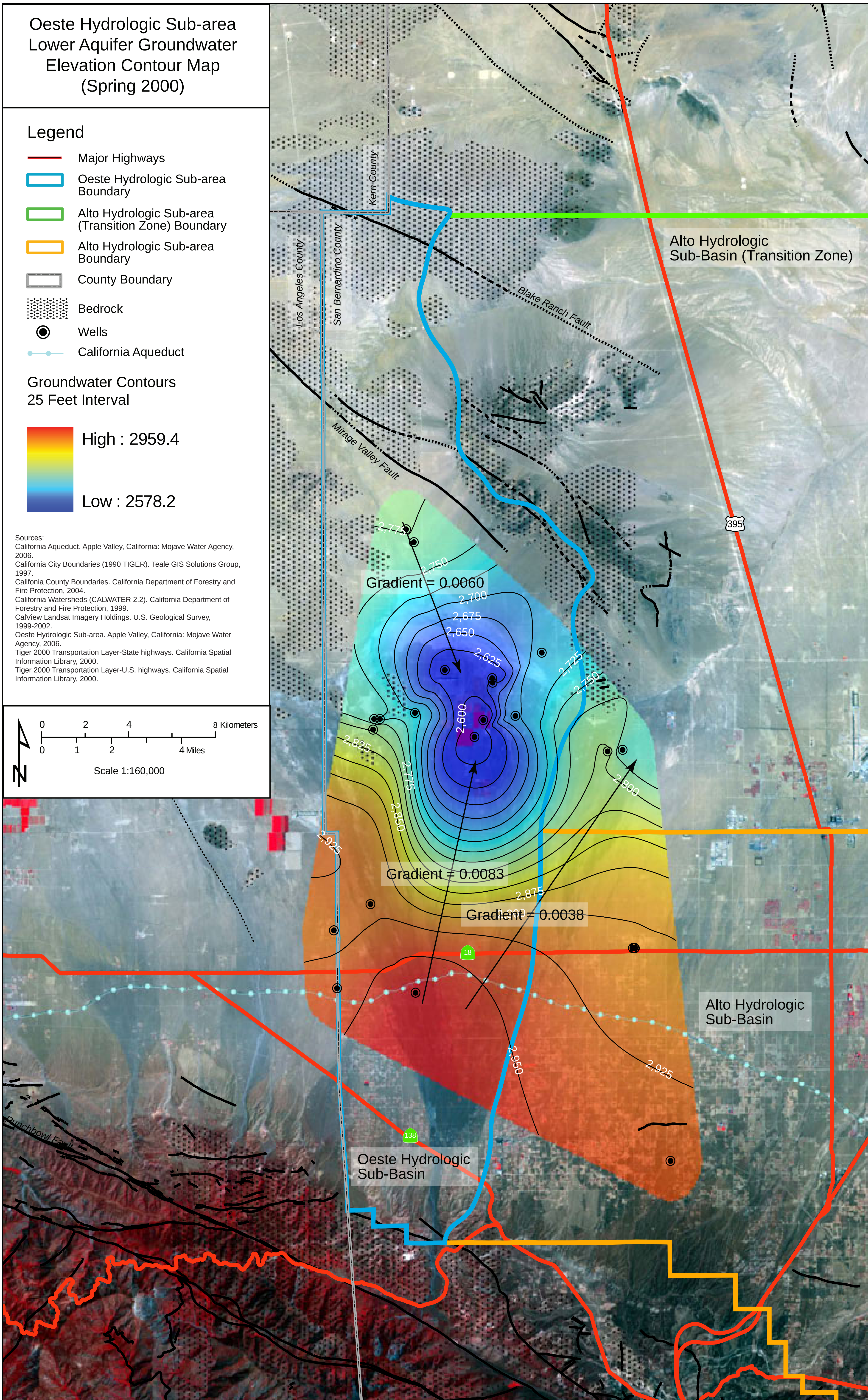
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.
N
0 2 4 8 Kilometers
0 1 2 4 Miles
Scale 1:160,000
Kern County
Los Angeles County
San Bernardino County
Blake Ranch Fault
Alto Hydrologic Sub-Basin (Transition Zone)
Mirage Valley Fault
395
2,840
2,830
2,820
2,830
2,840
2,840
2,850
2,860
2,870
2,880
Oeste Hydrologic Sub-Basin
18
138
Punchbowl Fault
Alto Hydrologic Sub-Basin



Oeste Hydrologic Sub-area
Upper Aquifer Groundwater
Elevation Contour Map
(1956 to 1957)
Legend
Major Highways
Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
County Boundary
Bedrock
Wells
California Aqueduct
Groundwater Contours
25 Feet Interval
High : 2951.8
Low : 2778.0
Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
Califonia County Boundaries. California Department of Forestry and Fire Protection, 2004.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
CalView Landsat Imagery Holdings. U.S. Geological Survey, 1999-2002.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.
0 2 4 8 Kilometers
0 1 2 4 Miles
N
Scale 1:160,000
Kern County
Los Angeles County
San Bernardino County
Blake Ranch Fault
Mirage Valley Fault
Punchbowl Fault
Alto Hydrologic
Sub-Basin (Transition Zone)
Oeste Hydrologic
Sub-Basin
Alto Hydrologic
Sub-Basin
395
18
138
2,800
2,810
2,820
2,830
2,840
2,850
2,860
2,870
2,880
2,890
2,900
2,780
2,790


Oeste Hydrologic Sub-area
Lower Aquifer Groundwater
Elevation Contour Map
(Spring 2000)
Legend
Major Highways
Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
County Boundary
Bedrock
Wells
California Aqueduct
Groundwater Contours
25 Feet Interval
High : 2959.4
Low : 2578.2
Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
Califonia County Boundaries. California Department of Forestry and Fire Protection, 2004.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
CalView Landsat Imagery Holdings. U.S. Geological Survey, 1999-2002.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.
0 2 4 8 Kilometers
0 1 2 4 Miles
N
Scale 1:160,000
Kern County
Los Angeles County
San Bernardino County
Blake Ranch Fault
Mirage Valley Fault
Punchbowl Fault
Alto Hydrologic
Sub-Basin (Transition Zone)
Alto Hydrologic
Sub-Basin
Oeste Hydrologic
Sub-Basin
395
18
138
Gradient = 0.0060
Gradient = 0.0083
Gradient = 0.0038
2,775
2,750
2,700
2,675
2,650
2,625
2,600
2,725
2,750
2,825
2,775
2,850
2,800
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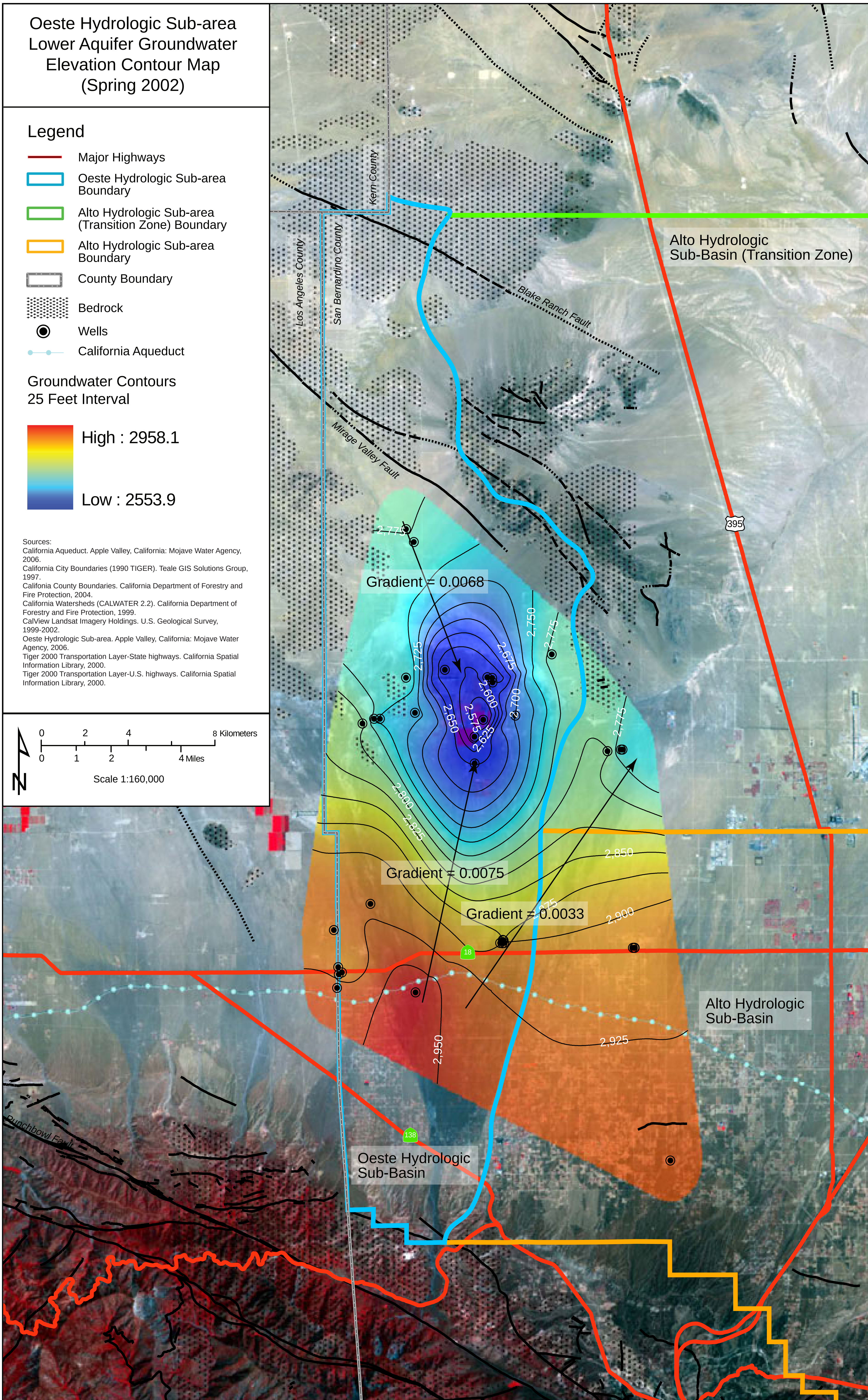
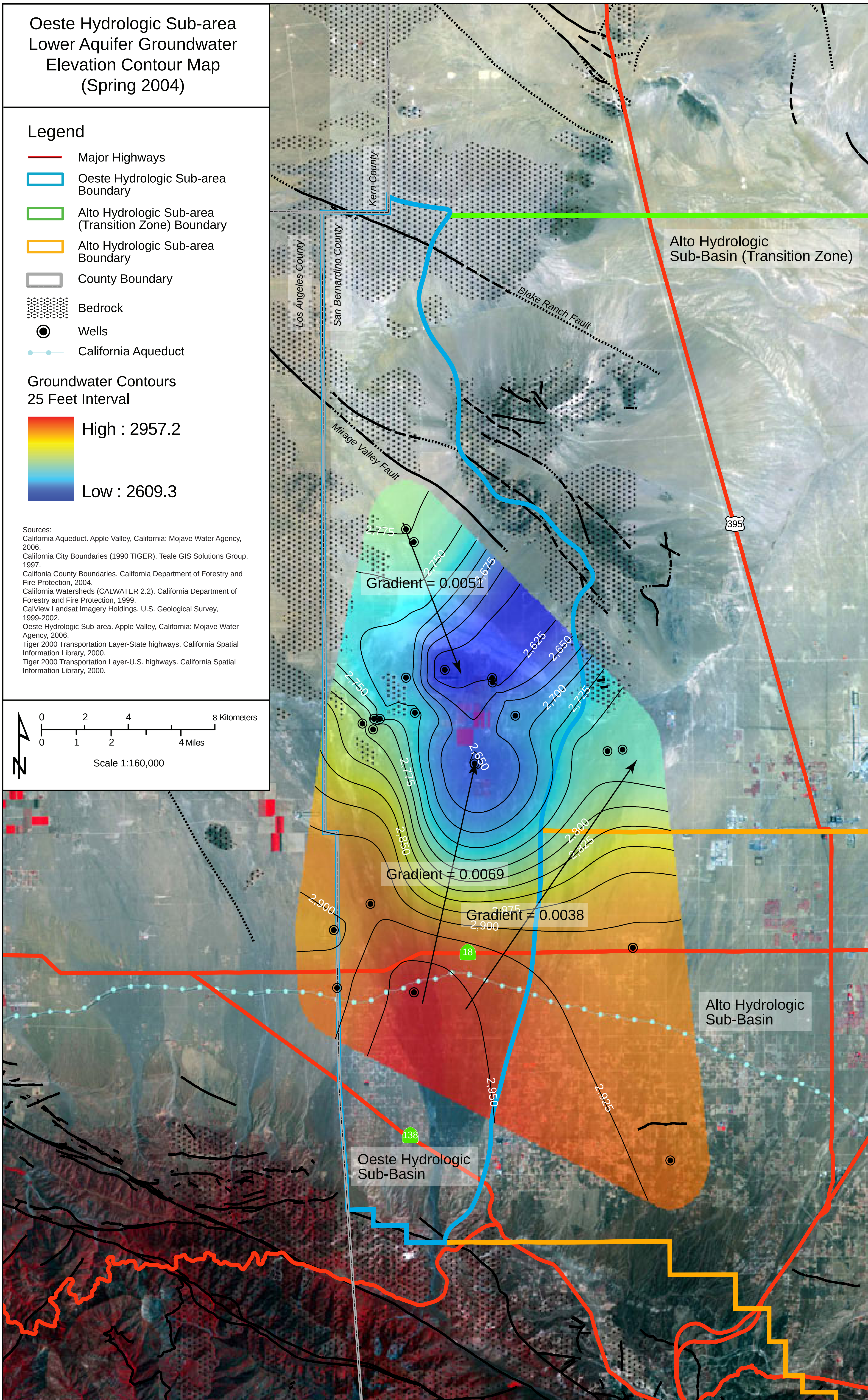
2,875
2,950
2,925


Oeste Hydrologic Sub-area
Lower Aquifer Groundwater
Elevation Contour Map
(Spring 2002)
Legend
Major Highways
Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
County Boundary
Bedrock
Wells
California Aqueduct
Groundwater Contours
25 Feet Interval
High : 2958.1
Low : 2553.9
Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
Califonia County Boundaries. California Department of Forestry and Fire Protection, 2004.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
CalView Landsat Imagery Holdings. U.S. Geological Survey, 1999-2002.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.
0 2 4 8 Kilometers
0 1 2 4 Miles
N
Scale 1:160,000
Kern County
San Bernardino County
Los Angeles County
Alto Hydrologic
Sub-Basin (Transition Zone)
Blake Ranch Fault
Mirage Valley Fault
395
Gradient = 0.0068
Gradient = 0.0075
Gradient = 0.0033
2,775
2,750
2,725
2,675
2,650
2,600
2,575
2,625
2,700
2,800
2,825
2,850
2,900
2,925
2,950
18
138
Alto Hydrologic
Sub-Basin
Oeste Hydrologic
Sub-Basin
Punchbowl Fault


Oeste Hydrologic Sub-area
Lower Aquifer Groundwater
Elevation Contour Map
(Spring 2004)
Legend
Major Highways
Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
County Boundary
Bedrock
Wells
California Aqueduct
Groundwater Contours
25 Feet Interval
High : 2957.2
Low : 2609.3
Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
Califonia County Boundaries. California Department of Forestry and Fire Protection, 2004.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
CalView Landsat Imagery Holdings. U.S. Geological Survey, 1999-2002.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.
0 2 4 8 Kilometers
0 1 2 4 Miles
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Scale 1:160,000
Kern County
San Bernardino County
Los Angeles County
Alto Hydrologic Sub-Basin (Transition Zone)
Blake Ranch Fault
Mirage Valley Fault
395
Gradient = 0.0051
Gradient = 0.0069
Gradient = 0.0038
2,775
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2,650
2,850
2,800
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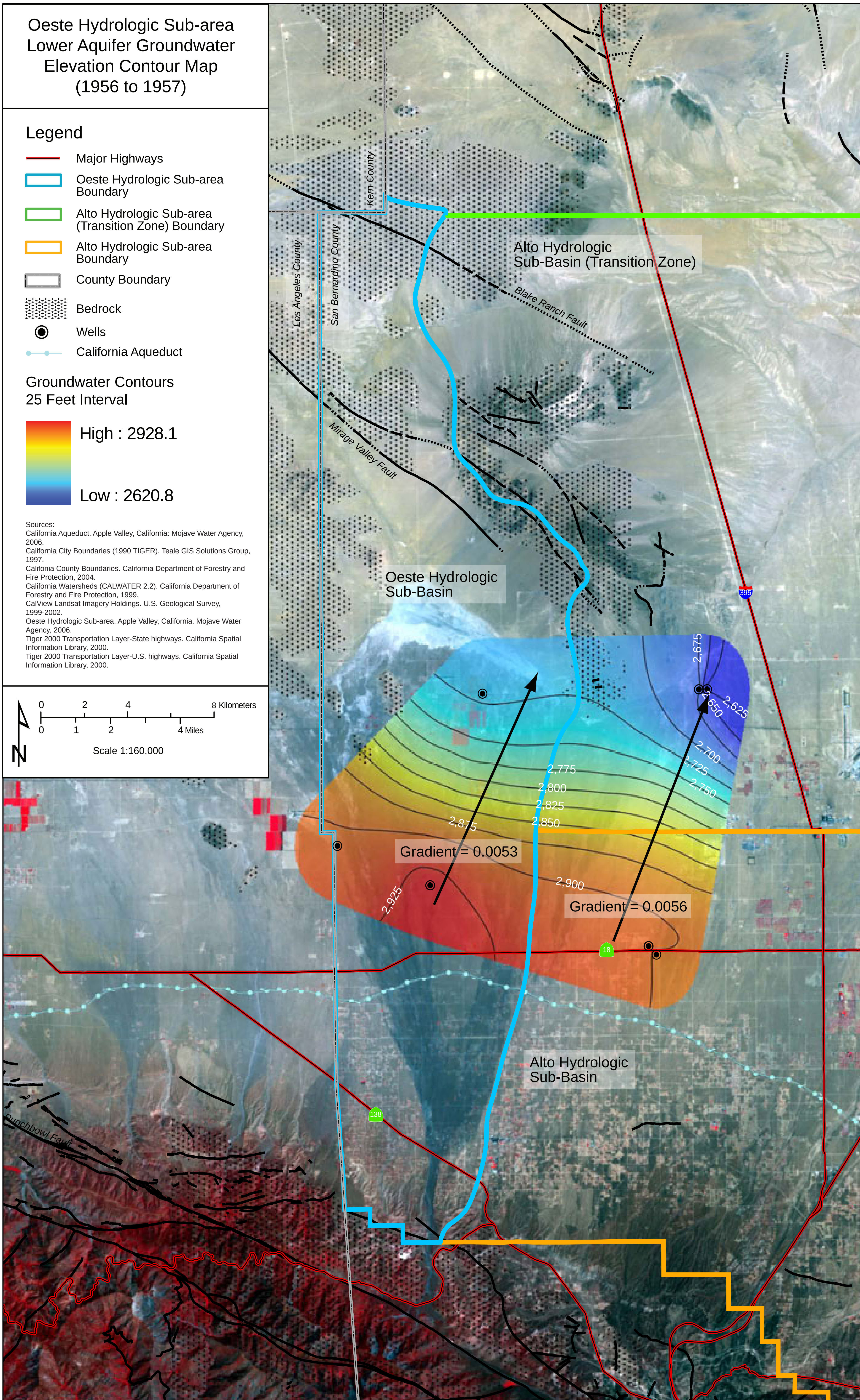
2,950
2,925
18
138
Alto Hydrologic Sub-Basin
Oeste Hydrologic Sub-Basin



Oeste Hydrologic Sub-area
Lower Aquifer Groundwater
Elevation Contour Map
(1956 to 1957)
Legend
Major Highways
Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
County Boundary
Bedrock
Wells
California Aqueduct
Groundwater Contours
25 Feet Interval
High : 2928.1
Low : 2620.8
Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
California County Boundaries. California Department of Forestry and Fire Protection, 2004.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
CalView Landsat Imagery Holdings. U.S. Geological Survey, 1999-2002.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.
0 2 4 8 Kilometers
0 1 2 4 Miles
N
Scale 1:160,000
Kern County
Los Angeles County
San Bernardino County
Alto Hydrologic
Sub-Basin (Transition Zone)
Blake Ranch Fault
Mirage Valley Fault
Oeste Hydrologic
Sub-Basin
395
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2,825
2,850
2,875
2,900
2,925
Gradient = 0.0053
Gradient = 0.0056
18
Alto Hydrologic
Sub-Basin
138
Punchbowl Fault

Appendix B – Water Quality Standards and Chemistry Data

- B-1 EPA National Primary Drinking Water Standards and USEPA VS CDHS Maximum Contaminant Levels and Regulation Dates for Drinking Water Contaminants
- B-2 Water Chemistry Data Sheets
- B-3 Star Diagrams

B-1 EPA National Primary Drinking Water Standards and USEPA VS CDHS Maximum Contaminant Levels and Regulation Dates for Drinking Water Contaminants

EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Acrylamide	TT[8]	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4[1]

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[7]; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	*Cryptosporidium*	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[8]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	*Giardia lamblia*	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadien e	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[7]; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	*Legionella*	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and *E. coli*)	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

NOTES

1 Definitions

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia*: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella:* No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

8 Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

National Secondary Drinking Water Standards

National Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

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EPA 816-F-03-016
www.epa.gov/safewater
June 2003

MCLs, DLRs, and PHGs for Regulated Drinking Water Contaminants Units are in milligrams per liter (mg/L), unless otherwise noted. PHG technical support documents are available from OEHHA.				
Contaminant	**MCL**	**DLR**	**PHG**	**Date of PHG**
Chemicals with MCLs in 22 CCR §64431—Inorganic Chemicals				
Aluminum	1	0.05	0.6	2001
Antimony	0.006	0.006	0.02	1997
Arsenic - The federal MCL is 0.010 mg/L	0.01	0.002	0.000004	2006
Asbestos (MFL = million fibers per liter; for fibers >10 microns long)	7 MFL	0.2 MFL	7 MFL	2003
Barium	1	0.1	2	2003
Beryllium	0.004	0.001	0.001	2003
Cadmium	0.005	0.001	0.00004	2006
Chromium, Total - OEHHA withdrew the 1999 0.0025-mg/L PHG in November 2001	0.05	0.01	withdrawn	1999
Chromium-6 - MCL to be established - currently regulated under the total chromium MCL	--	0.001	--	--
Cyanide	0.15	0.1	0.15	1997
Fluoride	2	0.1	1	1997
Mercury (inorganic)	0.002	0.001	0.0012	1999[a]
Nickel	0.1	0.01	0.012	2001
Nitrate (as NO3)	45	2	45	1997
Nitrite (as N)	1 as N	0.4	1 as N	1997
Nitrate + Nitrite	10 as N	--	10 as N	1997
Perchlorate - MCL to be established	--	0.004	0.006	2004
Selenium	0.05	0.005	--	--
Thallium	0.002	0.001	0.0001	1999[b]
Copper and Lead, 22 CCR §64672.3 *Values referred to as MCLs for lead and copper are not actually MCLs; instead, they are called "Action Levels" under the lead and copper rule*				
Copper	1.3	0.05	0.17	1997
Copper	--	--	0.1	2005 draft
Lead	0.015	0.005	0.002	1997
Radionuclides with MCLs in 22 CCR §64441 and §64443—Radioactivity [units are picocuries per liter (pCi/L), unless otherwise stated; n/a = not applicable]				
Gross alpha particle activity - OEHHA concluded in 2003 that a PHG was not practical	15	3	none	n/a
Gross beta particle activity - OEHHA concluded in 2003 that a PHG was not practical	4 mrem/yr	4	none	n/a
Radium-226	--	1	0.05	2006
Radium-228	--	1	0.019	2006
Radium-226 + Radium-228	5	--	--	--
Strontium-90	8	2	0.35	2006
Tritium	20,000	1,000	400	2006
Uranium	20	1	0.43	2001

