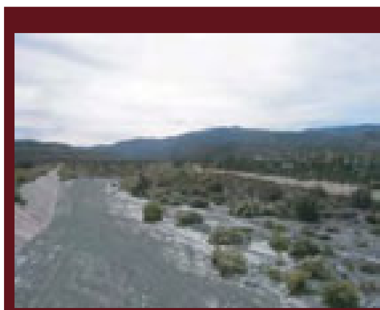
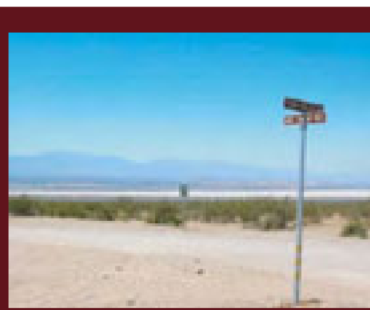
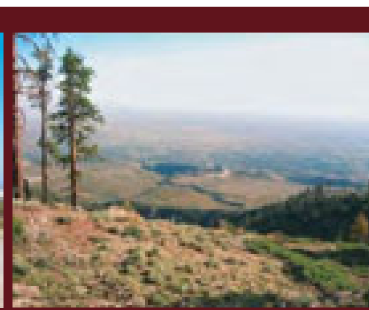
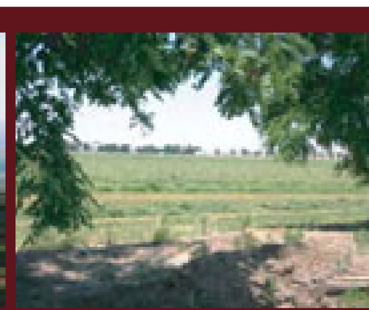
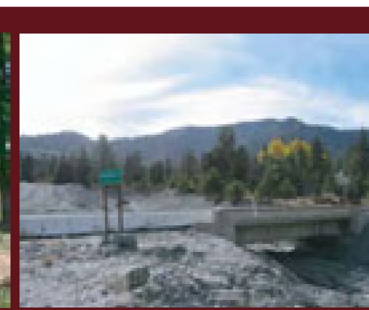