Chemicals with MCLs in 22 CCR §64444—Organic Chemicals				
(a) Volatile Organic Chemicals (VOCs)				
Benzene	0.001	0.0005	0.00015	2001
Carbon tetrachloride	0.0005	0.0005	0.0001	2000
1,2-Dichlorobenzene	0.6	0.0005	0.6	1997
1,4-Dichlorobenzene (p-DCB)	0.005	0.0005	0.006	1997
1,1-Dichloroethane (1,1-DCA)	0.005	0.0005	0.003	2003
1,2-Dichloroethane (1,2-DCA)	0.0005	0.0005	0.0004	1999[a]
1,1-Dichloroethylene (1,1-DCE)	0.006	0.0005	0.01	1999
cis-1,2-Dichloroethylene	0.006	0.0005	0.1	2006
trans-1,2-Dichloroethylene	0.01	0.0005	0.06	2006
Dichloromethane (Methylene chloride)	0.005	0.0005	0.004	2000
1,2-Dichloropropane	0.005	0.0005	0.0005	1999
1,3-Dichloropropene	0.0005	0.0005	0.0002	1999c
Ethylbenzene	0.3	0.0005	0.3	1997
Methyl tertiary butyl ether (MTBE)	0.013	0.003	0.013	1999
Monochlorobenzene	0.07	0.0005	0.2	2003
Styrene	0.1	0.0005	--	--
1,1,2,2-Tetrachloroethane	0.001	0.0005	0.0001	2003
Tetrachloroethylene (PCE)	0.005	0.0005	0.00006	2001
Toluene	0.15	0.0005	0.15	1999
1,2,4-Trichlorobenzene	0.005	0.0005	0.005	1999
1,1,1-Trichloroethane (1,1,1-TCA)	0.2	0.0005	1	2006
1,1,2-Trichloroethane (1,1,2-TCA)	0.005	0.0005	0.0003	2006
Trichloroethylene (TCE)	0.005	0.0005	0.0008	1999
Trichlorofluoromethane (Freon 11)	0.15	0.005	0.7	1997
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	1.2	0.01	4	1997
Vinyl chloride	0.0005	0.0005	0.00005	2000
Xylenes	1.75	0.0005	1.8	1997

(b) Non-Volatile Synthetic Organic Chemicals (SOCs)				
Alachlor	0.002	0.001	0.004	1997
Atrazine	0.001	0.0005	0.00015	1999
Bentazon	0.018	0.002	0.2	1999
Benzo(a)pyrene	0.0002	0.0001	0.000004	1997
Carbofuran	0.018	0.005	0.0017	2000
Chlordane	0.0001	0.0001	0.00003	1997c
2,4-Dichlorophenoxyacetic acid (2,4-D)	0.07	0.01	0.07	1997
Dalapon	0.2	0.01	0.79	1997
1,2-Dibromo-3-chloropropane (DBCP)	0.0002	0.00001	0.0000017	1999
Di(2-ethylhexyl)adipate	0.4	0.005	0.2	2003
Di(2-ethylhexyl)phthalate (DEHP)	0.004	0.003	0.012	1997
Dinoseb	0.007	0.002	0.014	1997
Diquat	0.02	0.004	0.015	2000
Endrin	0.002	0.0001	0.0018	1999
Endothal	0.1	0.045	0.58	1997
Ethylene dibromide (EDB)	0.00005	0.00002	0.00001	2003
Glyphosate	0.7	0.025	1	1997
Glyphosate	--	--	0.9	2006 draft
Heptachlor	0.00001	0.00001	0.000008	1999
Heptachlor epoxide	0.00001	0.00001	0.000006	1999
Hexachlorobenzene	0.001	0.0005	0.00003	2003
Hexachlorocyclopentadiene	0.05	0.001	0.05	1999
Lindane	0.0002	0.0002	0.000032	1999[a]
Methoxychlor	0.03	0.01	0.03	1999
Molinate	0.02	0.002	--	--
Oxamyl	0.05	0.02	0.05	1997
Pentachlorophenol	0.001	0.0002	0.0004	1997
Picloram	0.5	0.001	0.5	1997
Polychlorinated biphenyls (PCBs)	0.0005	0.0005	0.00009	2006 draft
Simazine	0.004	0.004	0.004	2001
2,4,5-TP (Silvex)	0.05	0.001	0.025	2003
2,3,7,8-TCDD (dioxin)	3×10^{-8}	5×10^{-9}	1×10^{-9}	2005 draft
Thiobencarb	0.07	0.001	0.07	2000
Toxaphene	0.003	0.001	0.00003	2003

[a]OEHHA's 2005 review of this chemical resulted in no change in the PHG

[b]OEHHA's 2004 review of this chemical resulted in no change in the PHG

[c]OEHHA's 2006 review of this chemical resulted in no change in the PHG

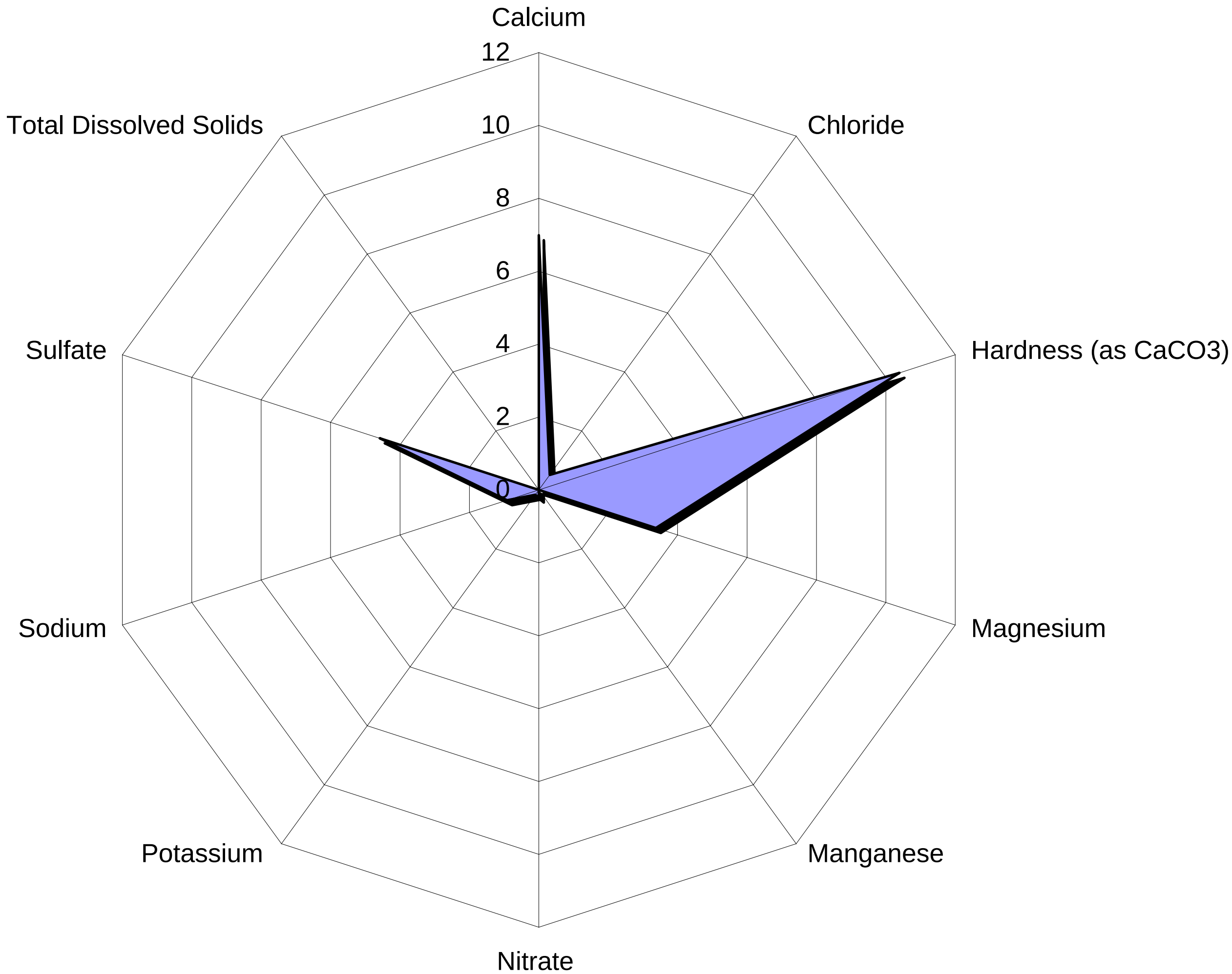
B-2 Water Chemistry Data Sheets

SWN	Y	X	Datum	Depth (ft)	Aquifer	DATE (mm/dd/yyyy)	Calcium (mg/l)	Chloride (mg/l)	Hardness as CaCO3 (mg/l)	Magnesium (mg/l)	Manganese (µg/l)	Nitrate NO3 (mg/l)	Potassium (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	Total Dissolved Solids (mg/l)	Specific Conductance (µS/cm)	Turbidity (ntu)	Zinc (µg/l)	Arsenic (µg/l)	Chromium (µg/l)	pH	Temp (Celsius)
04N07W16J01	34.431	-117.610	NAD27	100	U	12/4/1995		1.10							14.70	46.90	67.00					8.30	
05N07W14F01	34.523	-117.585	NAD83	150	U	6/6/2002										353.50	505.00					7.80	
05N07W17K01	34.518	-117.632	NAD27	100	U	12/21/1995		1.40				0.30			21.60	51.10	73.00						
05N07W17Q01	34.515	-117.630	NAD27	84	U	11/30/1995		2.20				0.94			114.00	130.90	187.00						
05N07W24D01	34.512	-117.570	NAD27	22	U	10/18/2001		42.00				0.83				136.50	195.00					6.10	
06N06W06Q03	34.634	-117.546	NAD27	150	U	6/6/2002										1190.00	1700.00					8.70	
06N06W18P03	34.603	-117.555	NAD27	104	U	6/5/2002	27.00	3.00	87.00	4.20	2.80	1.40	2.60	66.00	170.00	340.00	510.00	1.30	<20	4.00	7.10	7.30	
06N07W09L01	2049511.860	6674598.690			U	9/14/2002	54.00	11.00	180.00	12.00	1.60	4.70	2.00	68.00	190.00	460.00	670.00	0.30	110.00	2.10	2.20	7.90	
06N07W10P03	34.621	-117.605	NAD83	150	U																		
06N07W13Q04	34.604	-117.565	NAD27	150	U	6/6/2002	9.41	2.67		0.74				1.22	98.90	174.00	576.00		<20	5.20	2.00	8.50	25.50
06N07W15C04	34.615	-117.606	NAD27	80	U	6/4/2002										394.10	563.00				10.00	8.30	
06N07W15G03	2045509.750	6681404.210			U	9/14/2006	31.00	4.20	92.00	4.30	<1.00	2.30	4.00	68.00	170.00	350.00	550.00	1.40	<20	1.50	9.00	8.20	
06N07W16K02	2044248.660	6675763.520		140	U	8/9/2006	41.00	3.00	130.00	7.20	<1.00	2.00	4.90	45.00	190.00	340.00	500.00	<0.10	49.00	2.00	8.60	7.50	
06N07W16N01	34.604	-117.628	NAD27	100	U	6/5/2002										364.00	520.00					8.20	
06N07W17R01	2041885.480	6672671.540			U	8/9/2006	41.00	3.00	130.00	7.10	<1.00	2.10	4.90	45.00	180.00	340.00	510.00	<0.10	<20	1.50	11.00	7.30	
06N07W21A02	34.602	-117.616	NAD27	200	U	6/21/1991	44.00	3.40		7.70	2.00		5.30	52.00	200.00	367.50	525.00			1.00	10.00	7.90	21.00
06N07W21Q02	2037599.330	6675503.330		150	U	8/9/2006	34.00	2.90	110.00	6.20	<1.00	1.80	4.50	47.00	180.00	330.00	490.00	0.27	<20	1.60	<2.0	7.40	
06N07W22B05	2041564.500	6680653.700			U	8/9/2006	27.00	2.80	82.00	3.20	<1.00	1.20	3.30	68.00	190.00	340.00	520.00	0.72	32.00	2.00	3.30	7.10	
06N07W22D03	34.599	-117.611	NAD27	110	U	6/5/2002										372.40	532.00				15.00		
06N07W22G03	2039657.370	6680645.890		140	U	9/14/2006	35.00	3.00	100.00	4.30	<1.00	1.70	4.40	59.00	160.00	350.00	510.00	<0.10	<20	1.70	5.80	8.10	
06N07W27B03	2036193.190	6680801.650		300	U	8/15/2006	26.00	2.50	73.00	1.80	<1.00	0.86	2.40	78.00	200.00	340.00	510.00	<0.10	<20	2.00	<2.0	7.50	
06N07W24B01	34.601	-117.566	NAD27	159	U	9/9/1998	35.00	3.96		3.90			3.02	94.10	229.00	473.90	677.00			4.00		8.30	32.20
06N07W24D01	34.601	-117.575	NAD83	100	U	6/3/2002	29.80	3.22		2.46			2.33	73.60	177.00	361.20	516.00			3.40	7.00	7.80	23.00
06N07W27B07	34.585	-117.605	NAD83	155	U	1/23/2003	29.90	2.54		3.32	11.60		3.63	78.00	180.00	357.00	510.00			4.60		8.20	22.00
06N07W27B08	34.585	-117.605	NAD83	112	U	1/23/2003	39.20	2.47		6.28	16.70		4.80	55.20	180.00	347.20	496.00			1.70	14.30	8.20	22.00
06N07W28B02	2036079.530	6675477.820		200	U	9/14/2006	31.00	3.00	100.00	7.20	<1.00	1.90	4.20	56.00	220.00	330.00	490.00	0.54	41.00	1.50	<2.0	8.30	
06N07W29P02	2031548.220	6668651.620			U	8/15/2006	36.00	3.40	130.00	11.00	<1.00	2.00	5.00	48.00	200.00	340.00	500.00	<0.10	<20	1.50	2.50	7.50	
						low	9.41	1.10	73.00	0.74	1.60	0.30	2.00	1.22	14.70	46.90	67.00	0.27	32.00	1.00	2.00	6.10	21.00
						high	54.00	42.00	180.00	12.00	16.70	4.70	5.30	94.10	229.00	1190.00	1700.00	1.40	110.00	5.20	15.00	8.70	32.20
						average	33.55	5.08	110.36	5.46	6.94	1.72	3.83	58.95	163.26	345.39	515.46	0.76	58.00	2.43	7.70	7.84	24.28

SWN	Y	X	Datum	Depth (ft)	Aquifer	DATE (mm/dd/yyyy)	Calcium (mg/l)	Chloride (mg/l)	Hardness as CaCO3 (mg/l)	Magnesium (mg/l)	Manganese (µg/l)	Nitrate NO3 (mg/l)	Potassium (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	Total Dissolved Solids (mg/l)	Specific Conductance (µS/cm)	Turbidity (ntu)	Zinc (µg/l)	Arsenic (µg/l)	Chromium (µg/l)	pH	Temp (Celsius)
03N07W04R02	34.372	-117.609	NAD27	324.00	L	6/6/2002	140.00	18.00	520.00	41.00		13.00	5.90	18.00	170.00	679.70	971.00					7.20	
03N07W04R03	1957910.740	6679728.520	NAD83	340.00	L	6/6/2002						13.00											
03N07W04R04	1957783.590	6679730.010	NAD83	350.00	L	2006						13.00											
03N07W04R05	1958014.840	6679652.080	NAD83	429.00	L	5/7/2001	160.00	18.00	510.00	30.00	<20	15.00	7.30	18.00	190.00	640.00	970.00	0.10	<50.00	<2.00	<10.00	7.00	55.70
03N07W04R06	1958008.280	6679757.800	NAD83		L	2004	130.00	19.00	500.00	41.00		13.00	5.90	18.00	170.00							7.10	56.90
03N07W04R07	1957751.590	6679875.490	NAD83	350.00	L	2005	130.00	13.00	460.00	49.00		10.00	5.70	15.00	170.00							7.10	56.30
03N07W04R08	1957873.680	6679735.040	NAD83		L	2004	140.00	18.00	530.00	45.00		13.00	6.50	23.00	240.00							7.40	47.50
03N07W04R09	1957511.610	6679983.100	NAD83		L																		
03N07W09H02	1954311.050	6679745.310	NAD83		L	2005	140.00	18.00	460.00	36.00		20.00	6.00	14.00	160.00							7.70	55.80
04N06W04D01	34.467	-117.521	WGS84		X	4/22/2004	46.00	<1.0	140.00	8.10	<20	3.10	4.20	64.00	170.00	350.00	500.00	0.10	<50.00	<2.00	<10.00	7.40	
04N06W04D02	34.467	-117.520	WGS84		X	2/12/2004	39.00	6.70	120.00	6.80	<20	3.50	3.30	43.00	150.00	320.00	457.14	0.10	<50.00	<2.00	<10.00	8.10	
04N07W32C01	1964992.560	6671575.120	NAD83		X	8/16/2004	5.30	7.50	14.00	0.07	14.00	<0.50	0.66	140.00	230.00	420.00	600.00	0.95		2.60	<2.00	8.50	
04N07W33J01	34.388	-117.607	NAD27	451.00	L	6/4/2002	136.00	15.60		38.70	<2		5.97	14.70	173.00	623.00	889.00			0.30	<0.80	6.80	15.50
04N07W33J02	34.388	-117.608	WGS84		X	1/13/2004	150.00	17.00	500.00	36.00	<20	13.00	6.00	18.00	180.00	610.00	871.43	0.10	57.00	<2.00	<10.00	7.10	
04N07W33J04	34.388	-117.609	WGS84		X		140.00	16.00	510.00	41.00		19.50	13.00	17.00	200.00	665.00	950.00						
05N07W07R01	34.529	-117.647	NAD83		X	6/6/2002	39.80	4.40		12.20			6.01		163.00	348.60	498.00			1.40	59.30	7.90	24.50
05N07W08Q01	34.530	-117.632	NAD83	617.00	L	6/7/2002															20.00		
05N07W14A01	34.526	-117.573	NAD27		X	6/6/2002	25.10	3.34		4.03			3.33	74.00	1.67	357.70	511.00			4.30	8.60	8.30	28.70
05N07W15D01	34.526	-117.603	NAD83		X	6/7/2002															20.00		
05N07W17D01	34.528	-117.642	NAD27		X	5/14/2003	41.70	5.50		12.60	19.70		6.58	33.90	166.00	373.80	534.00					8.10	25.00
05N07W23A01	34.511	-117.574	WGS84		X	2/13/2004	11.00	7.70	29.00	<1.0	<20	3.70	2.30	94.00	120.00	270.00	385.71	0.10	<50.00	4.00	<10.00	8.30	
05N07W24D02	34.512	-117.572	WGS84		X	3/10/2005	180.00	14.00	470.00	28.00	<20	12.00	5.00	23.00	190.00	590.00	870.00	5.90	390.00	<2.00	<10.00	7.30	
05N07W24D03	34.511	-117.571	NAD27	660.00	L	5/14/2003	21.00	3.05	56.00	2.57	3.50	0.10	3.63	82.30	165.00	362.60	518.00			2.50	2.50	8.30	29.50
05N07W24D04	34.512	-117.572	WGS84		X	2/13/2004	16.00	7.10	44.00	1.30	<20	3.60	3.10	92.00	140.00	300.00	428.57	0.10	<50.00	3.20	<10.00	8.20	
05N07W24D07	34.511	-117.572	WGS84		X	2/26/2004	16.00	7.40	45.00	1.90	22.00	3.40	3.40	80.00	140.00	290.00	414.29	2.40	<50.00	2.70	<10.00	7.90	
05N07W24D07	34.512	-117.572	NAD83		X	6/4/2002										330.40	472.00			3.00		8.60	
05N07W28L01	34.490	-117.618	NAD27		X	6/3/2002	49.30	4.67		18.70			5.60	28.70	133.00	368.90	527.00			1.00	25.20	7.90	25.00
05N07W28L07	34.490	-117.619	NAD27	280.00	L	12/17/1995		1.41				0.12			21.09	44.58	63.69						
05N07W30D01	34.498	-117.660	WGS84		X	1/17/2003	52.00	4.60	180.00	16.00	<20	2.00	2.40	32.00	130.00	320.00	457.14	0.20	<50.00	<2.00	<10.00	7.50	
05N07W30D02	34.499	-117.659	WGS84		X	2/19/2004	54.00	6.20	190.00	15.00	21.00	2.60	7.30	49.00	140.00	320.00	457.14	1.90	<50.00	<2.00	<10.00	7.60	
05N07W30D03	34.498	-117.660	WGS84		X	10/27/2004	58.00	6.60	160.00	12.00	<20	3.00	4.80	46.00	120.00	320.00	457.14	0.20	<50.00	<2.00	15.00	8.10	
05N07W31J03	34.474	-117.645	WGS84		X	2/12/2004	66.00	6.10	220.00	18.00	<20	2.60	4.90	33.00	140.00	360.00	514.29	0.10	<50.00	<2.00	<10.00	7.70	
05N07W31J04	34.474	-117.644	WGS84		X	7/15/2004	58.00	6.60	220.00	22.00	77.00	2.40	5.40	38.00	140.00	350.00	500.00	0.40	<50.00	<2.00	<10.00	7.60	
05N08W25J01	2001225.000	6663672.000	NAD83	1110.00	L	3/4/2004	35.00	7.30	120.00	11.00	<20.00	3.30	4.10	55.00	110.00	310.00	460.00	0.60	<50.00	<20.00	11.00	7.70	
06N06W06Q05	2053498.490	6696907.430	NAD83	3950.00	L	9/27/2006	67.00	160.00	180.00	0.67	3.00	<0.50	2.00	280.00	620.00	1100.00	1571.43	0.36	<20.00	7.30	<2.00	6.71	
06N07W10B01	34.627	-117.602	NAD27		X	4/10/1980	90.00	200.00	260.00	7.70			2.40	240.00	440.00	1134.00	1620.00					7.90	22.00
06N07W10P02	34.620	-117.605	NAD27	320.00	L	7/20/1989	32.00	4.30	150.00	5.10	2.00		3.60	68.00	190.00	394.10	563.00			2.00		8.20	20.00
06N07W10Q02	34.620	-117.604	NAD27		X	5/13/2003	104.00	81.10		14.90	1.00		4.98	108.00		300.50	429.29			1.00		8.10	20.50
06N07W14K01	34.606	-117.582	NAD27	570.00	L	8/15/2006	25.00	38.00	69.00	2.50	<1.0	2.40	1.20	160.00	340.00	580.00	828.57	<0.10	<20.00	5.20	<2.00	7.40	
06N07W16R01	34.604	-117.615	NAD27		X	6/3/2002	34.10	3.02		7.77			4.00	53.00		333.90	477.00			1.70	5.50	8.00	24.00
06N07W17Q05	2041918.340	6671004.040	NAD83		X	8/15/2006	45.00	3.40	140.00	7.90	1.20	1.70	3.70	49.00	210.00	360.00	514.29	0.25	33.00	<1.0	<2.00	7.70	
06N07W19M02	2038769.670	6662127.620	NAD83	303.10	L	9/26/2006	4.60	2.40	21.00	0.58	16.00	<0.50	0.77	130.00	490.00	390.00	557.14	21.00	<20	2.90	<2.00	7.80	25.00
06N07W23C01	34.599	-117.587	NAD27		X	7/26/1980	5.40	5.70	65.00	0.25			0.60	97.00	150.00	345.80	494.00			10.00		8.70	22.00
06N07W23F01	2040384.020	6685835.170	NAD83		X	8/15/2006	7.60	21.00	17.00	0.37	1.20	<0.50	0.68	100.00	170.00	340.00	485.71	<0.10	<20.00	8.60	<2.00	7.60	
06N07W24E01	34.596	-117.576	NAD27		X	6/6/2002	38.20	3.51		4.18			3.62	62.70	183.00	369.60	528.00			3.30	23.90	8.00	24.00
06N07W25M02	34.578	-117.577	NAD27		X	6/5/2002	188.00	61.20		26.10			6.55	107.00	638.00	1036.00	1480.00			2.50	56.10	7.90	29.00
06N07W26J01	2033731.030	6688540.680	NAD83		X	9/30/2006	9.40	4.80	23.00	1.00	<1.0	6.50	0.81	74.00	96.00	260.00	371.43	<0.10	<20.00	12.00	<2.00	7.50	
06N07W26J02	34.576	-117.583	NAD83	605.00	L	6/5/2002	49.60	13.90		5.68			3.22	84.90	249.00	475.30	679.00			3.20	3.80	8.20	
06N07W27B03	34.587	-117.605	NAD83	300.00	L	6/7/2002										358.40	512.00					8.30	
06N07W27B05	34.583	-117.605	NAD83	275.00	L	1/22/2003	30.90	2.90		1.76	15.10		2.46	73.90	171.00	361.20	516.00			2.00			23.00
06N07W27B06	34.585	-117.605	NAD83	240.00	L	1/22/2003	24.60	2.38		2.33	11.40		2.79	86.90	179.00	362.60	518.00			5.30		8.20	23.00
06N07W27K01	34.579	-117.600	NAD27	325.00	L	6/7/2002										359.10	513.00					8.30	
06N07W29N02	34.574	-117.645	NAD83	300.00	L	6/3/2002										359.10	513.00					7.50	
						low	4.60	1.41	14.00	0.07	1.00	0.10	0.60	14.00	1.67	44.58	63.69	0.10	33.00	0.30	2.50	6.71	15.50
						high	188.00	200.00	530.00	49.00	77.00	20.00	13.00	280.00	638.00	1134.00	1620.00	21.00	390.00	12.00	59.30	8.70	56.90
						average	65.92	20.24	223.32	15.16	14.86	7.35	4.22	69.95	198.78	435.09	623.80	1.94	160.00	3.83	20.91	7.79	31.09

B-3 Star Diagrams

03N07W04R05



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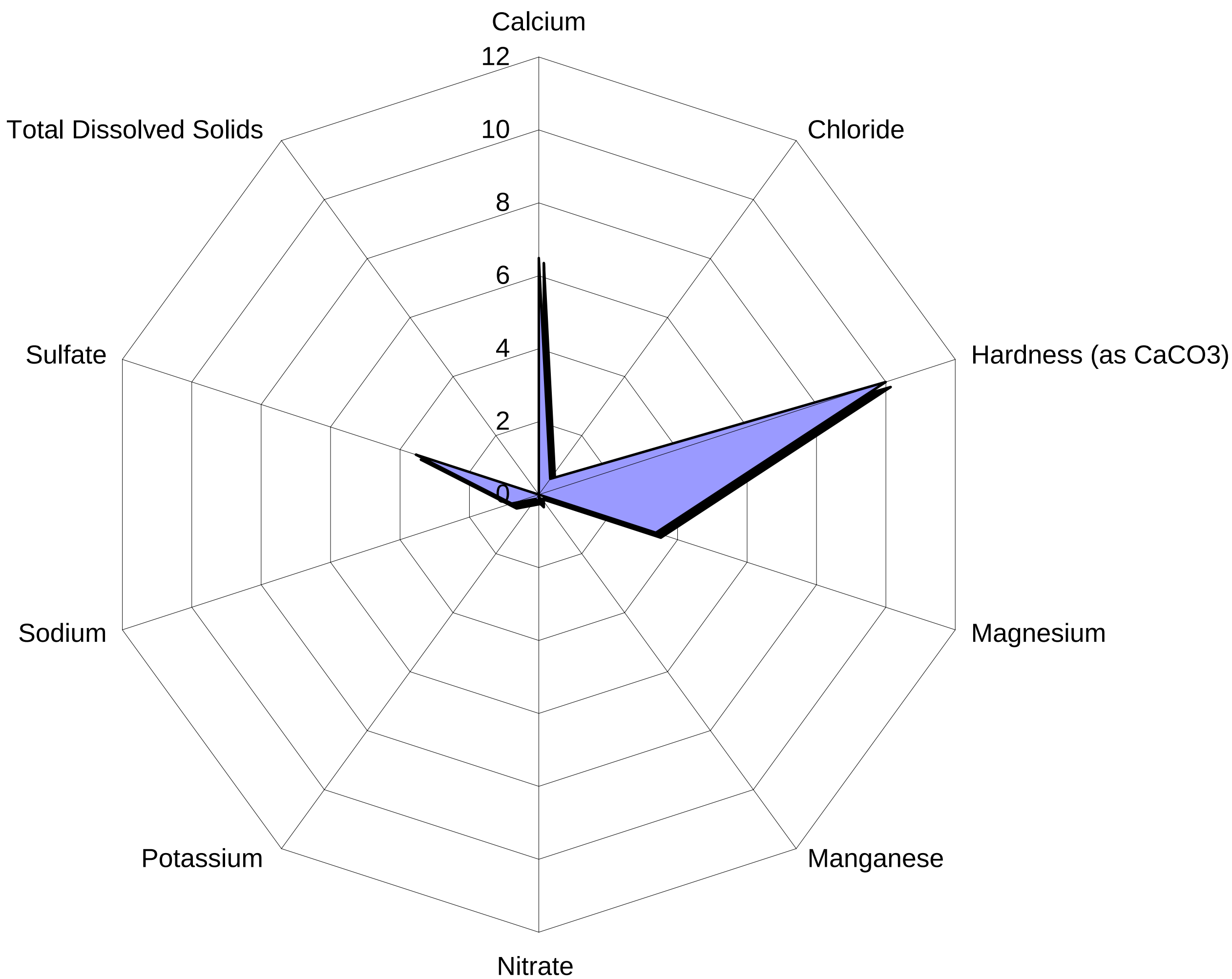
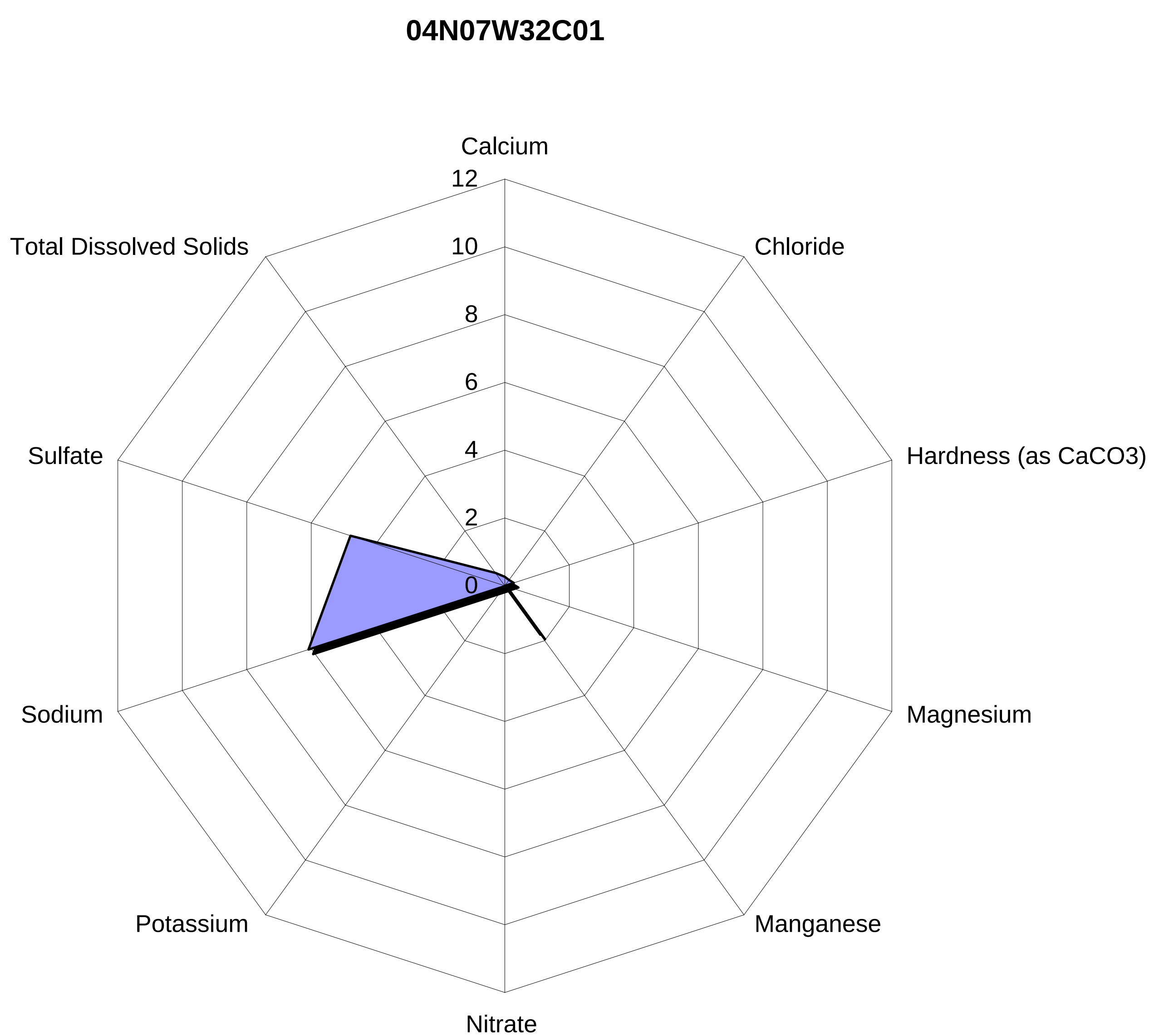
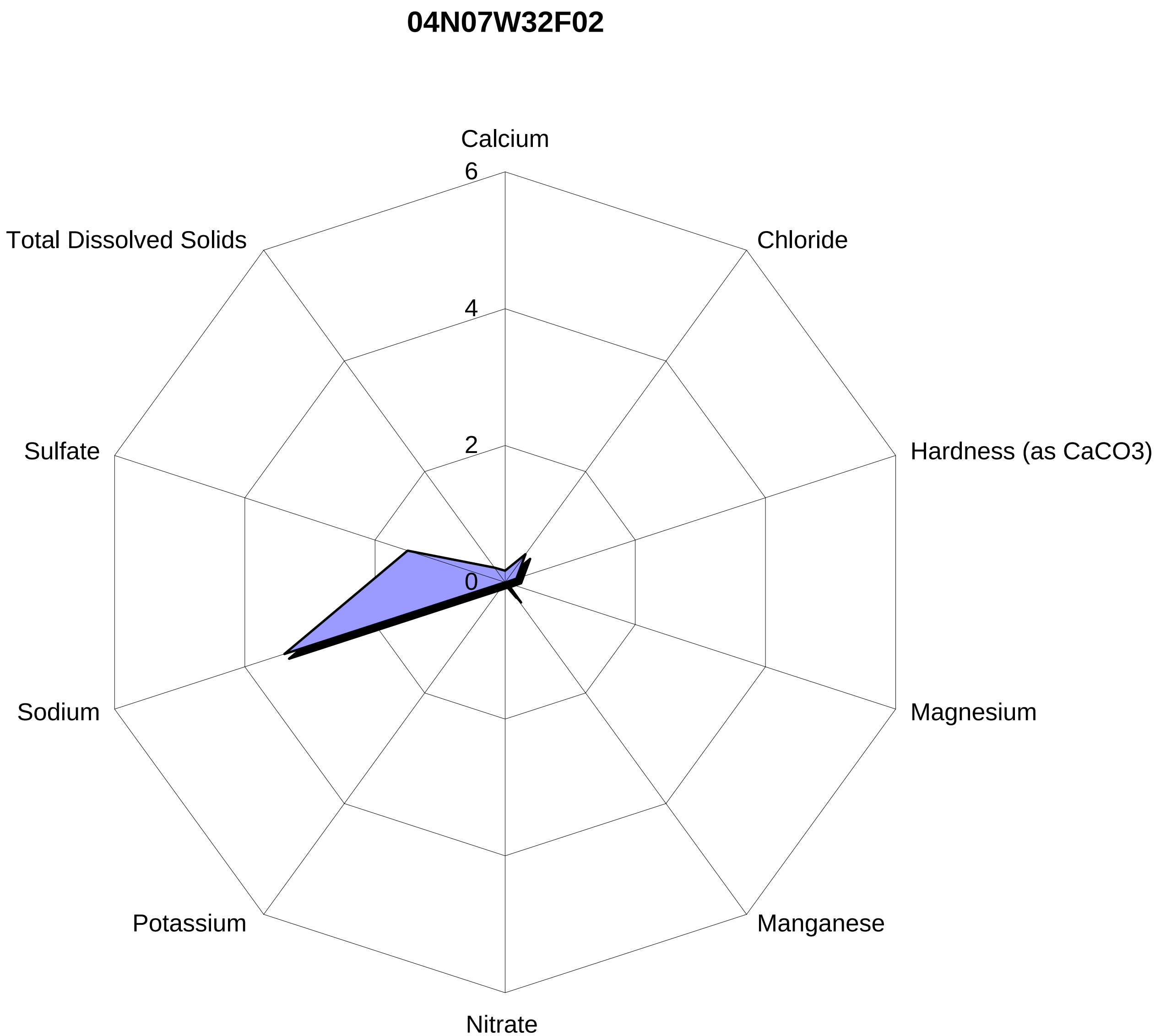
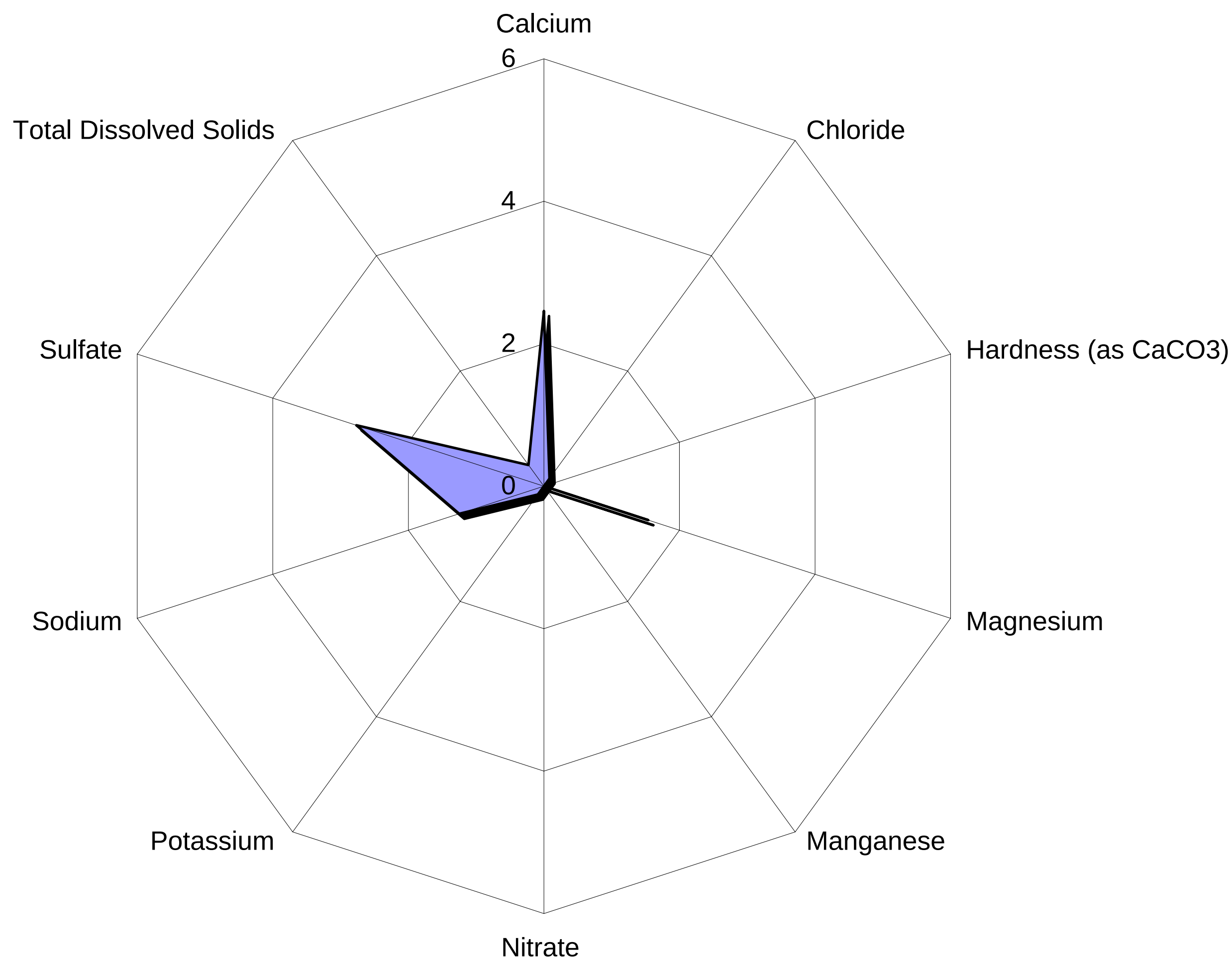


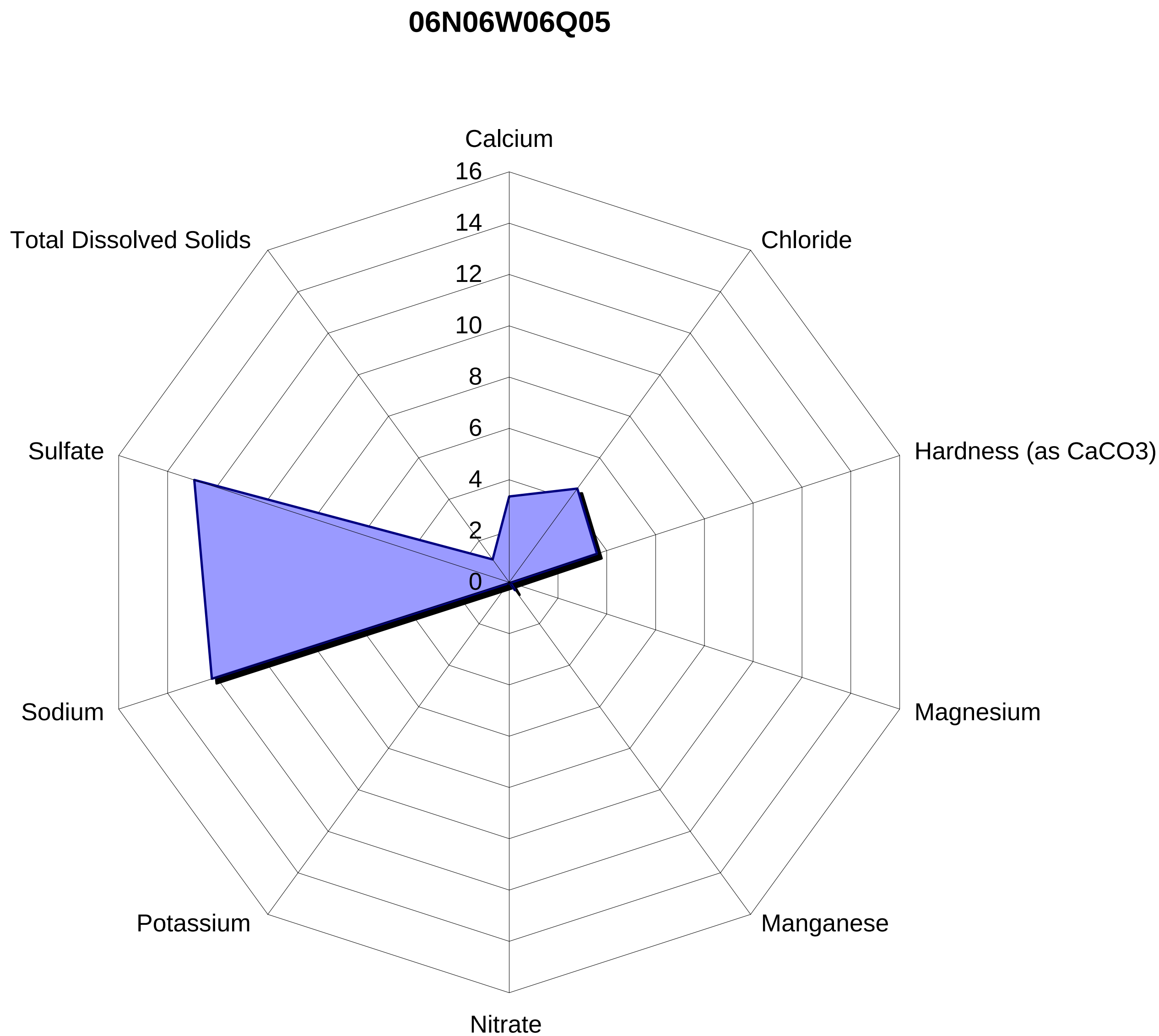

04N07W32C01
Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
12
10
8
6
4
2
0