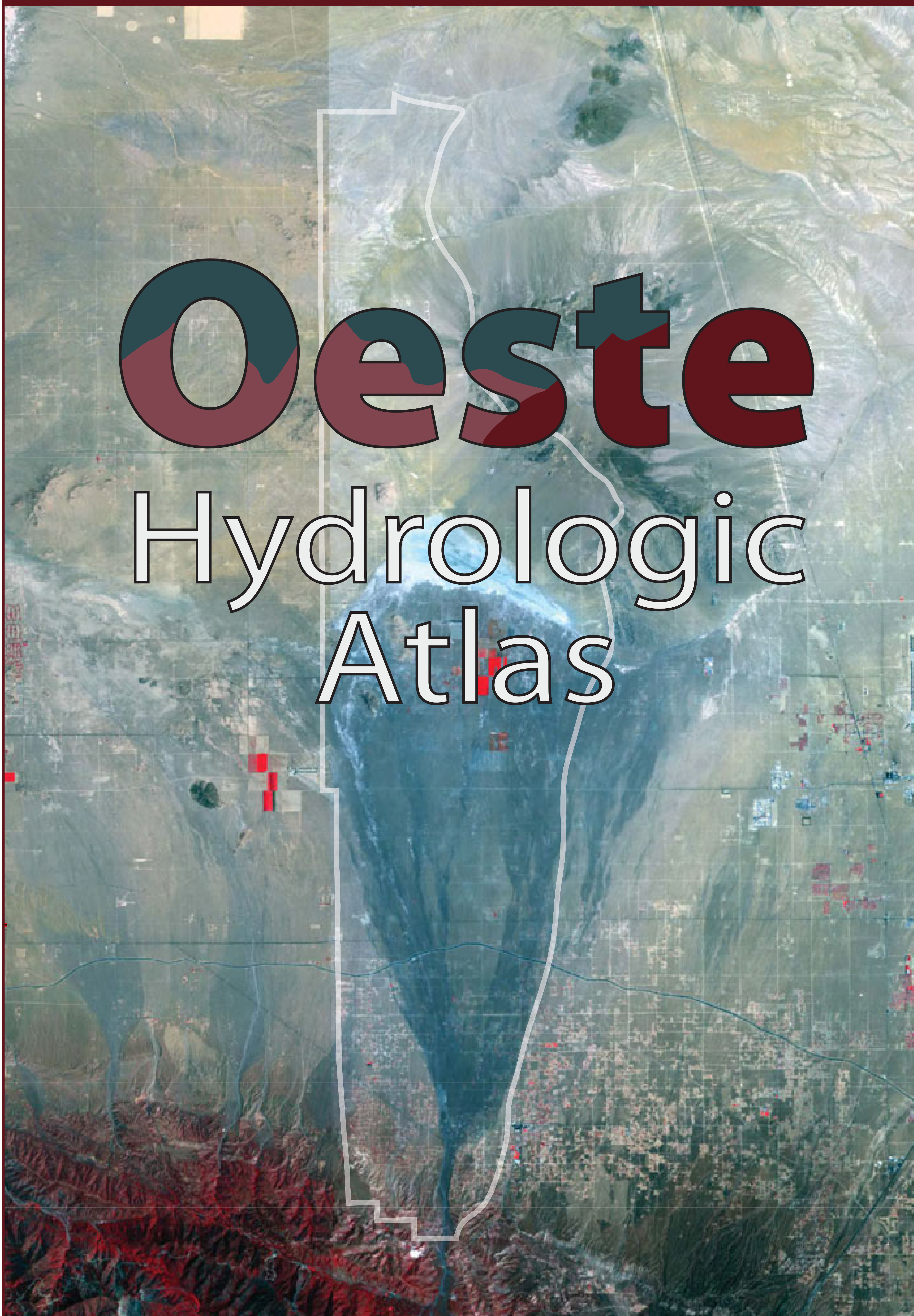








Oeste Hydrologic Atlas



Preface and Contents

Table of Contents:

Using the Atlas:

If you are interested in the Oeste Hydrologic Sub-area in general, we suggest that you page through this document and linger on the features that interest you. This atlas is organized by general heading and subdivided into more specific areas.

General information about the Oeste Hydrologic Sub-area and the region can be found on pages 6-11.

Discussions on the **water cycle** and the **Oeste Hydrologic Sub-area watershed** are found on pages 4 and 10.

The **geology** in the Oeste Hydrologic Sub-area, including an overview of the sediments within the watershed, is discussed on pages 12-14.

Information regarding **surface water** and **groundwater** in the Oeste Hydrologic Sub-area can be found on pages 15-18.

Groundwater quality standards and **analyses** can be found on pages 19 - 26.

A general map explanation, information tables and a **glossary of terms** used in this atlas can be found on pages 27-36.

- Key words, included in the glossary, are ***bold-italicized*** in the text.

California State University, Fullerton
College of Natural Sciences and Mathematics
Department of Geological Sciences
July 2009

Mojave Water Agency

22450 Headquarters Drive ◊ Apple Valley, CA 92307-0019
Phone (760) 946-7000 ◊ Fax (760) 240-2642 ◊ www.mojavewater.org

July 8, 2009

The Mojave Water Agency (MWA) has been entrusted with managing the long-term reliability of water resources within an approximately 5,000 square mile area of the Mojave Desert. The MWA has worked closely with academic faculty and students of the Geological Sciences Department from the California State University at Fullerton (CSUF) to build a synergistic relationship. This commitment has resulted in the ability for professional staff from the MWA to call upon the academic resources provided by CSUF to assist with studying groundwater resource management issues.