04N07W32F02
Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
6
4
2
0

05N07W28L01
Summer 2002

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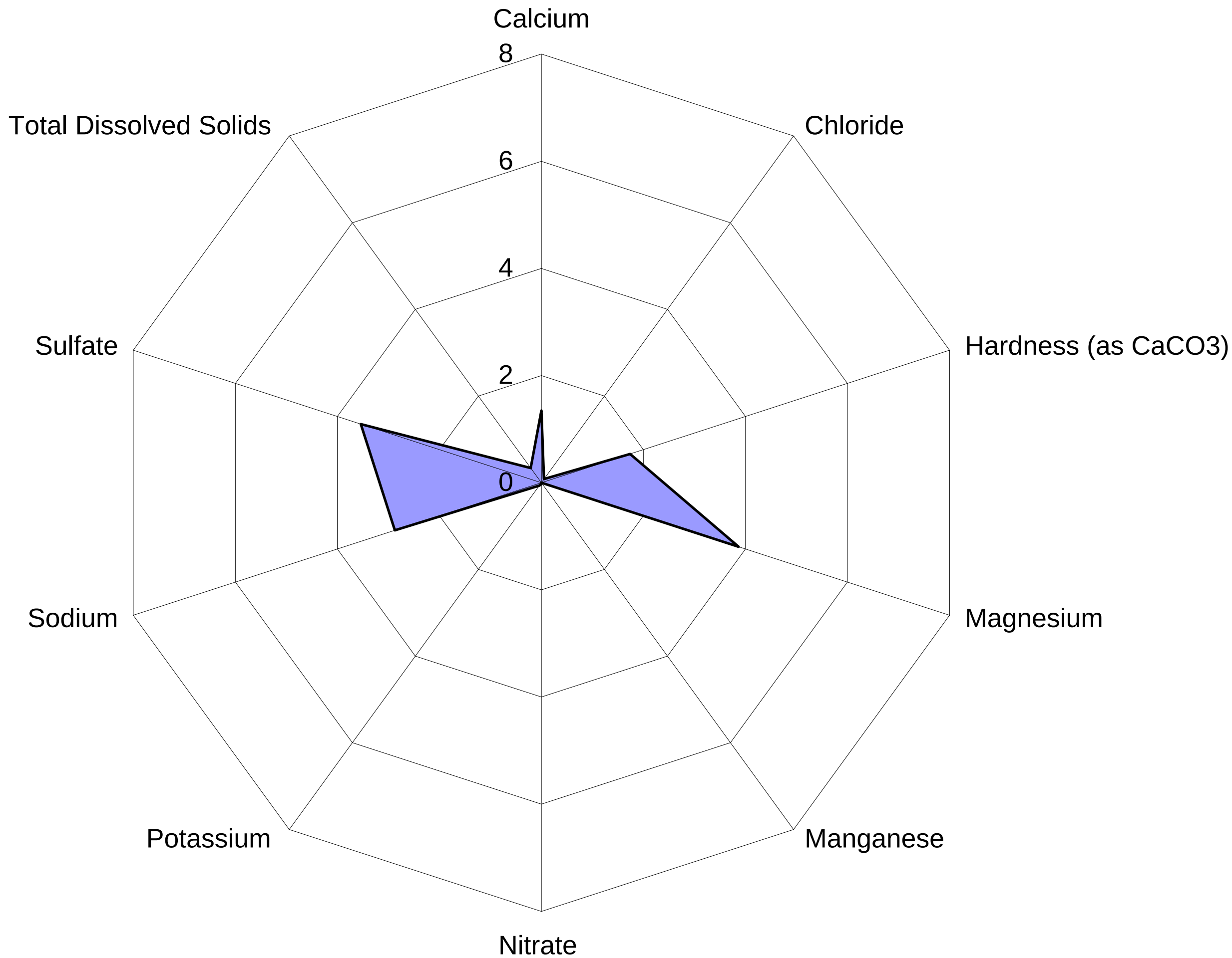
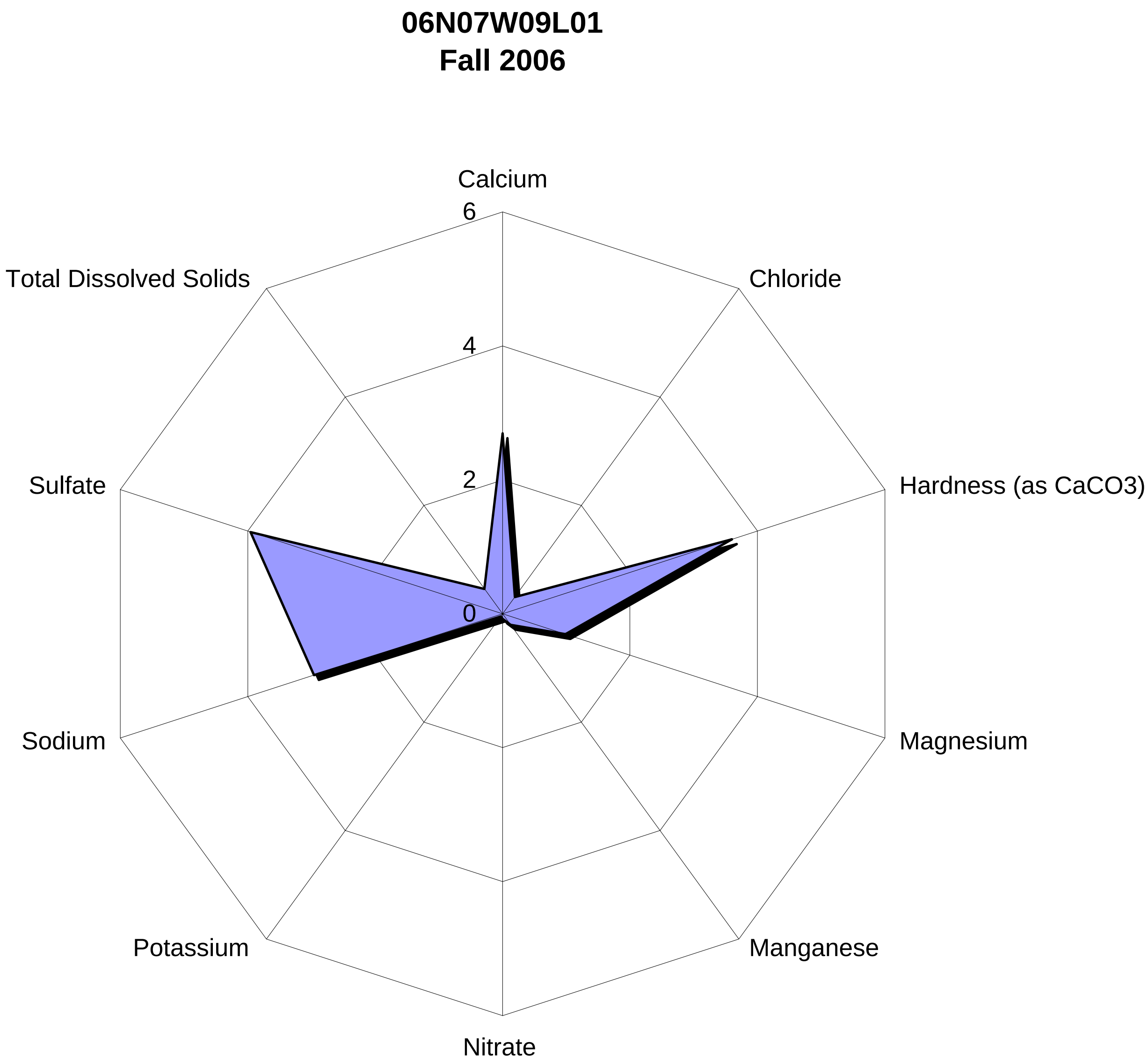
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
16
14
12
10
8
6
4
2
0

06N06W18P03
Summer 2006

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Fall 2006
Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
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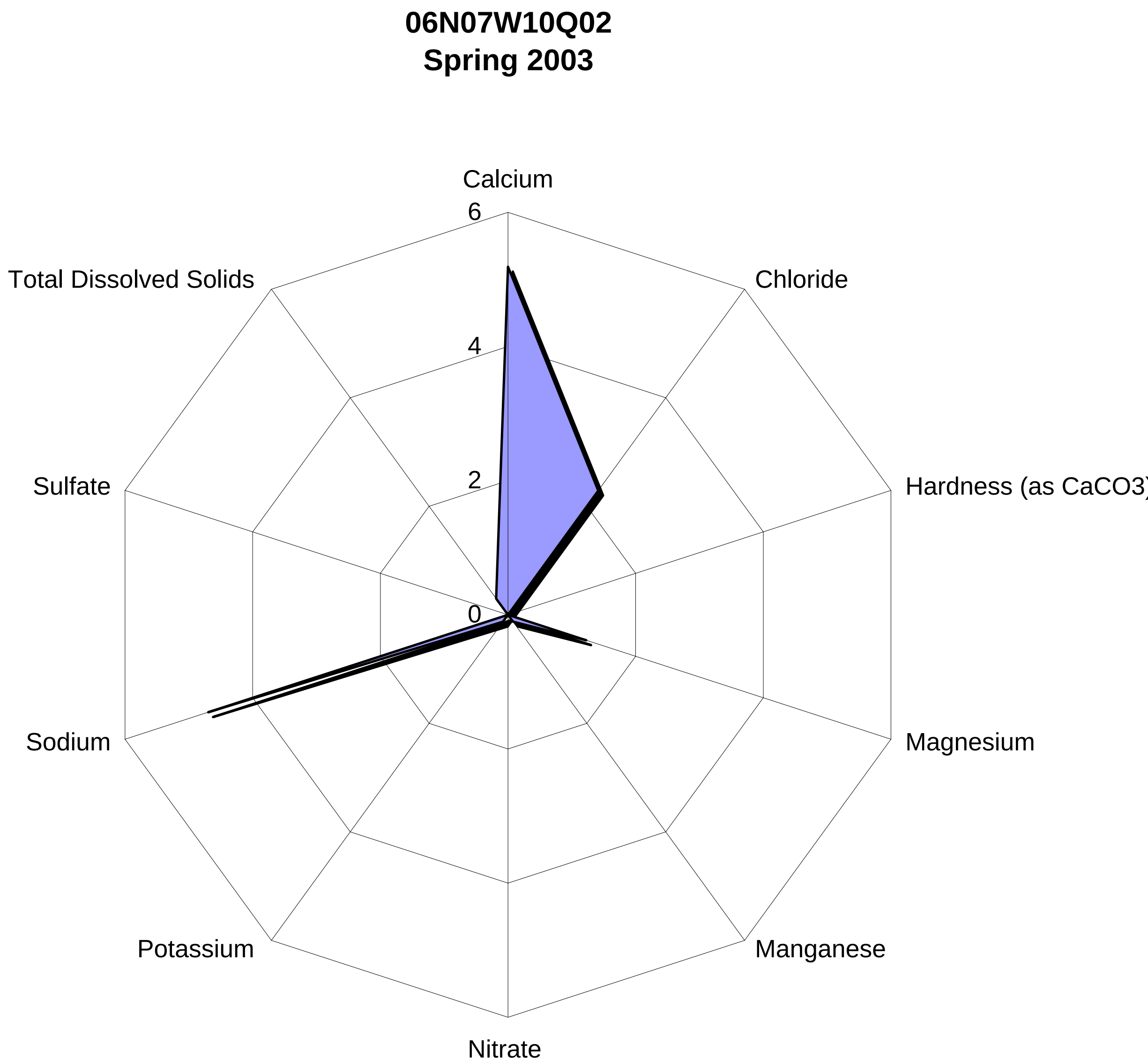
4
2
0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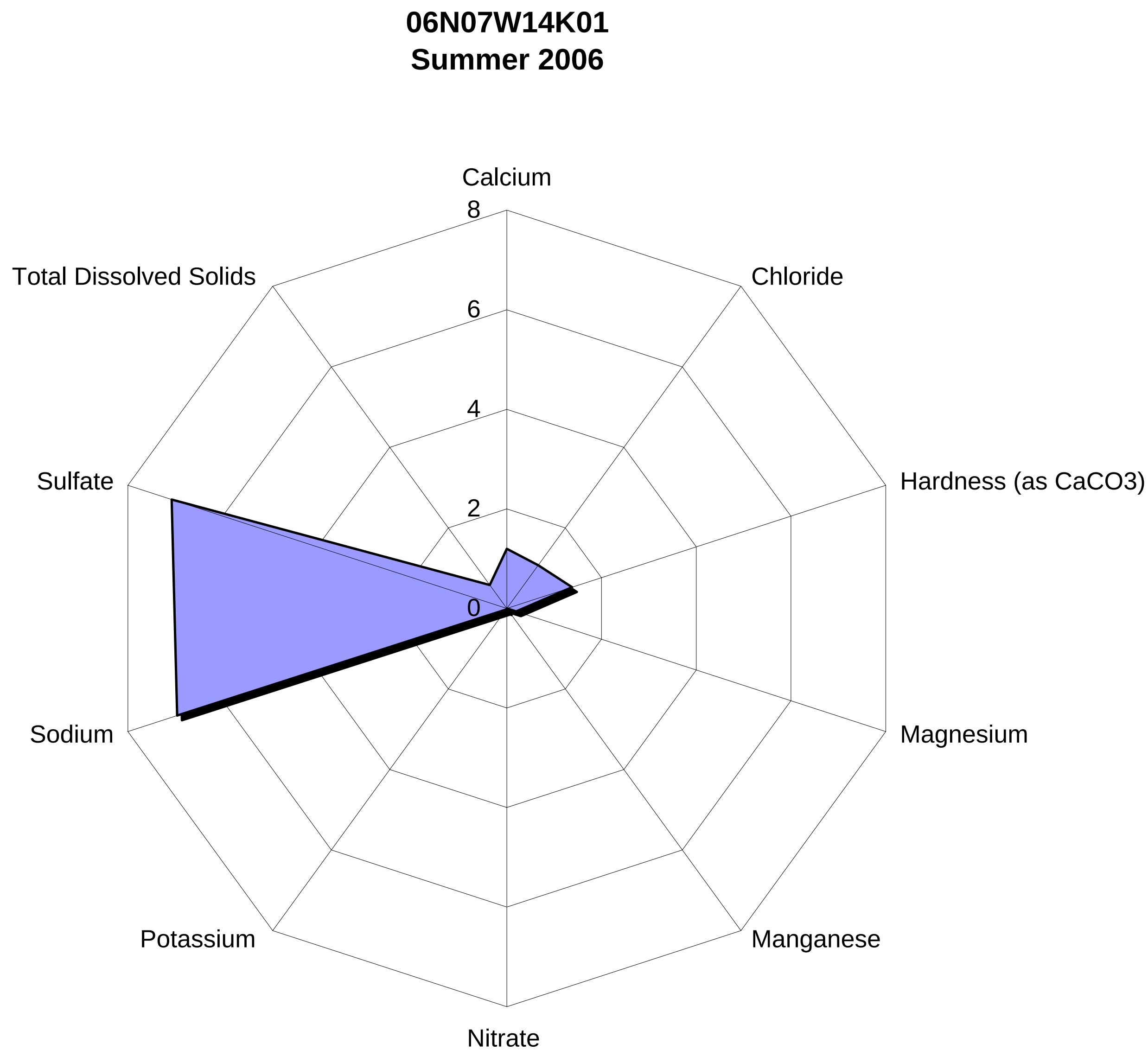
Spring 2003
Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
6
4
2
0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Summer 2006
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Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
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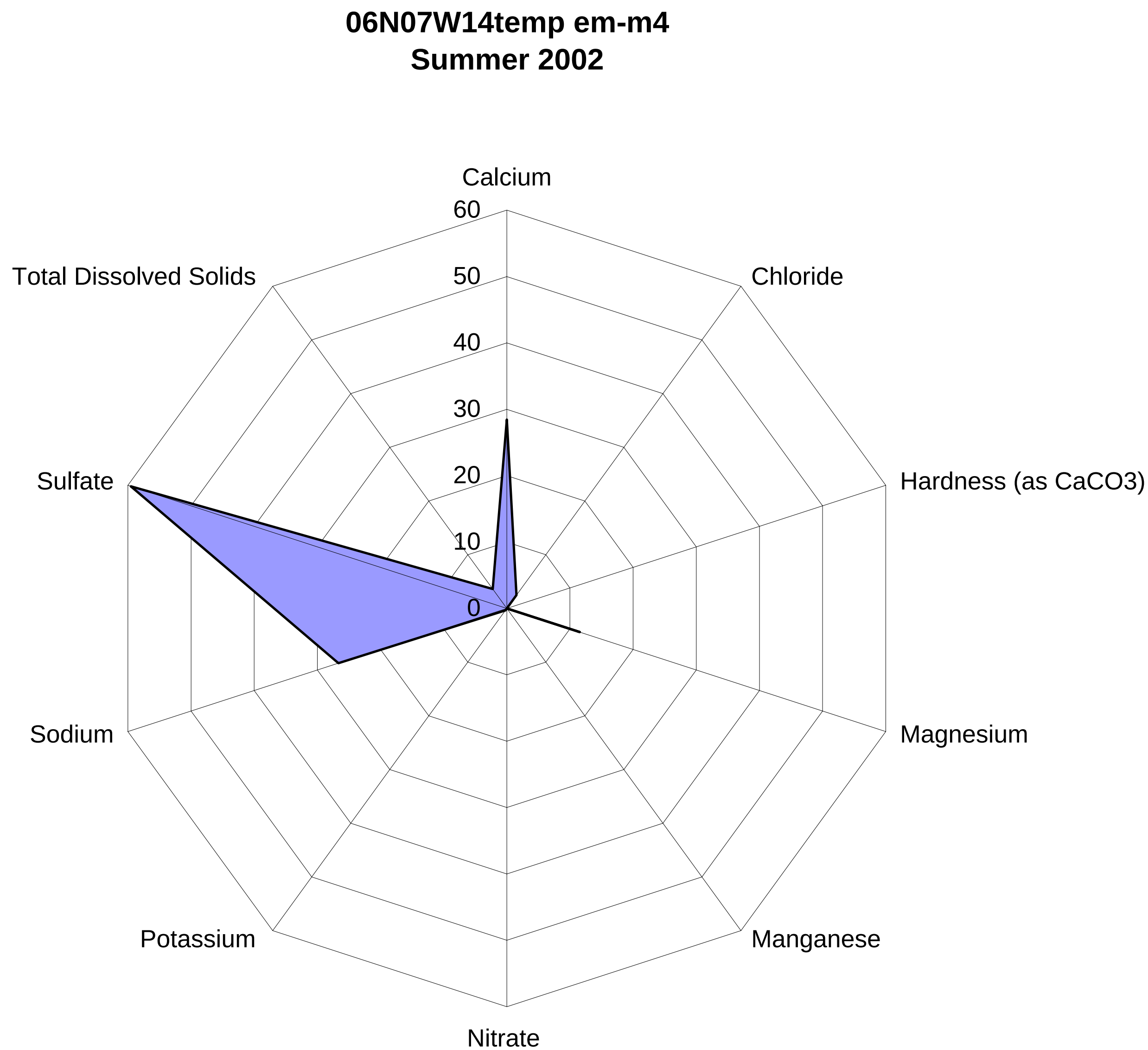
6
4
2
0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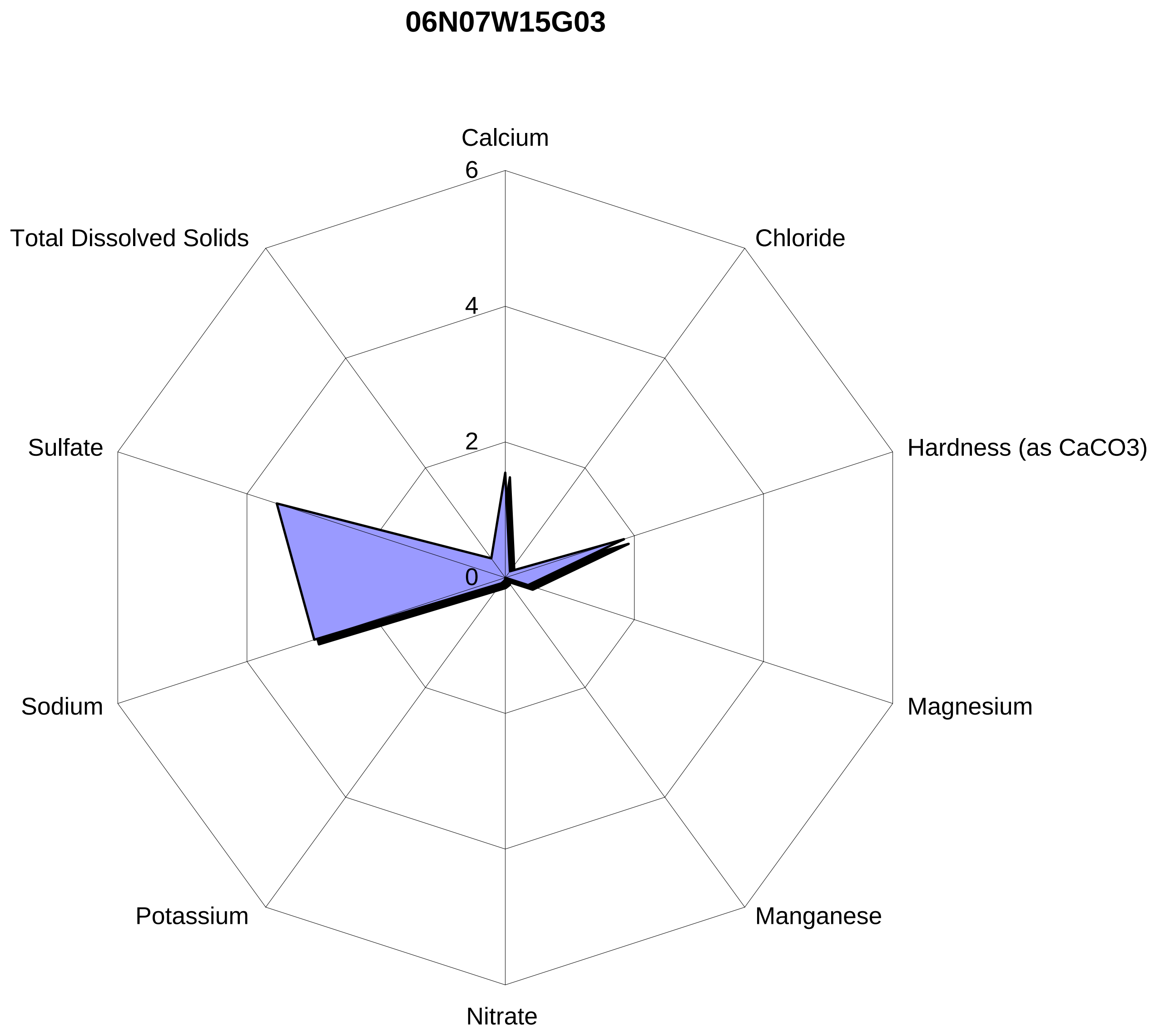
Summer 2002
Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
60
50
40
30
20
10
0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Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
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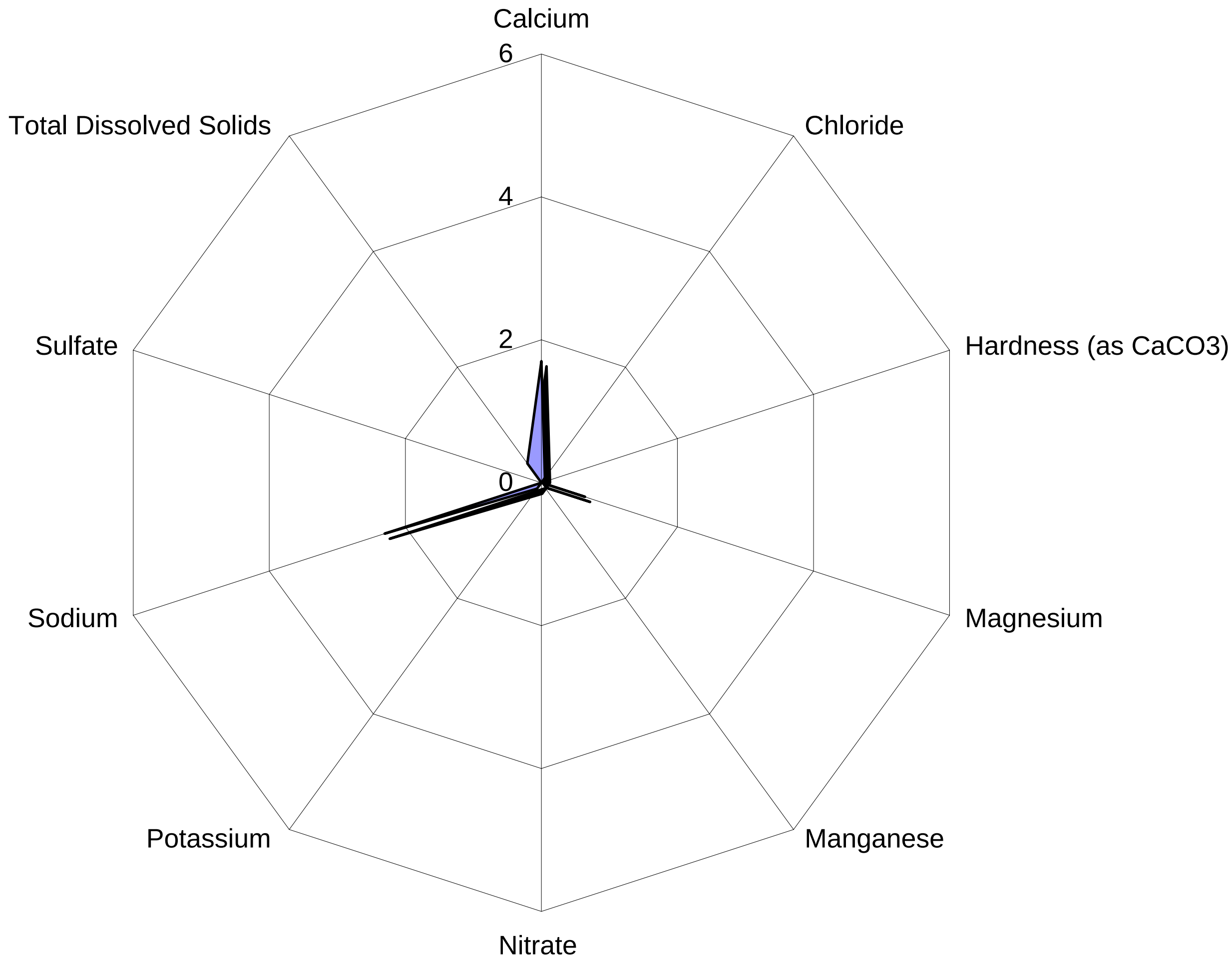
4
2
0

06N07W16R01
Summer 2002



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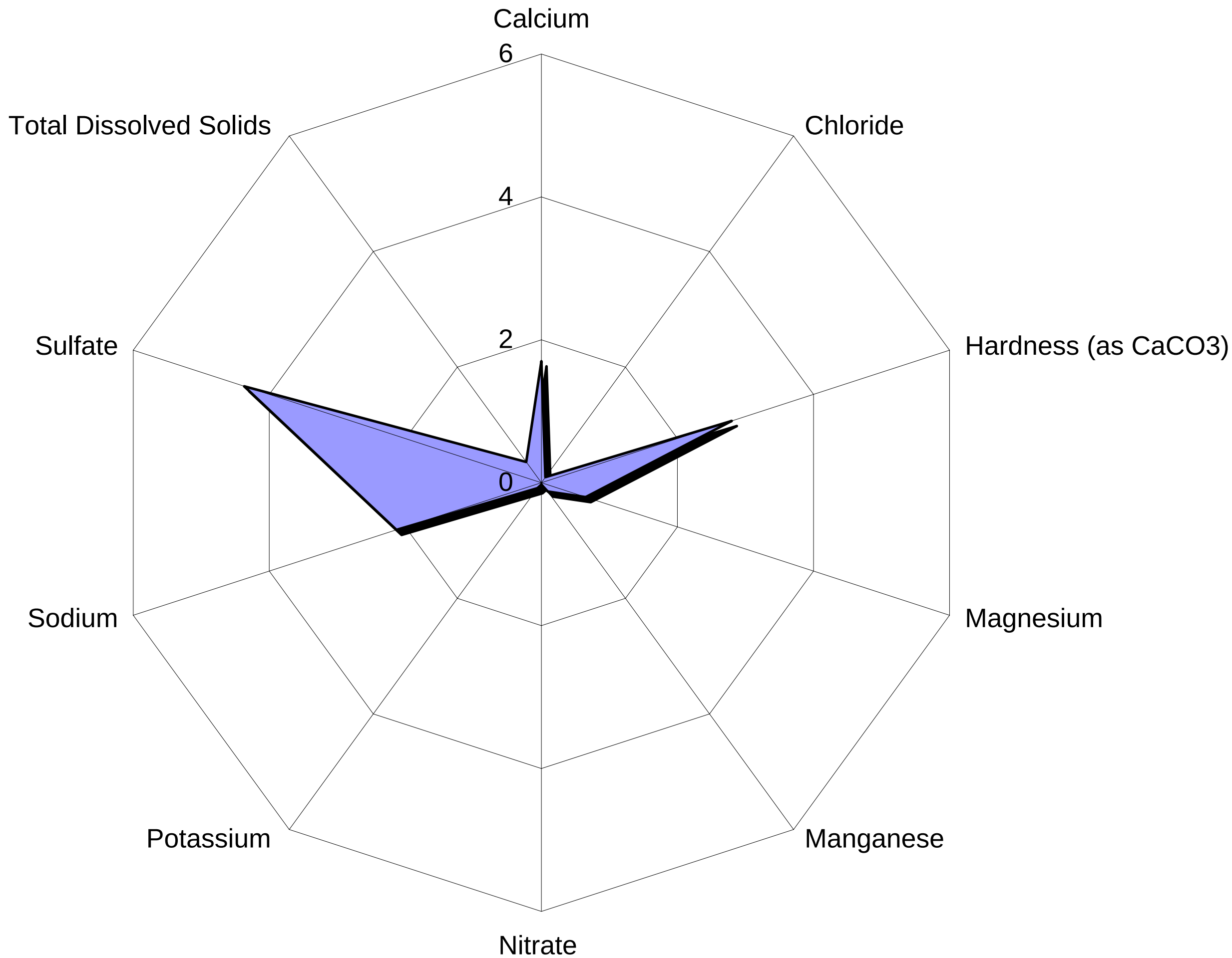
Fall 2006



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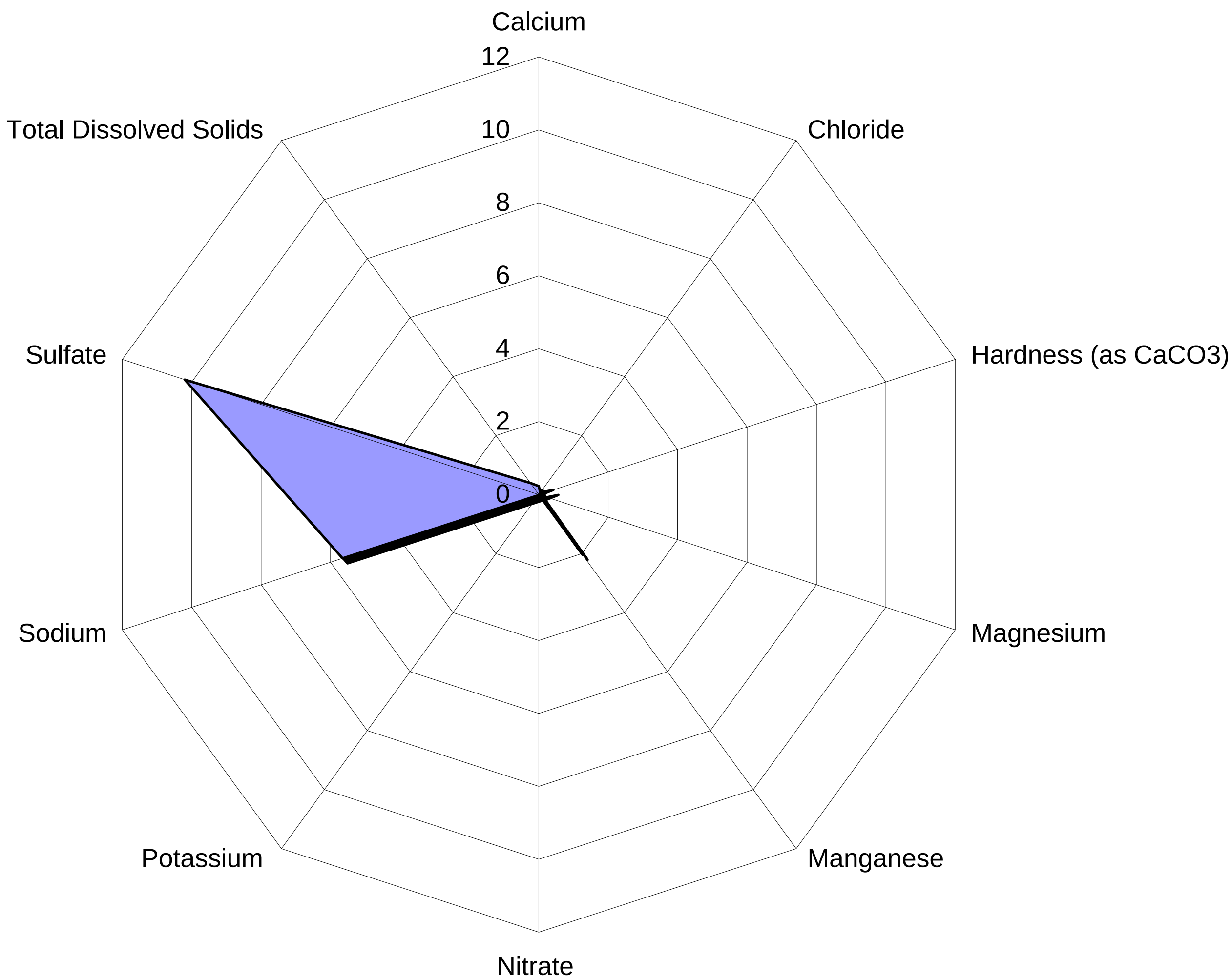

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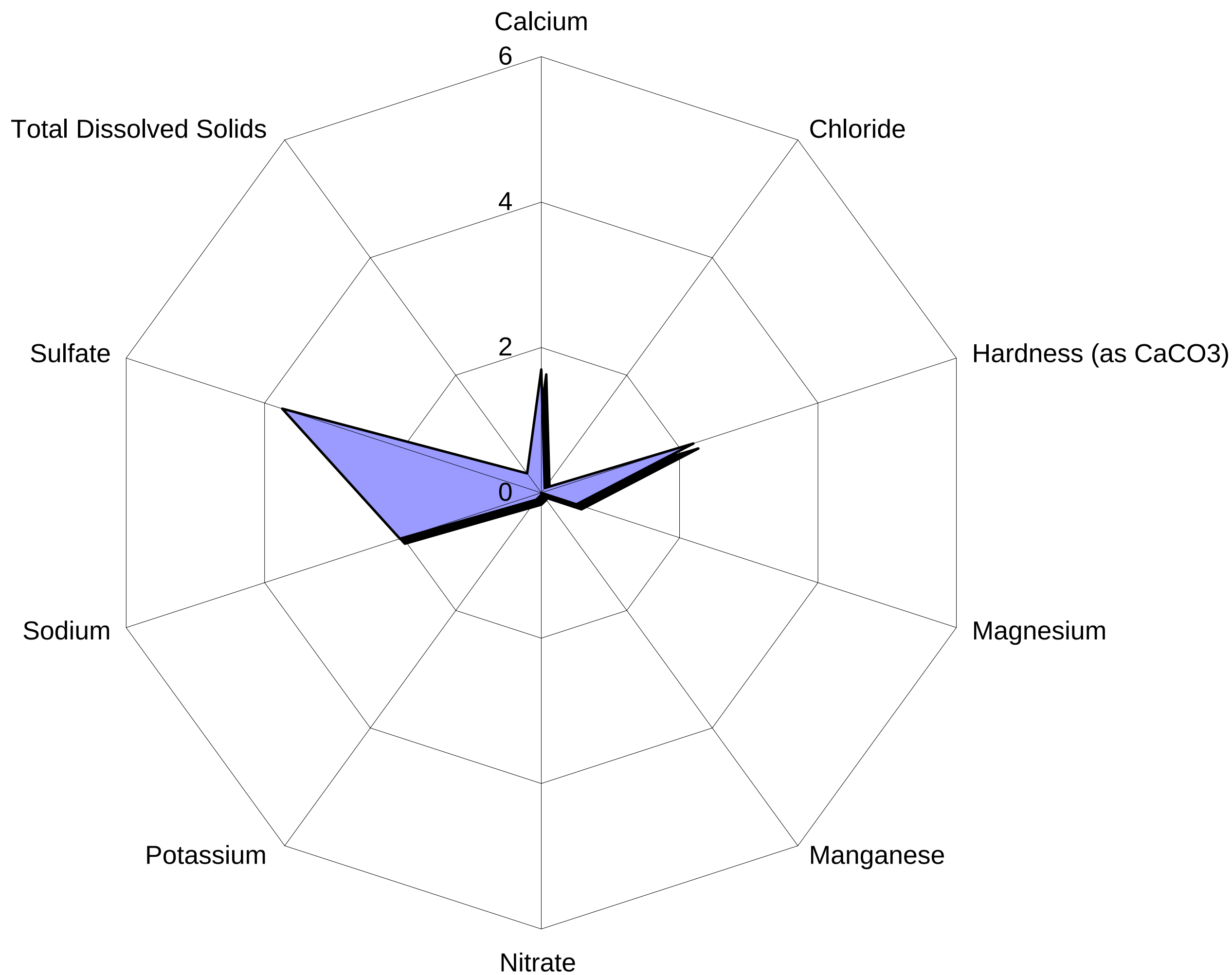

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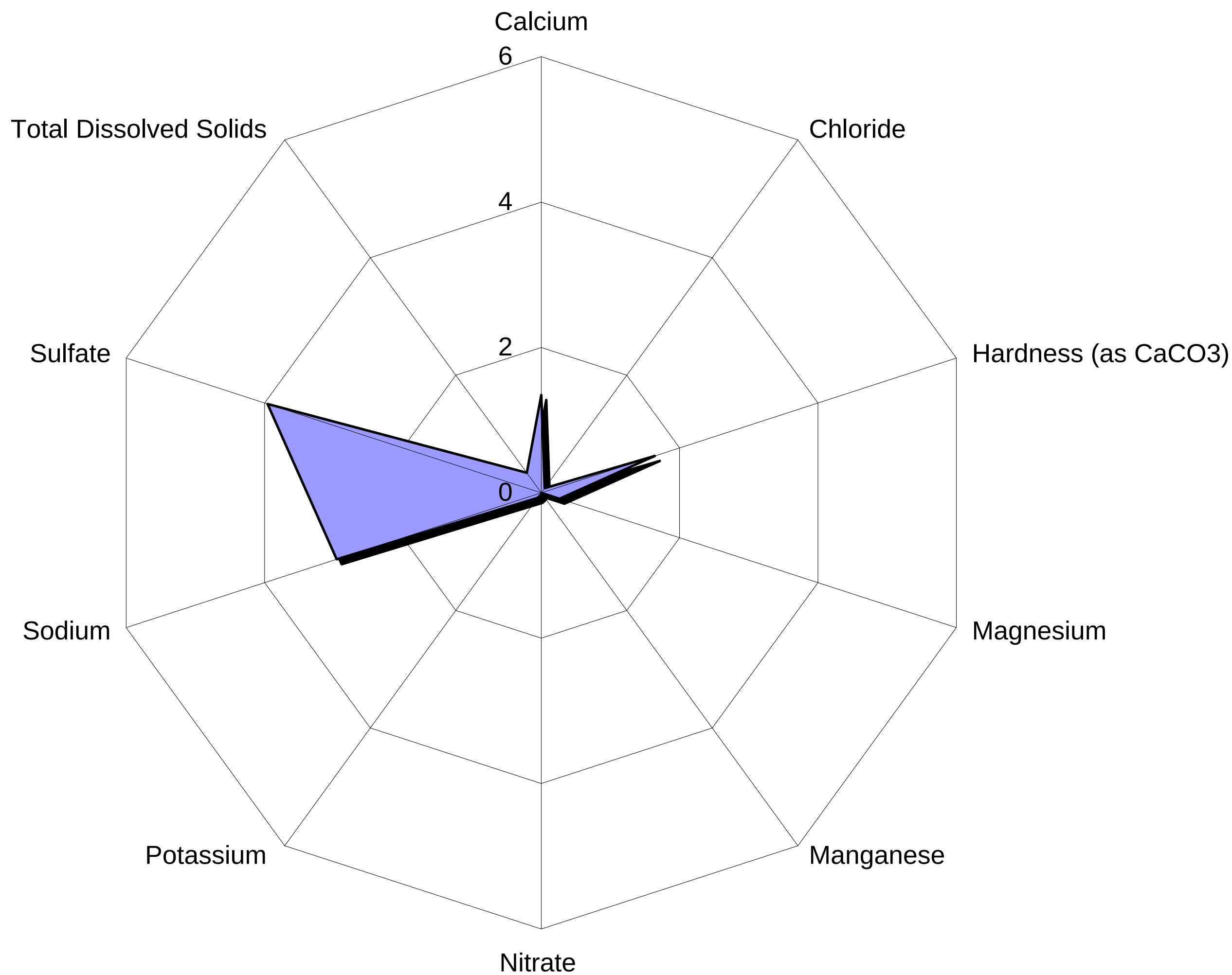

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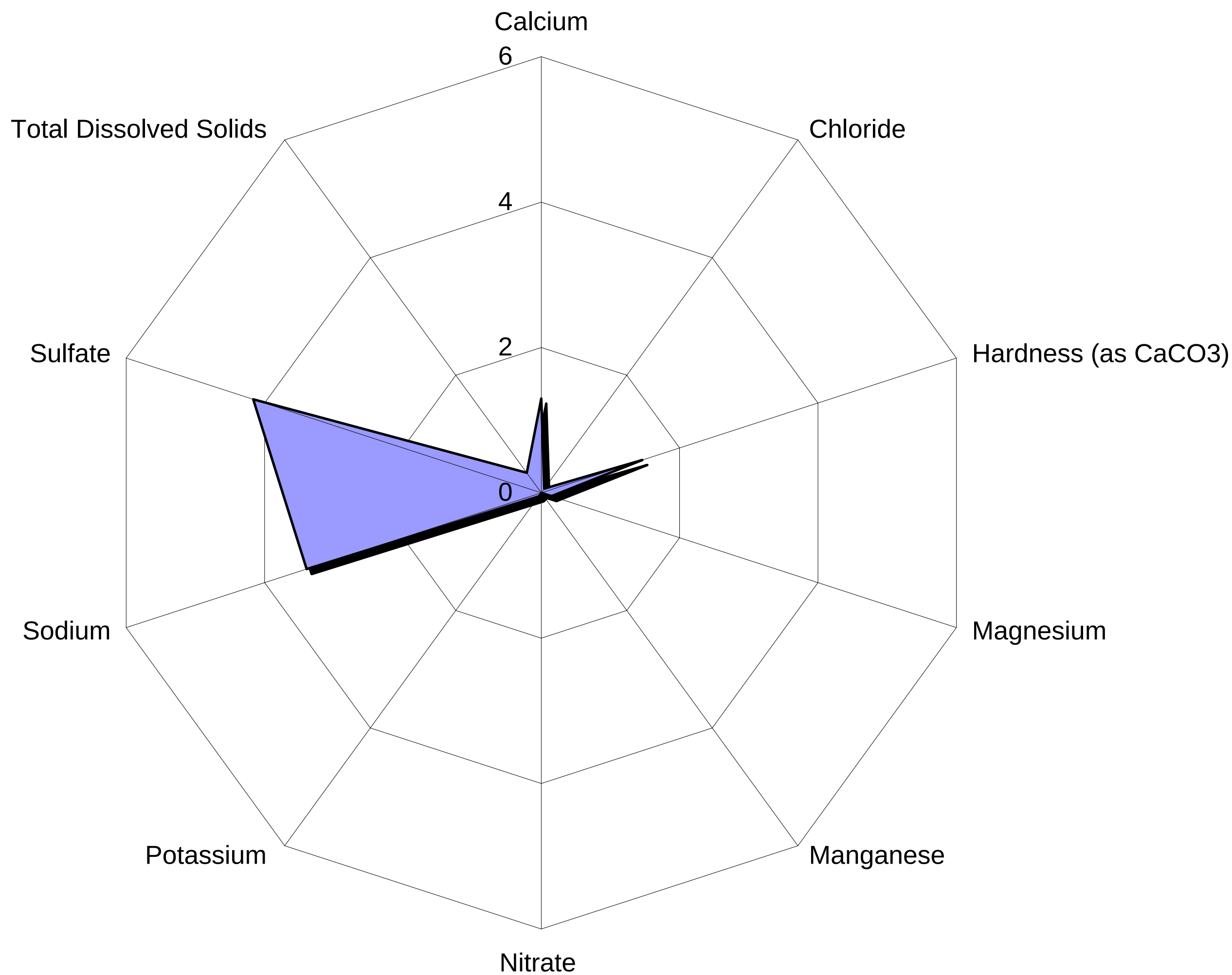