In order to support scientific based decision making related to water resources management within the Oeste Sub-area, the MWA and CSUF embarked on a data gathering mission to obtain and integrate geologic and hydrologic information available for the region. The Oeste Hydrologic Atlas is a culmination of our efforts. This hydrogeologic assessment of the Oeste Sub-area has provided us with information regarding groundwater in storage, aquifer space available for water banking, review of the basin water budget, groundwater flow direction(s), flow rates, and water quality data. In addition, wells identified during the course of this study have been incorporated into the MWA's Key Well Program, which is used to monitor water levels and water quality within the MWA service area.

The findings of this collaborative endeavor between MWA professional staff and CSUF professors and students will help with the proper long-term management of water resources within the Oeste Subarea.

Sincerely,

Lance Eckhart, PG, CHG, REA
Principal Hydrogeologist

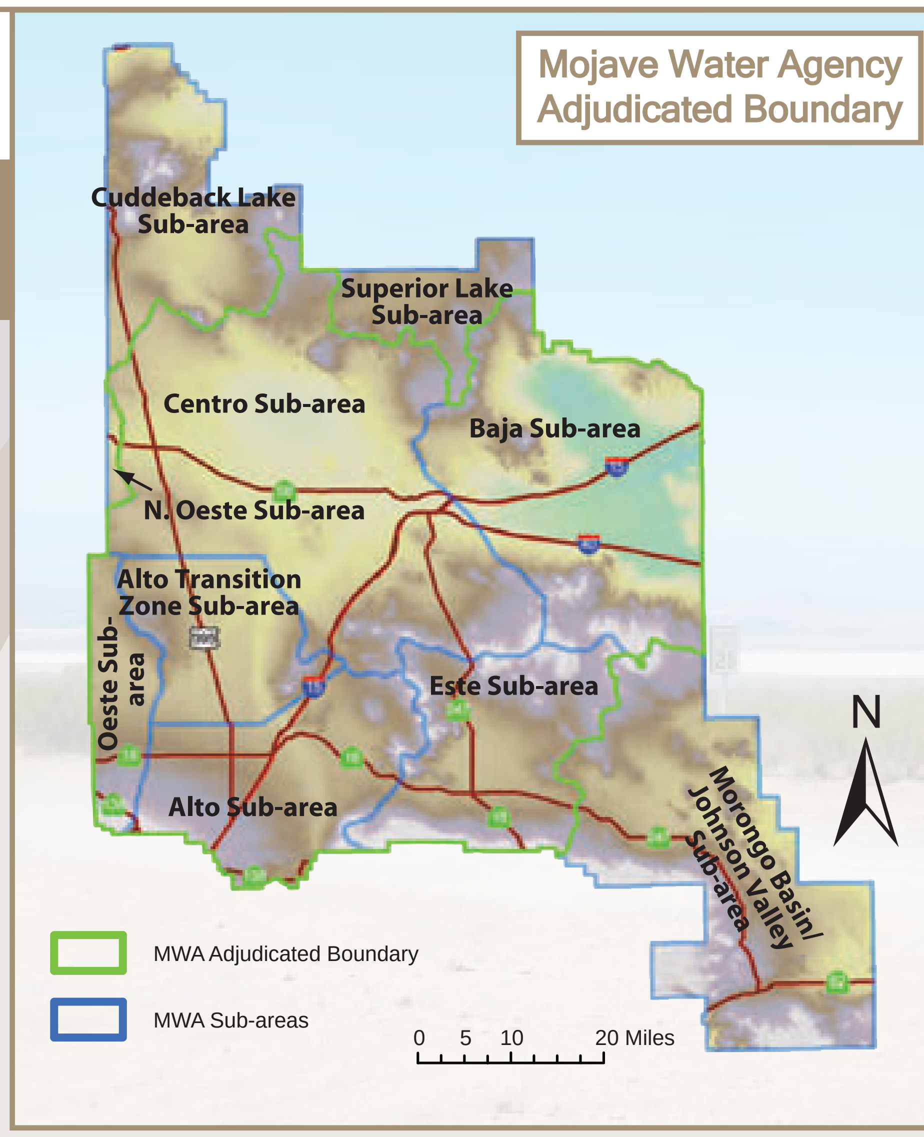
Introduction

Overview

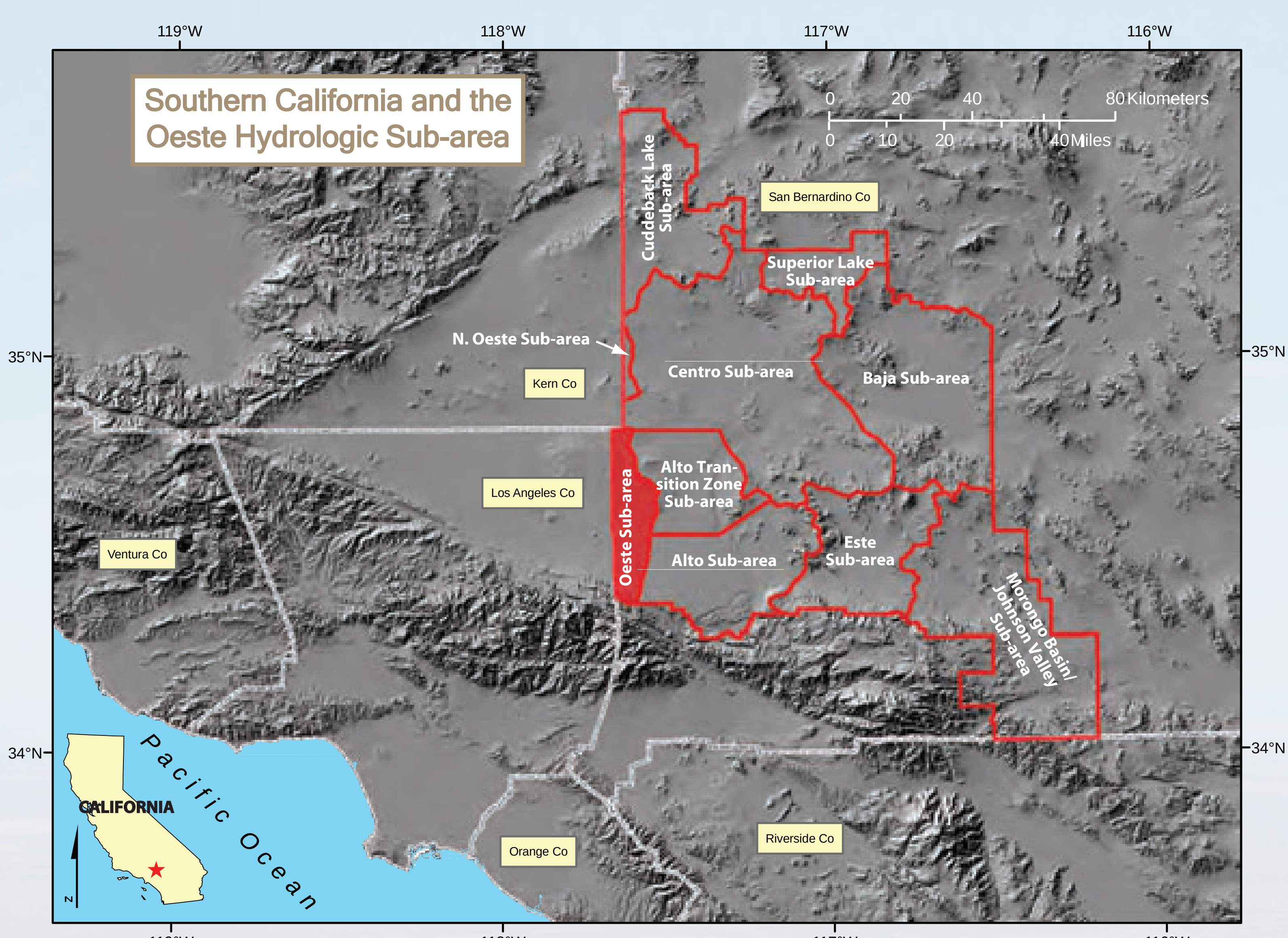
This atlas presents an overview of previously published data and new data on the geography, climate, geology, ***hydrology***, ***hydrogeology***, and groundwater chemistry of the Oeste Hydrologic Sub-area. An awareness of the challenges in watershed management and possible solutions is imperative to 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.