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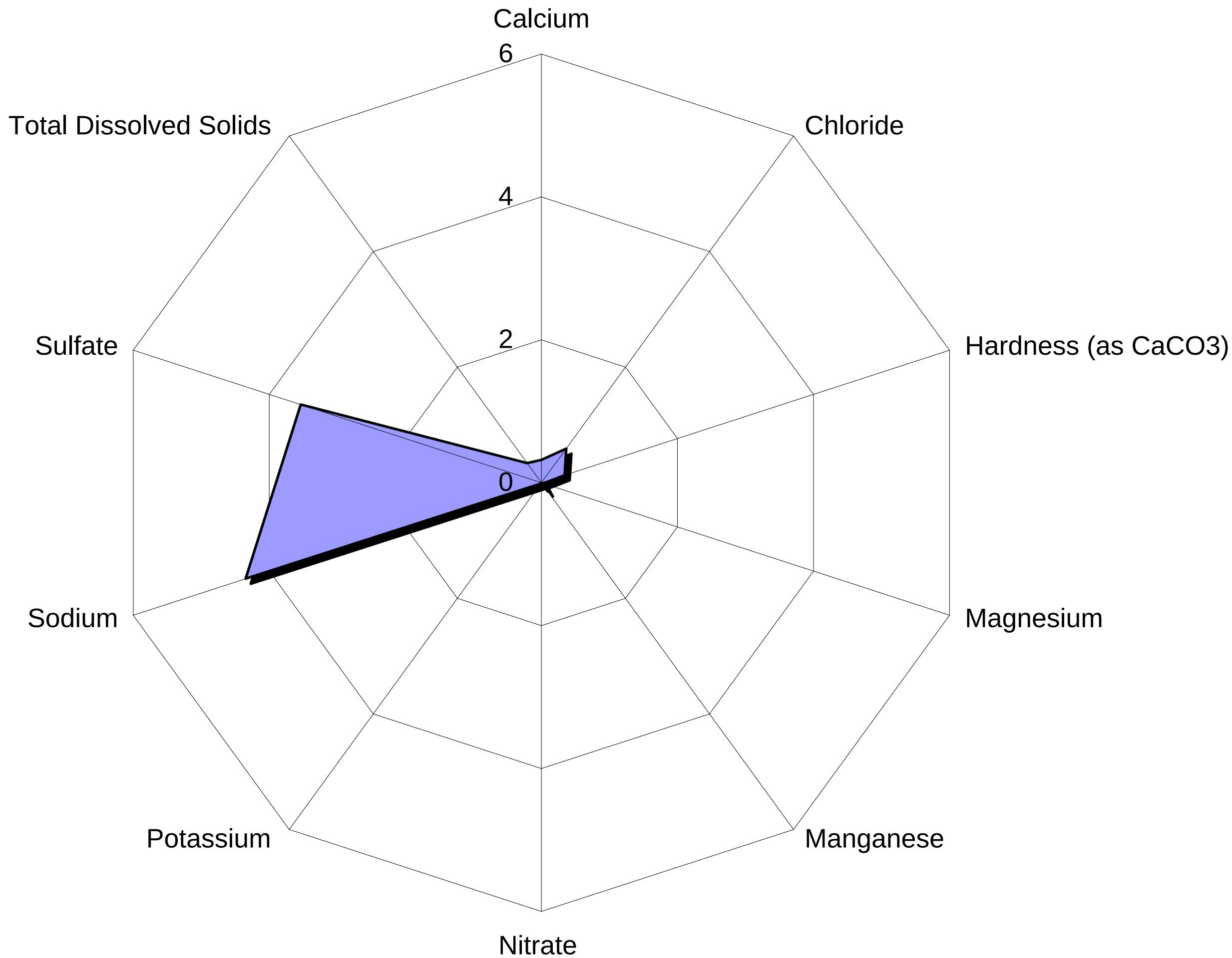
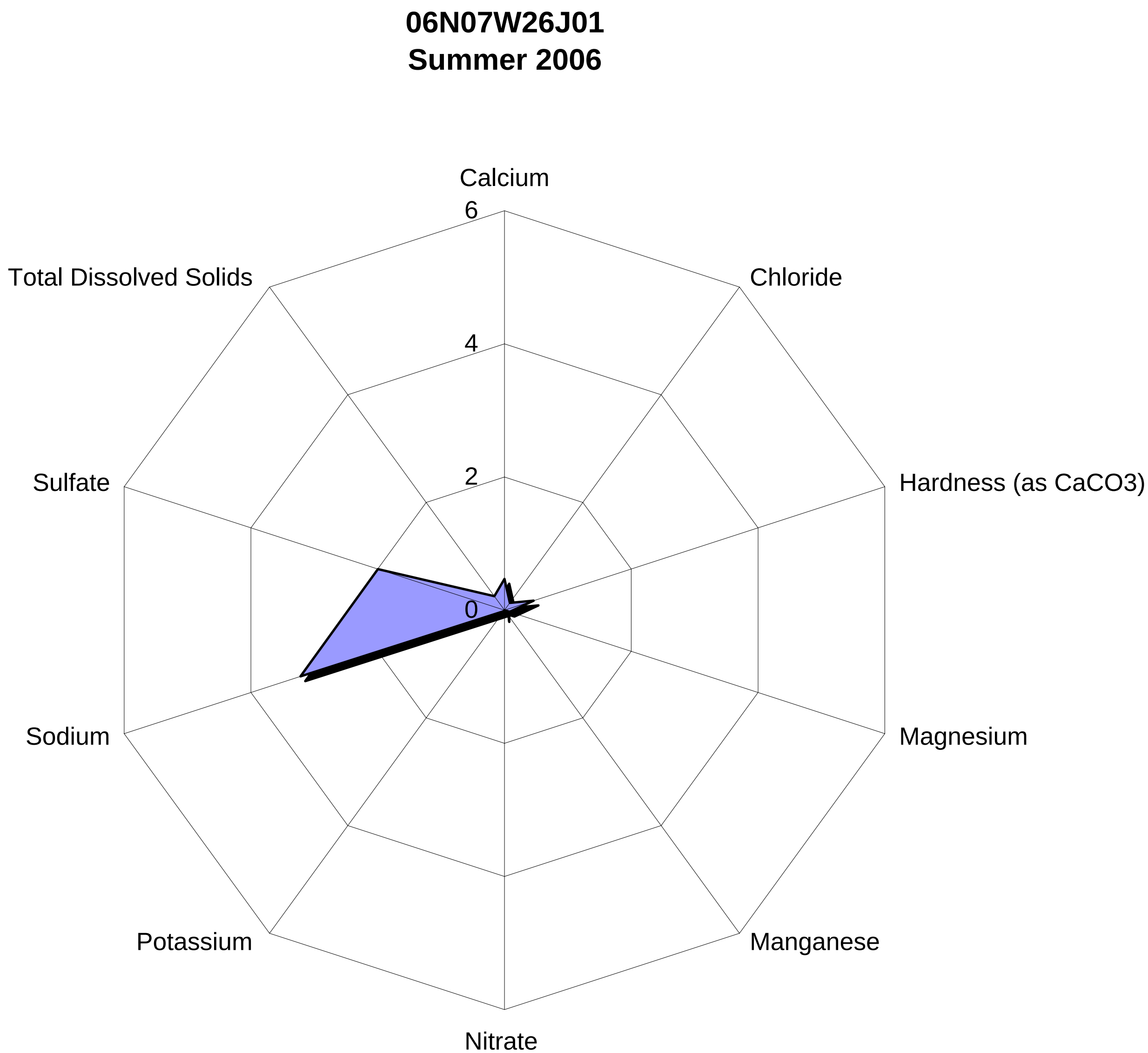
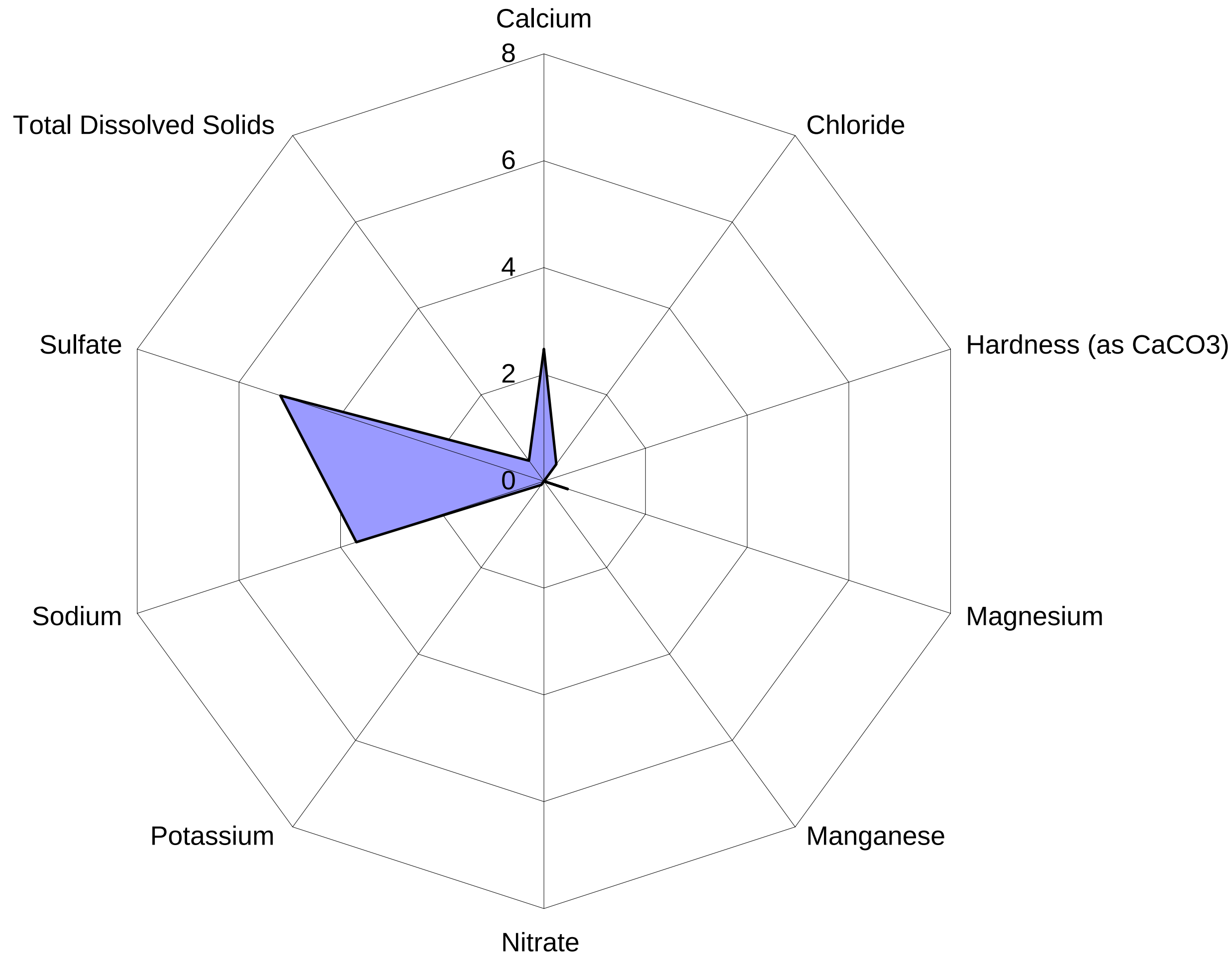
Fall 2006




06N07W26J01
Summer 2006
Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
6
4
2
0

06N07W26J02
Summer 2002



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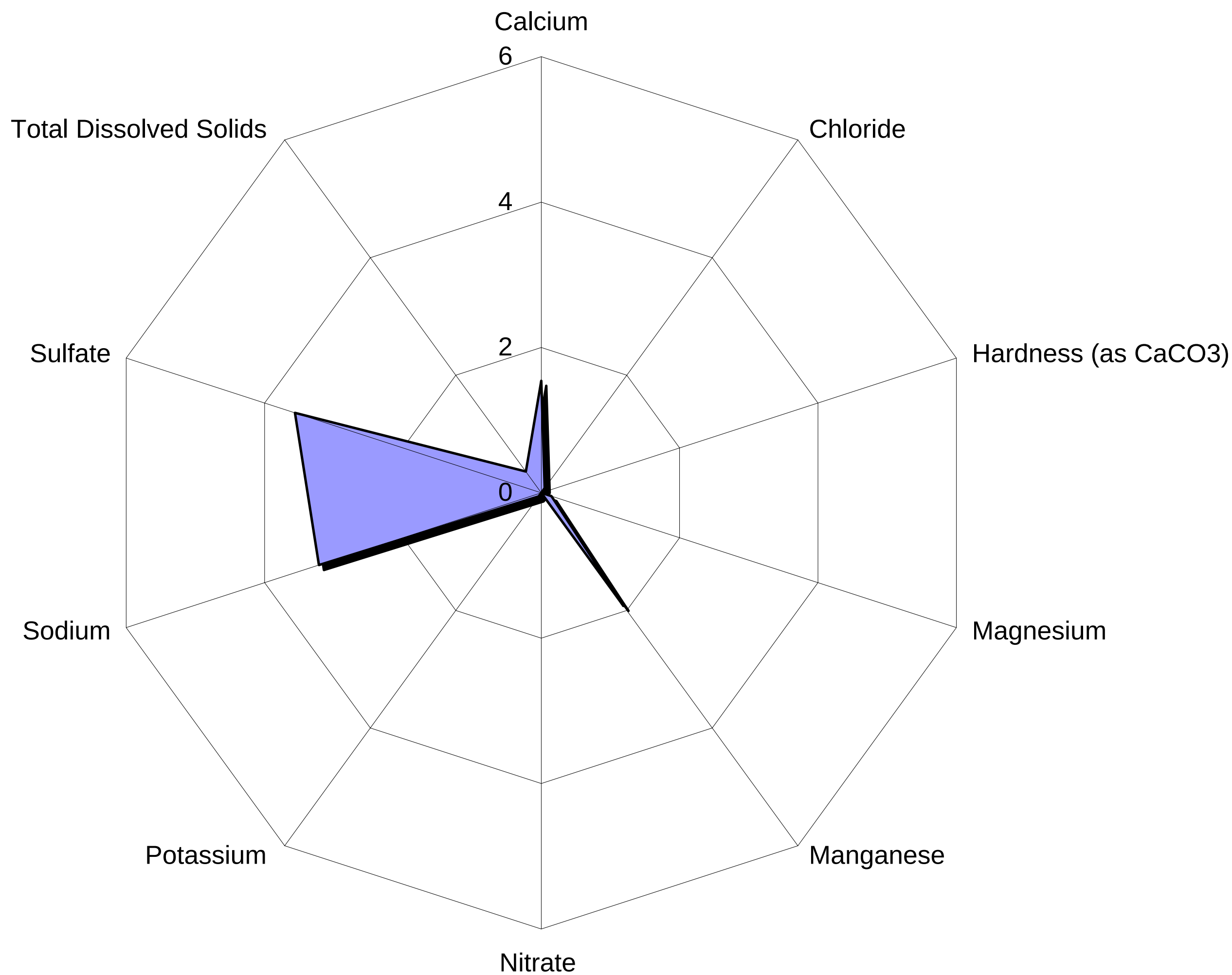
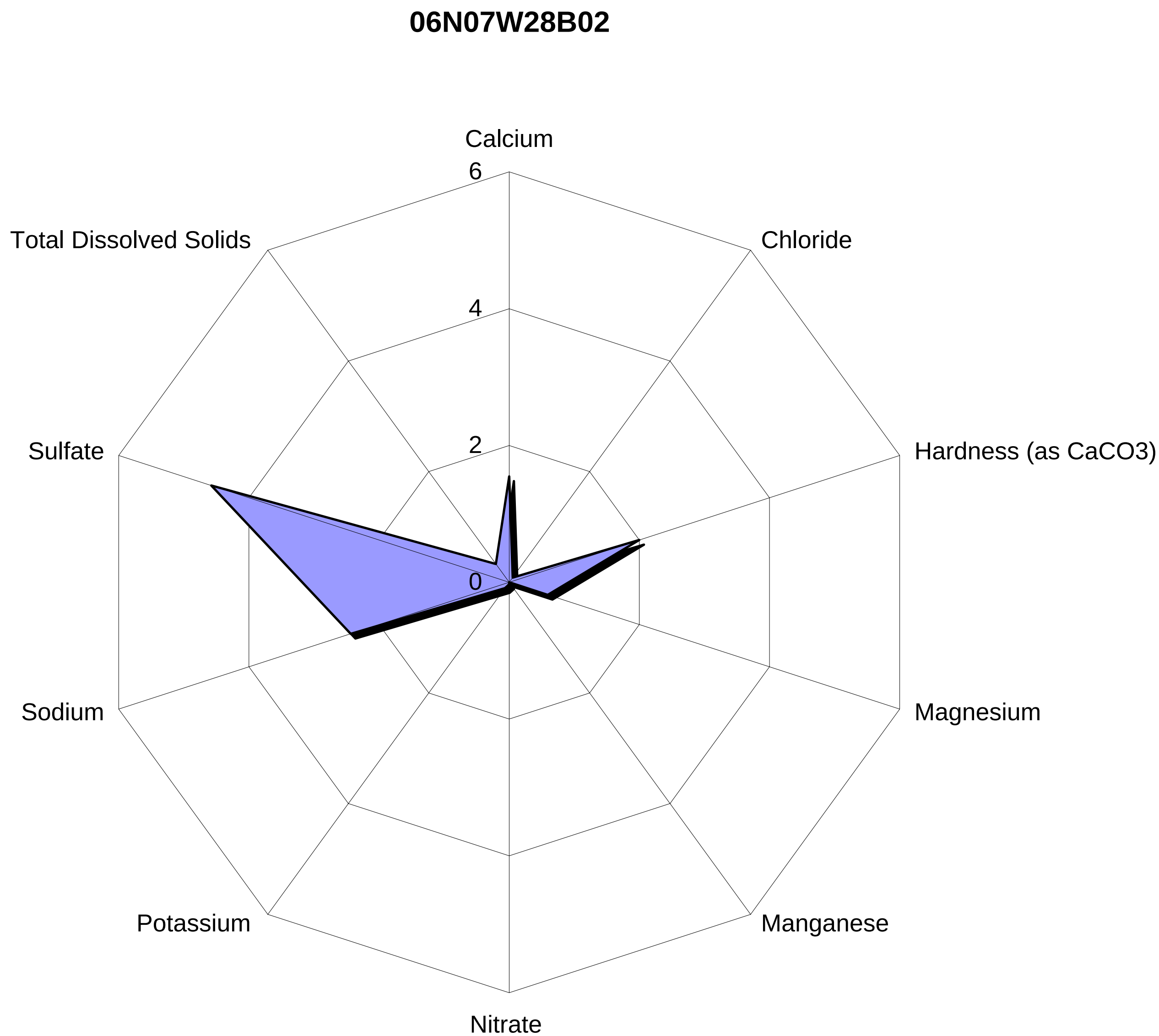
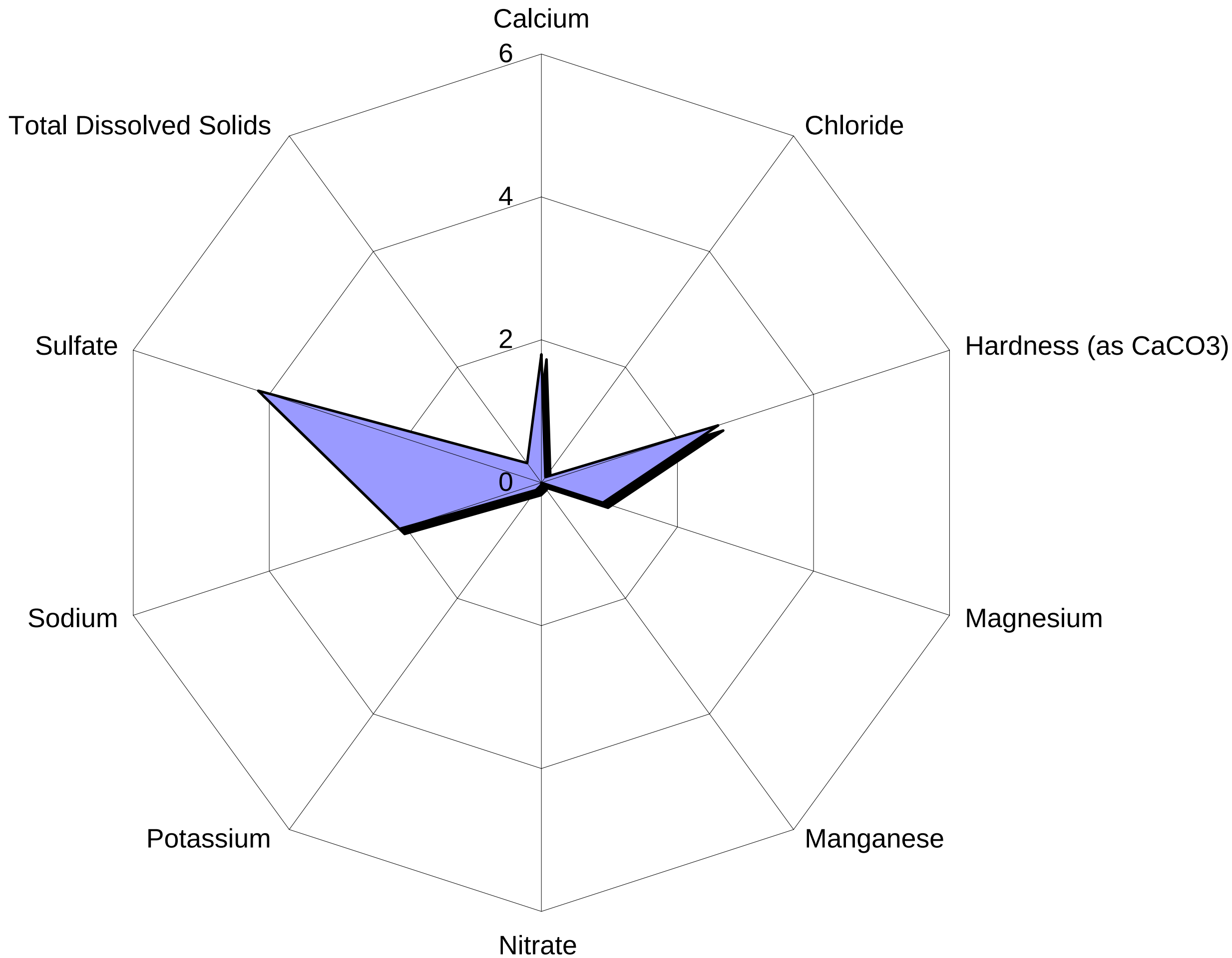



06N07W28B02
Calcium
Chloride
Hardness (as CaCO3)
Magnesium
Manganese
Nitrate
Potassium
Sodium
Sulfate
Total Dissolved Solids
6
4
2
0

06N07W29P02
Fall 2006



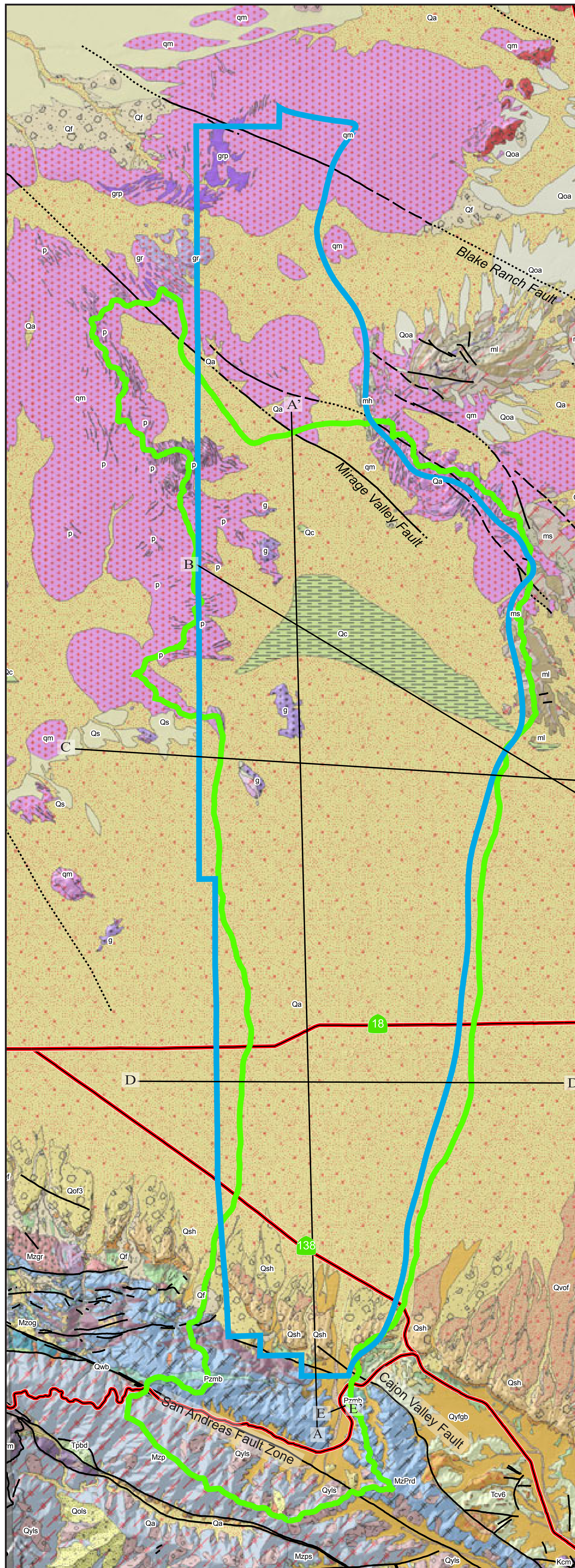
Appendix C – Well Information
C-1 Well Logs

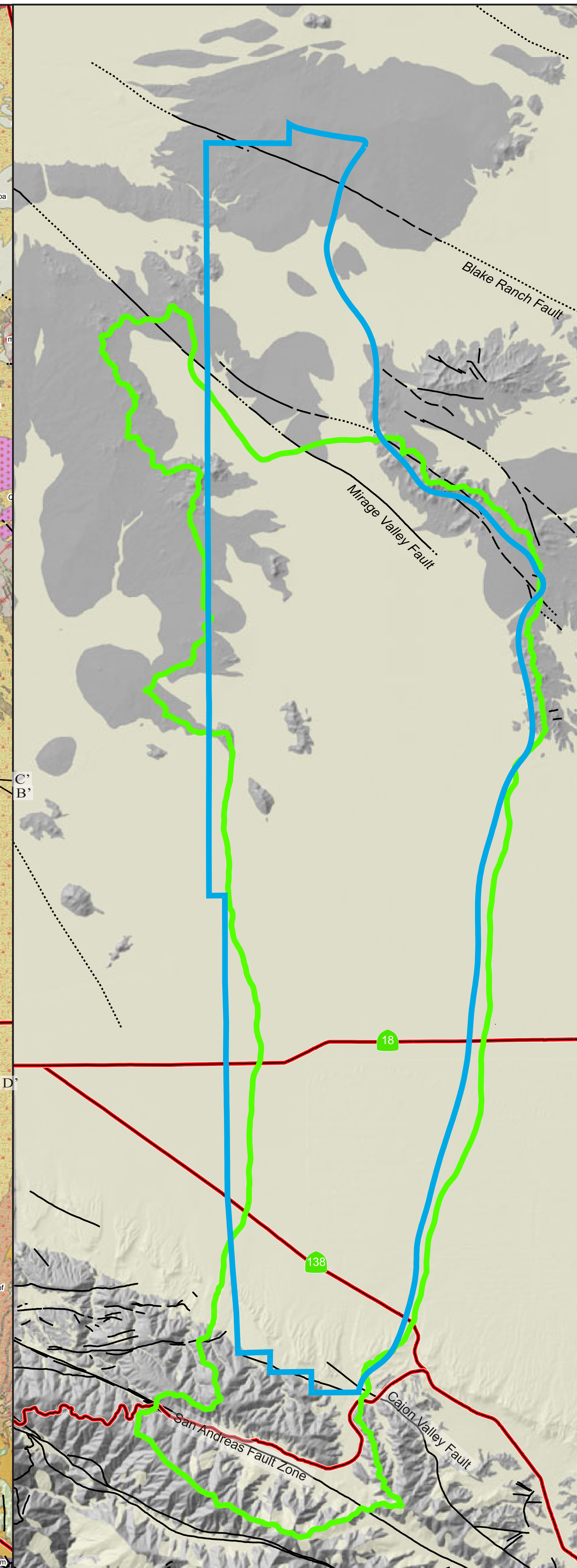
Well Completion Reports

Not Available for Public Release

Appendix D – Plates

Plate 1. Oeste Hydrologic Sub-area Physiographic Map.





QUATERNARY DEPOSITS

- Qdg — Disturbed ground
- Qaf — Artificial fill
- Qw — Very young wash deposits
- Qa — Alluvial gravel and sand
- Qc — Playa clay
- Qcs — Playa clay and windblown sand
- Qf — Fanglomerate
- Qs — Windblown sand
- Qsb — Wave-deposited bars
- Qt — Very young talus deposits
- Qls — Very young landslide deposits
- Ql — Very young lacustrine deposits
- Qyw — Young wash deposits
- Qyt — Young talus deposits
- Qyls — Young landslide deposits
- Qys — Young surficial deposits
- Qyf — Young alluvial-fan deposits
- Qof — Old alluvial-fan deposits
- Qoa — Older Alluvial Sediments
- Qols — Old landslide deposits
- Qvof — Very old alluvial-fan deposits
- Qvols — Very old landslide deposits
- Qvos — Very old surficial deposits
- Qsh — Shoemaker Gravel
- Qh — Harold Formation
- QTpp — Phelan Peak deposits,
- QTfz — QTfz Crushed rock in fault zones

TERTIARY DEPOSITS

- Ttus — Sandstone
- Tv — Vaqueros Formation
- Ttuc — Chert
- Ttug — Granitic Breccia
- Ttrb — Red Buttes quartz basalt of Tropico group
- Tb — Olivine basalt
- Ttlc — Clay shale
- Ttll — Limestone and (or) dolomite and shale
- Ttls — Sandstone
- Ttlt — Ryolitic tuff
- Ttb — Bissell Formation limestone and (or) dolomite
- Ttgh — Gem Hill Formation ryolitic tuff
- Tdv — Dacite vitrophyre of Tropico group
- Td — Dacite
- Tpbd — Diorite-clast unit
- Tpp — Phelan Peak deposits of Weldon (1984)
- Tcv — Cajon Valley Formation
- Ttp — Granodiorite of Telegraph Peak
- Tsf — San Francisquito Formation

MESOZOIC PLUTONIC ROCKS

- ql — Quartz Latite
- gr — Granite
- grp — Granite pegmatite-aplite
- g — Granite
- p — Pegmatite and aplite dikes
- qm — Quartz monzonite
- hd — Hornblende diorite
- hg — Hornblende granite
- Kpg — Monzogranite of Punchbowl Fault area
- Ksa — Quartz diorite of Mount San Antonio
- Kgdc — Biotite granodiorite, Cajon area
- Kcm — Tonalite of Circle Mountain
- KPm — Mylonitic orthogneiss related to Vincent Thrust Fault
- Tl — Mount Lowe Intrusive Suite

- Mzp — Pelona Schist, undifferentiated
- Mzps — Pelona Schist, muscovite schist unit
- Mzpr — Gneiss of Pinyon Ridge
- MzPb — Mixed metamorphic and granitic rocks of Big Dalton Canyon
- Mzgr — Biotite monzogranite of Big John Peak
- Mzgd — Gneissic granodiorite of Holcomb Ridge
- Mzog — Heterogeneous hornblende-biotite orthogneiss
- MzPm — Mixed granitic and metasedimentary rocks
- MzPd — Gneiss of Devil Canyon
- mhs — Hornblende schist
- ml — Crystalline limestone and dolomite
- mh — Lime silicate hornfels
- ms — Hornfels schist
- mq — Quartzite
- bs — Biotite schist
- hs — Hornblende schist or gneiss
- gs — Greenstone
- gt — Garnet tactite

PALEOZOIC METAMORPHIC ROCKS

- Pzmg — Marble, San Gabriel Mountains
- Pzmb — Marble, San Bernardino Mountains

PROTEROZOIC METAMORPHIC ROCKS

- Pgn — Layered gneiss, undifferentiated
- bgc — Coarse-grained biotite granite-augen gneiss

Explanation

- Major Highways
- Oeste Hydrologic Sub-area Boundary
- El Mirage Watershed
- Fault - Solid where known, dashed where approximate, dotted where inferred

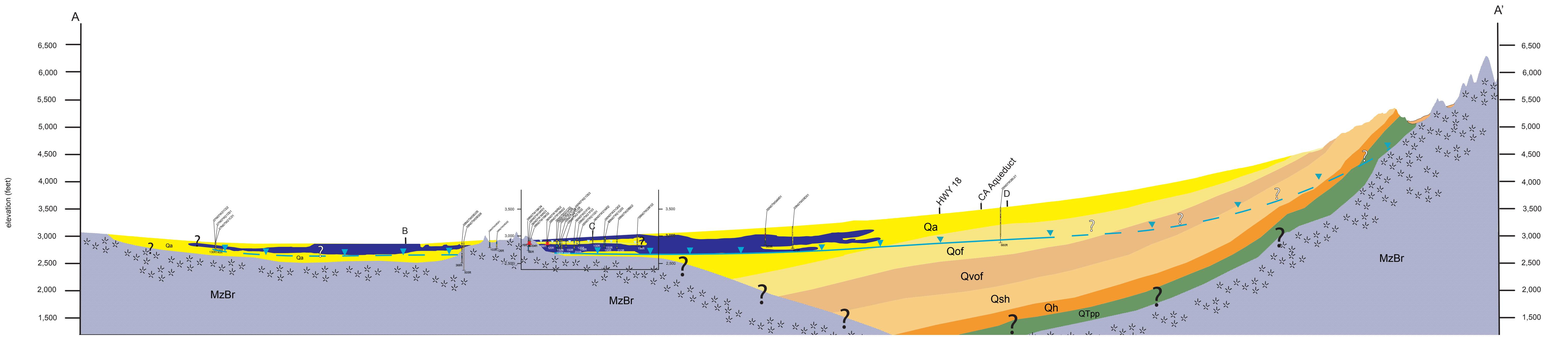
N

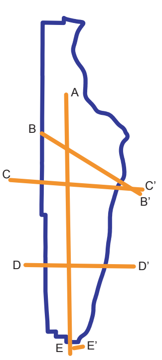
0 2 4 8 Kilometers
0 1 2 4 Miles

Descriptions modified from T.W. Dibblee, Jr. geologic map quadangles: Roger and Kramer, 1960; Shadow Mountains, 1960. San Bernardino 100,1000 Quadrangle (Morton and Miller, 2003).

Plate 2. Oeste Hydrologic Sub-area Generalized Geology and Bedrock Alluvium Map.

Generalized Geology Cross-section A-A'
Plate 3a





Explanation

- **Qa** Alluvial Deposits
  Sheep Creek Fan deposits, abundant Pelona Schist
- **cl** Clay Deposits
  Lucustrine clay deposits
- Regional Watertable 2006
- Perched Watertable, Original
- USGS 2006
- **Qof** Old Alluvial Fan Deposits
  Massive to poorly bedded, sand to boulder alluvium with Pelona Schist fragments
- **Qvof** Very Old Alluvial Fan Deposits
  Medium to very coarse sand, gravel and conglomerate with abundant Pelona Schist fragments
- **Qsh** Shoemaker Gravel
  Lithic arkosic conglomerate and lithic arkosic sandstone wtih abundant Pelona Schist fragments
- **?** Inferred Geologic Feature
- **Qh** Harold Formation
  Arkosic conglomerate sandstone with abundant Pelona Schist fragments
- **QTpp** Phelan Peak Formation
  Arkosic sandstone with no Pelona Schist fragments
- **MzBr** Basement Rocks
  Granitic and Metamorphic Rocks
- **?** Inferred Watertable

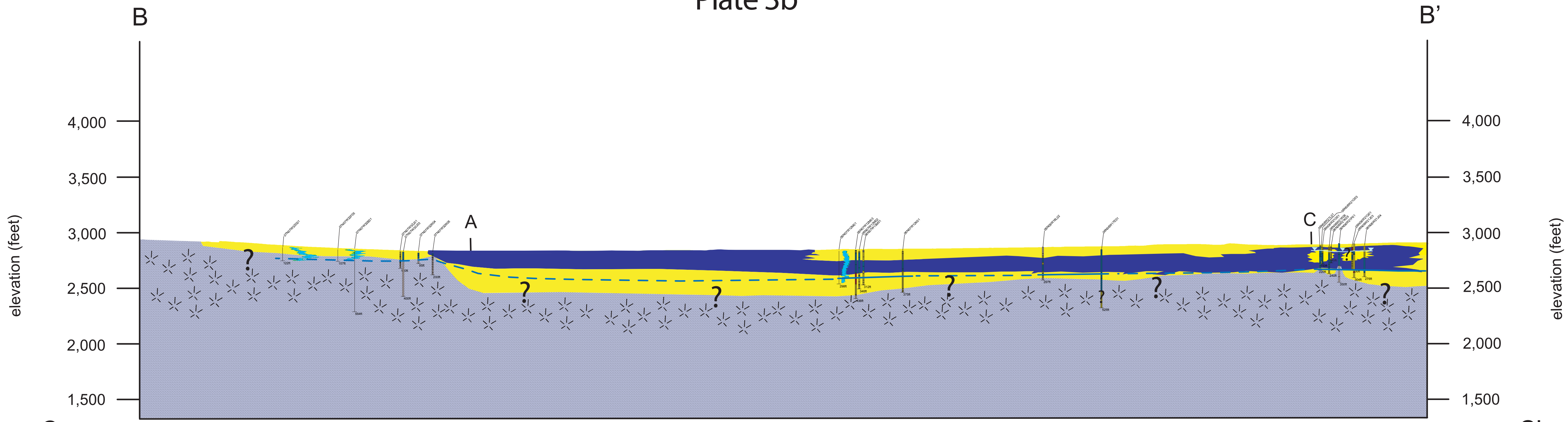
Scale

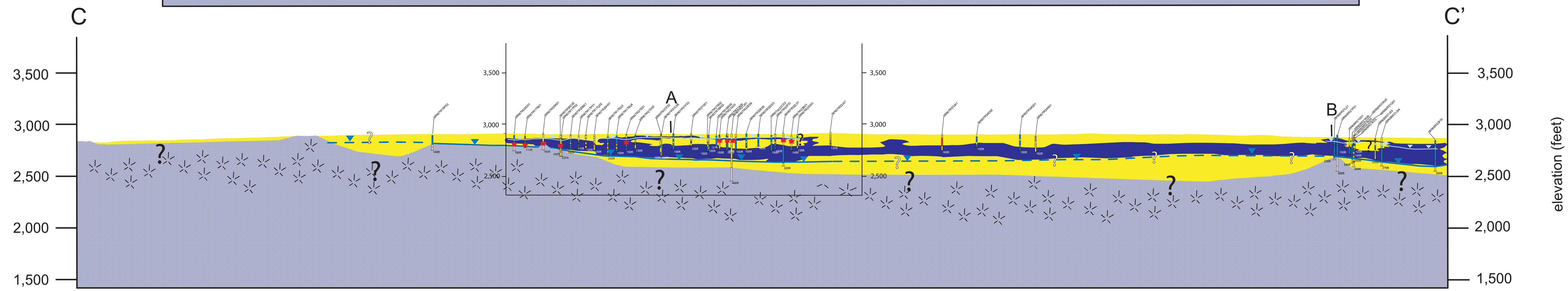
0 5,000 10,000 15,000 20,000 Feet

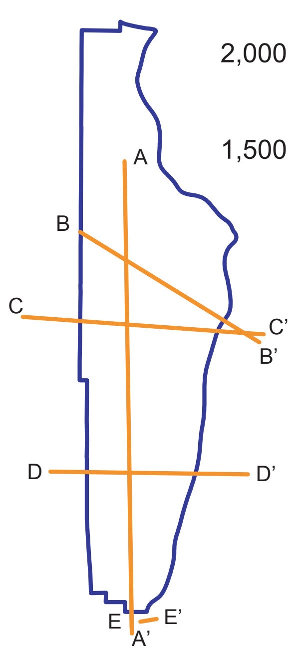
V.E. = 5X

Generalized Geology Cross Section B-B' and C-C'

Plate 3b







Explanation

Qa — Alluvial Deposits
Unconsolidated gravel, sand, and silt

cl — Clay Deposits
Lacustrine deposits

MzBr — Basement Rocks
Granitic and Metamorphic Rocks

? — Inferred Geologic Feature

? — Inferred Watertable

Regional Watertable 2006

Perched Watertable, Original

USGS 2006

Geophysical Log Only

Scale

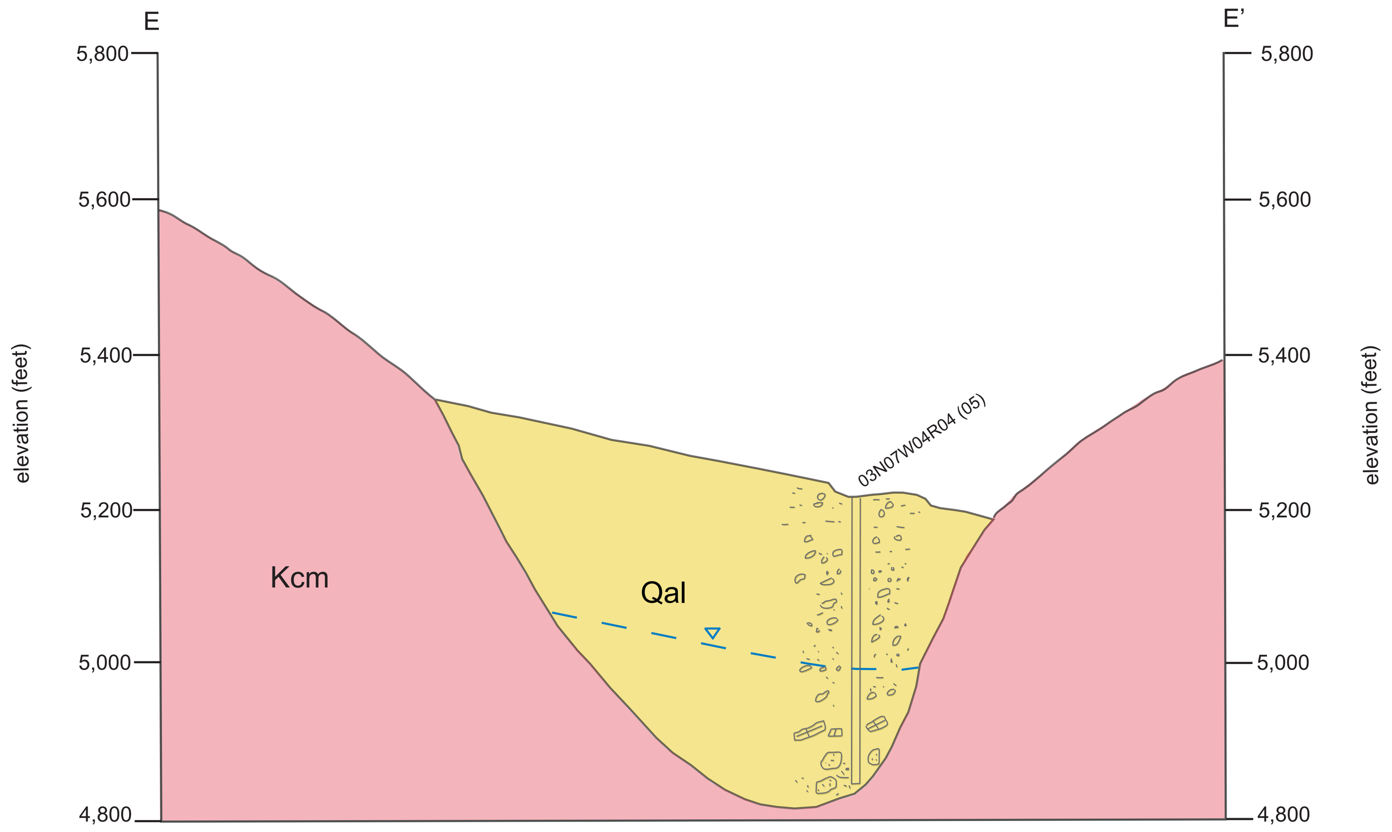
0 5,000 10,000

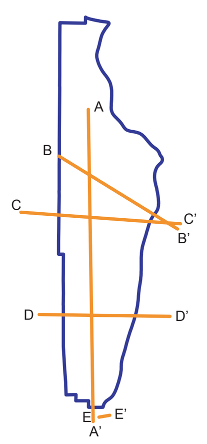
V.E. = 5X

Generalized Geology Cross-Section E-E', D-D', Insert A and Insert B

Plate 3c

Oeste Hydrologic Sub-area Geologic Cross Section E-E'





Explanation

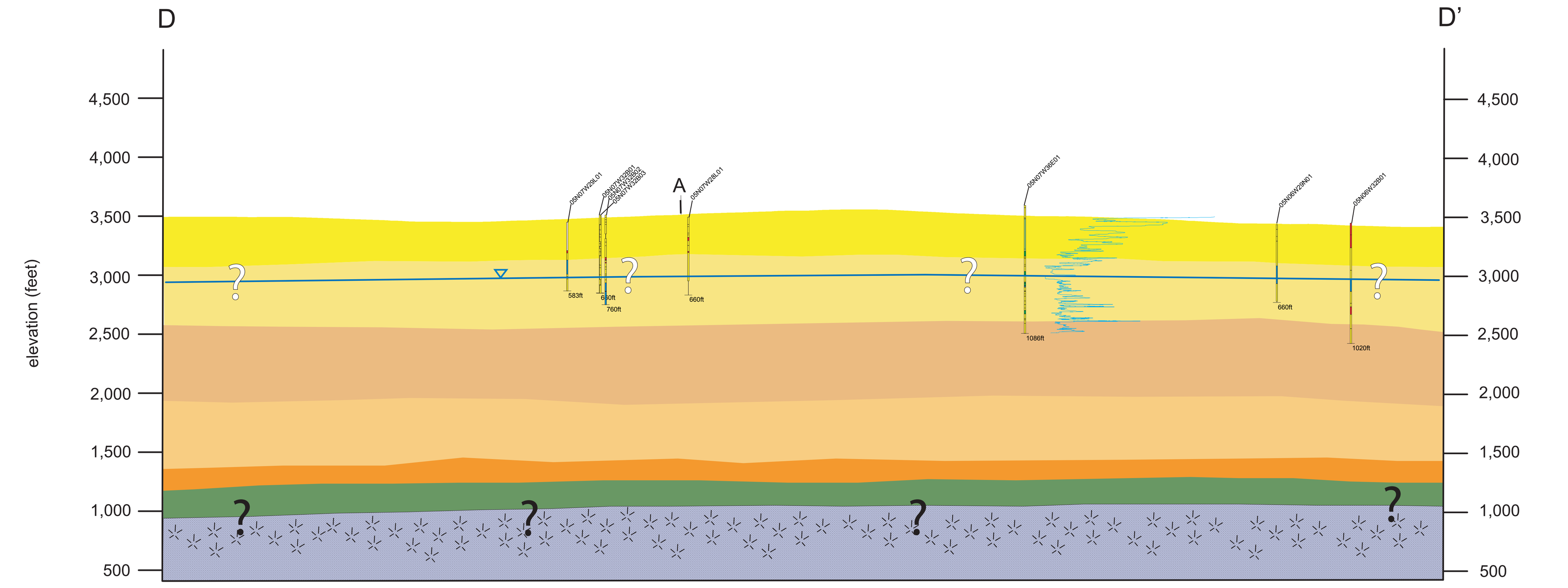
Qal — Alluvial Deposits
Unconsolidated boulders, sand, clay with limestone and abundant pelona schist fragments

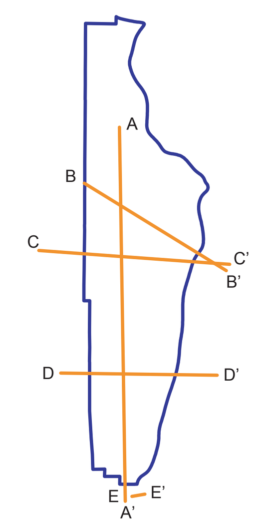
Kcm — Tonalite of Circle Mountain
Mixed Tonalite and gneiss

Groundwater Table 2006

Scale
0 400 800 1,200 1,600 Feet
V.E. = 2X

Oeste Hydrologic Sub-area Geologic Cross Section D-D'





Explanation

Qa — Alluvial Deposits
Sheep Creek Fan deposits, abundant Pelona Schist

Qof — Old Alluvial Fan Deposits
Massive to poorly bedded, sand to boulder alluvium, Pelona Schist

Qvof — Very Old Alluvial Fan Deposits
Medium to very coarse sand, gravel and conglomerate, abundant Pelona Schist

Qsh — Shoemaker Gravel
Lithic arkosic conglomerate and lithic arkosic sandstone, abundant Pelona Schist

? Inferred Geologic Feature

? Inferred Watertable

Qh — Harold Formation
Arkosic conglomerate sandstone, abundant Pelona Schist

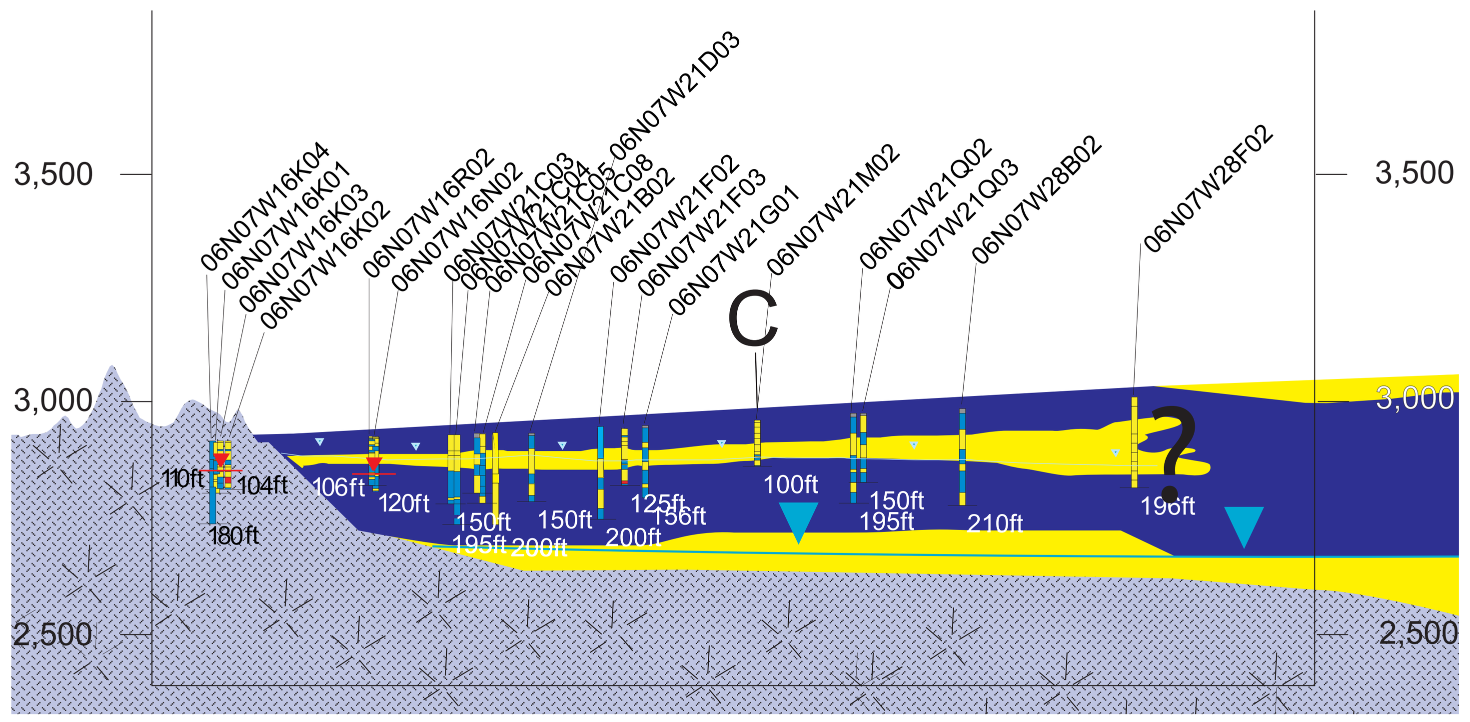
QTpp — Phelan Peak Formation
Arkosic sandstone, no Pelona Schist

MzBr — Basement Rocks
Granitic and Metamorphic Rocks

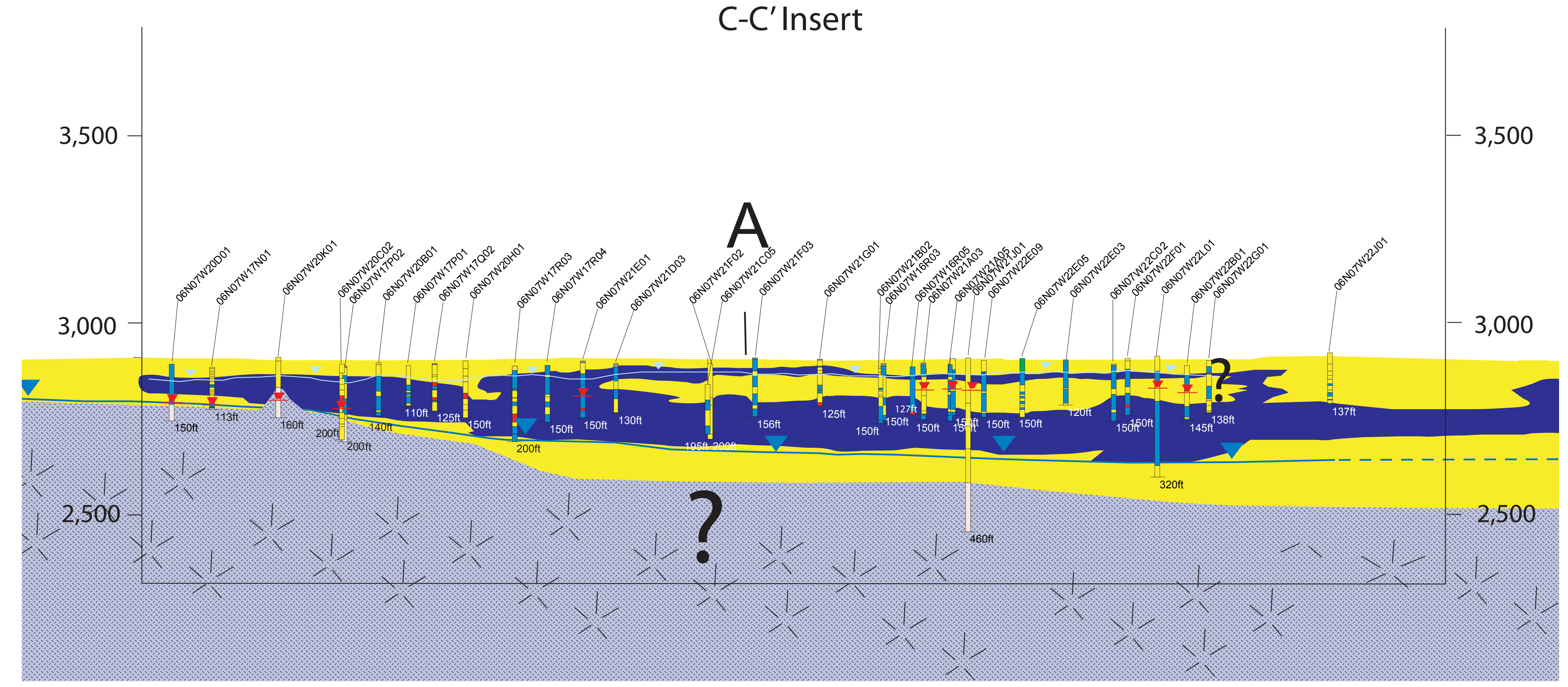
Groundwater Table
Spring 2004 Lower Aquifer

Scale
0 5,000 10,000 15,000 20,000 Feet
V.E. = 5X

A-A' Insert



C-C' Insert



Insert Explanation

Scale
0 500 1000 1500 2000 Feet

Qa — Alluvial Deposits
Unconsolidated gravel, sand, and silt

cl — Clay Deposits
Lacustrine deposits

MzBr — Basement Rocks
Granitic and Metamorphic Rocks

? Inferred Geologic Feature

? Inferred Watertable

Regional Watertable 2006

Perched Watertable, Original

USGS 2006

Scale
0 500 1000 1500 2000 Feet

Plate 4. Oeste Hydrologic Sub-area Groundwater Chemistry for Specific Wells Located Throughout the Oeste Hydrologic Sub-area. Red = Upper Aquifer, Yellow = Unknown Well Depth, and Green = Lower Aquifer.

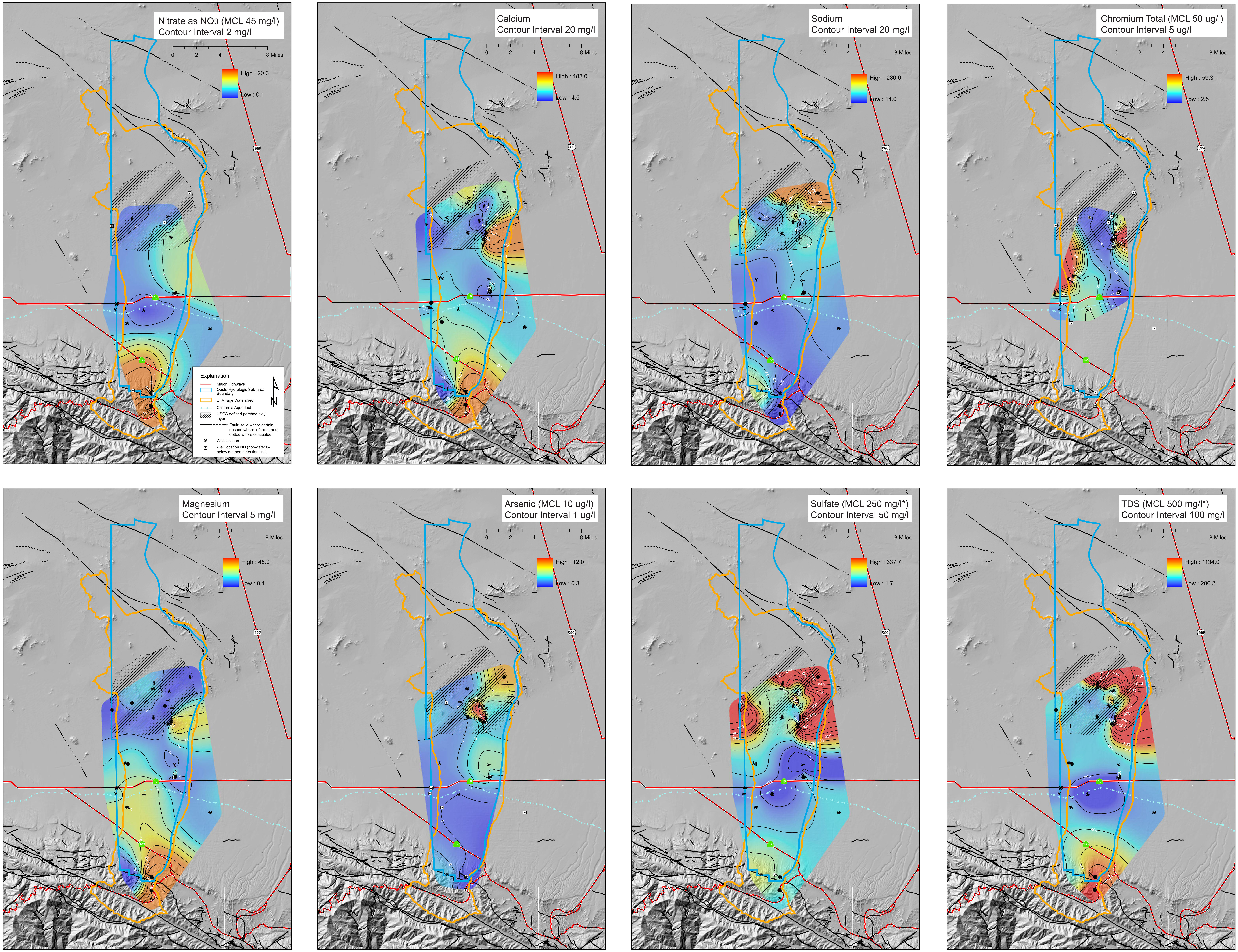


Plate 5. Regional Groundwater Chemistry. State MCLs are reported for Nitrate as NO_3, Chromium, and Arsenic. For map sources see Figure 9 and Plate 2.
*Indicates California Secondary MCL.

06N06W06Q03

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	X
Sodium	X
Chromium Total	X
Magnesium	X
Arsenic	X
Sulfate	X
TDS	1190

06N06W18P03

Constituent	mg/l
Nitrate (as No_3)	1.4
Calcium	27
Sodium	66
Chromium Total	7.1 ug/l
Magnesium	4.2
Arsenic	4.0 ug/l
Sulfate	170
TDS	340

06N07W13Q04

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	9.41
Sodium	1.22
Chromium Total	2.0 ug/l
Magnesium	0.739
Arsenic	5.2 ug/l
Sulfate	98.9
TDS	174

06N07W15C04

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	X
Sodium	X
Chromium Total	10.0 ug/l
Magnesium	X
Arsenic	X
Sulfate	X
TDS	394.1

06N07W16N01

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	X
Sodium	X
Chromium Total	X
Magnesium	X
Arsenic	X
Sulfate	X
TDS	364

06N07W21A02

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	44
Sodium	52
Chromium Total	10.0 ug/l
Magnesium	7.7
Arsenic	1.0 ug/l
Sulfate	200
TDS	367.5

06N07W22D03

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	X
Sodium	X
Chromium Total	15.0 ug/l
Magnesium	X
Arsenic	X
Sulfate	X
TDS	372.4

06N07W24B01

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	35
Sodium	94.1
Chromium Total	X
Magnesium	3.9
Arsenic	4.0 ug/l
Sulfate	229
TDS	473.9

06N07W24D01

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	29.8
Sodium	73.6
Chromium Total	7.0 ug/l
Magnesium	2.46
Arsenic	3.4 ug/l
Sulfate	177
TDS	361.2

06N07W27B08

Constituent	mg/l
Nitrate (as No_3)	X
Calcium	39.2
Sodium	55.2
Chromium Total	14.3 ug/l
Magnesium	6.28
Arsenic	1.7 ug/l
Sulfate	180
TDS	347.2

06N07W09L01

Constituent	mg/l
Nitrate (as No_3)	4.7
Calcium	54
Sodium	68
Chromium Total	2.2 ug/l
Magnesium	12
Arsenic	2.1 ug/l
Sulfate	190
TDS	460

06N07W15G03

Constituent	mg/l
Nitrate (as No_3)	2.3
Calcium	31
Sodium	68
Chromium Total	9.0 ug/l
Magnesium	4.3
Arsenic	1.5 ug/l
Sulfate	170
TDS	350

06N07W16K02

Constituent	mg/l
Nitrate (as No_3)	2
Calcium	41
Sodium	45
Chromium Total	8.6 ug/l
Magnesium	7.2
Arsenic	2.0 ug/l
Sulfate	190
TDS	340

06N07W17R01

Constituent	mg/l
Nitrate (as No_3)	2.1
Calcium	41
Sodium	45
Chromium Total	11 ug/l
Magnesium	7.1
Arsenic	1.5 ug/l
Sulfate	180
TDS	340

06N07W21Q02

Constituent	mg/l
Nitrate (as No_3)	1.8
Calcium	34
Sodium	47
Chromium Total	N/D
Magnesium	6.2
Arsenic	1.6 ug/l
Sulfate	180
TDS	330

06N07W22B05

Constituent	mg/l
Nitrate (as No_3)	1.2
Calcium	27
Sodium	68
Chromium Total	3.3 ug/l
Magnesium	3.2
Arsenic	2.0 ug/l
Sulfate	190
TDS	340

06N07W22G03

Constituent	mg/l
Nitrate (as No_3)	1.7
Calcium	35
Sodium	59
Chromium Total	5.8 ug/l
Magnesium	4.3
Arsenic	1.7 ug/l
Sulfate	160
TDS	350

06N07W27B03

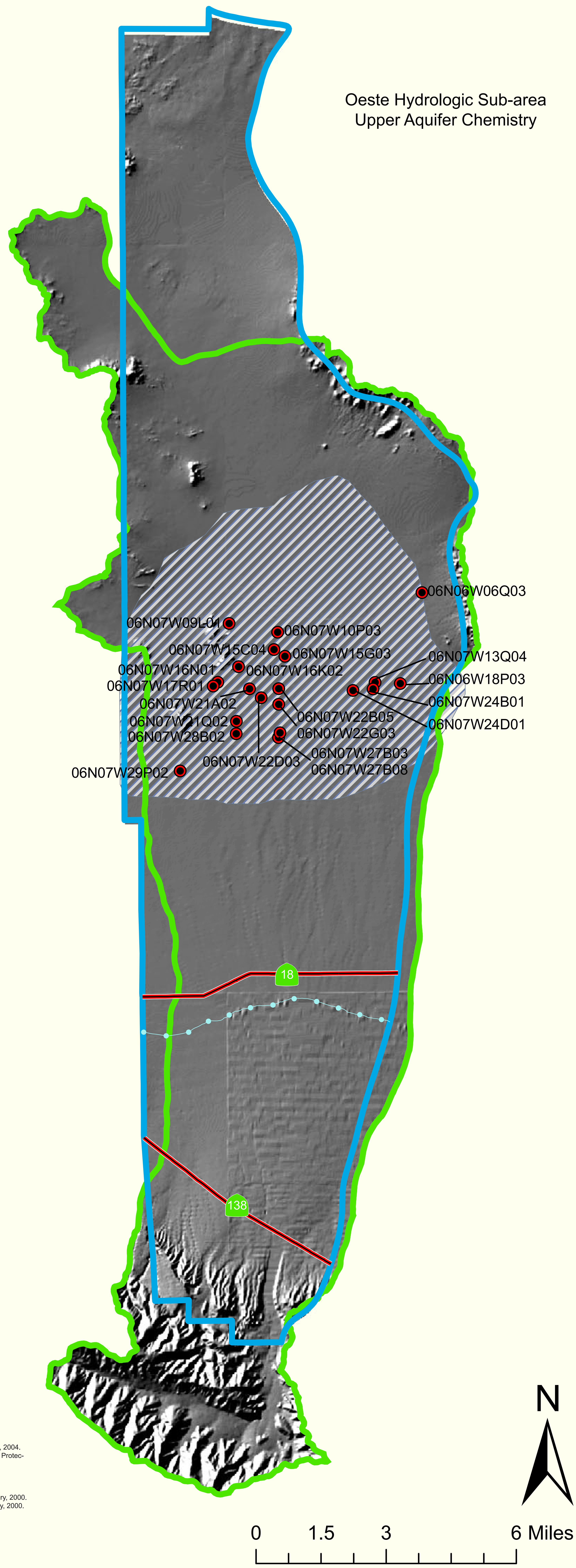
Constituent	mg/l
Nitrate (as No_3)	0.86
Calcium	26
Sodium	78
Chromium Total	N/D
Magnesium	1.8
Arsenic	2.0 ug/l
Sulfate	200
TDS	340

06N07W28B02

Constituent	mg/l
Nitrate (as No_3)	1.9
Calcium	31
Sodium	56
Chromium Total	N/D
Magnesium	7.2
Arsenic	1.5 ug/l
Sulfate	220
TDS	330

06N07W29P02

Constituent	mg/l
Nitrate (as No_3)	2
Calcium	36
Sodium	48
Chromium Total	2.5 ug/l
Magnesium	11
Arsenic	1.5 ug/l
Sulfate	200
TDS	340



Major Highways
Oeste Hydrologic Sub-area Boundary
El Mirage Valley Watershed
California Aqueduct
Chemistry Wells
USGS Perched Water Table

Sources:
California Aqueduct. Apple Valley, California: Mojave Water Agency, 2006.
California City Boundaries (1990 TIGER). Teale GIS Solutions Group, 1997.
California County Boundaries. California Department of Forestry and Fire Protection, 2004.
California Watersheds (CALWATER 2.2). California Department of Forestry and Fire Protection, 1999.
CalView Landsat Imagery Holdings. U.S. Geological Survey, 1999-2002.
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency, 2006.
Perched Clay Zone U.S. Geological Survey, 2003.
Tiger 2000 Transportation Layer-State highways. California Spatial Information Library, 2000.
Tiger 2000 Transportation Layer-U.S. highways. California Spatial Information Library, 2000.

Plate 6. El Mirage Valley Clay Zone Generalized Water Quality.
N/D = Non-Detect; X = Constiuent not measured.