This atlas has been prepared by students and faculty associated with the Applied Geosciences in the Department of Geological Sciences at California State University Fullerton under contract to the Mojave Water Agency (MWA). This atlas is a condensed version of the Oeste Hydrologic Sub-area Report and is intended to provide generalized information for public consumption. This report was prepared with the understanding that the results will be used to help manage the water resources of the area. It is also significant that the draft of this atlas was critically reviewed by members of MWA and that their comments and recommendations were incorporated into this final atlas.



The Oeste Hydrologic Sub-area (also referred to as El Mirage Valley) is located just north of the San Gabriel Mountains along the southern edge of the Mojave Desert, San Bernardino County, California and is part of the Oeste Sub-area boundary of the Mojave Water Agency (MWA). El Mirage Valley lies approximately 25 miles west of Victorville. El Mirage Valley can be accessed by way of either, highway 18, highway 395 via the city of Victorville or highway 138 through the community of Phelan.



Introduction

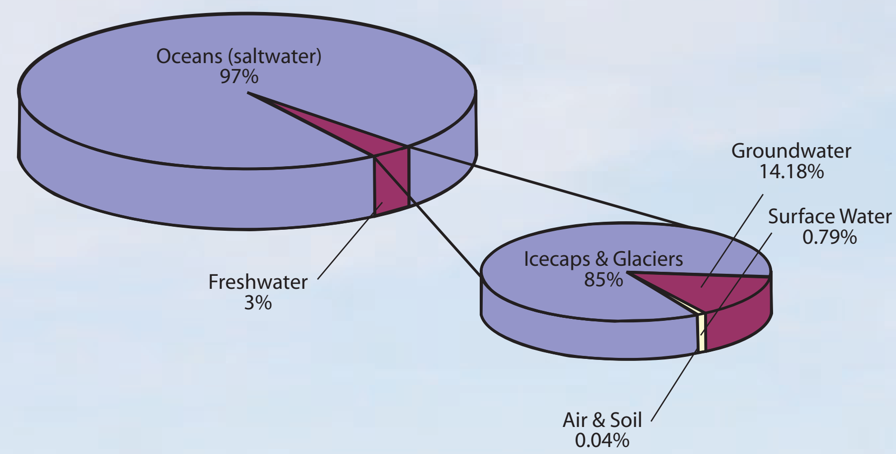
Hydrologic Cycle

The endless circulation of water between the oceans, atmosphere, and land is called the ***hydrologic cycle***. The term refers to the constant movement of water above, on, and below the Earth's surface. The concept of the hydrologic cycle is elementary to any understanding of the occurence, development, and management of water.

The movement of water through the hydrologic cycle consists of many processes working together to keep Earth's water circulating. Six processes are at work in the hydrologic cycle: evaporation, evapotranspiration, condensation, precipitation, infiltration, runoff. These occur simultaneously, and except for precipitaion, also occur continuously.

First and foremost in the hydrologic cycle is the sun, the great heat engine which drives the hydrologic cycle. Water evaporates from the land or water surface, condenses, and forms clouds. These water vapors then return to the land or water surface in the form of ***precipitation*** (rain, snow or sleet). Precipitation falls to the surface and infiltrates the soil or flows to the ocean as runoff. The degree of land slope, the amount and type of vegetation, soil type, rock type, moisture and gravity potential of the soil all determine the amount of water that will actually infiltrate the earth's surface. More openings in the surface (cracks, pores, joints) increases ***infiltration***. Water that doesn't infiltrate the soil flows along the surface as runoff. Precipitation that reaches the surface of the Earth, but does not infiltrate the soil is called runoff. Runoff can also come from melted snow and ice. The illustration below (The Hydrologic Cycle) demonstrates the forementioned concepts.

Earth's Water Distribution

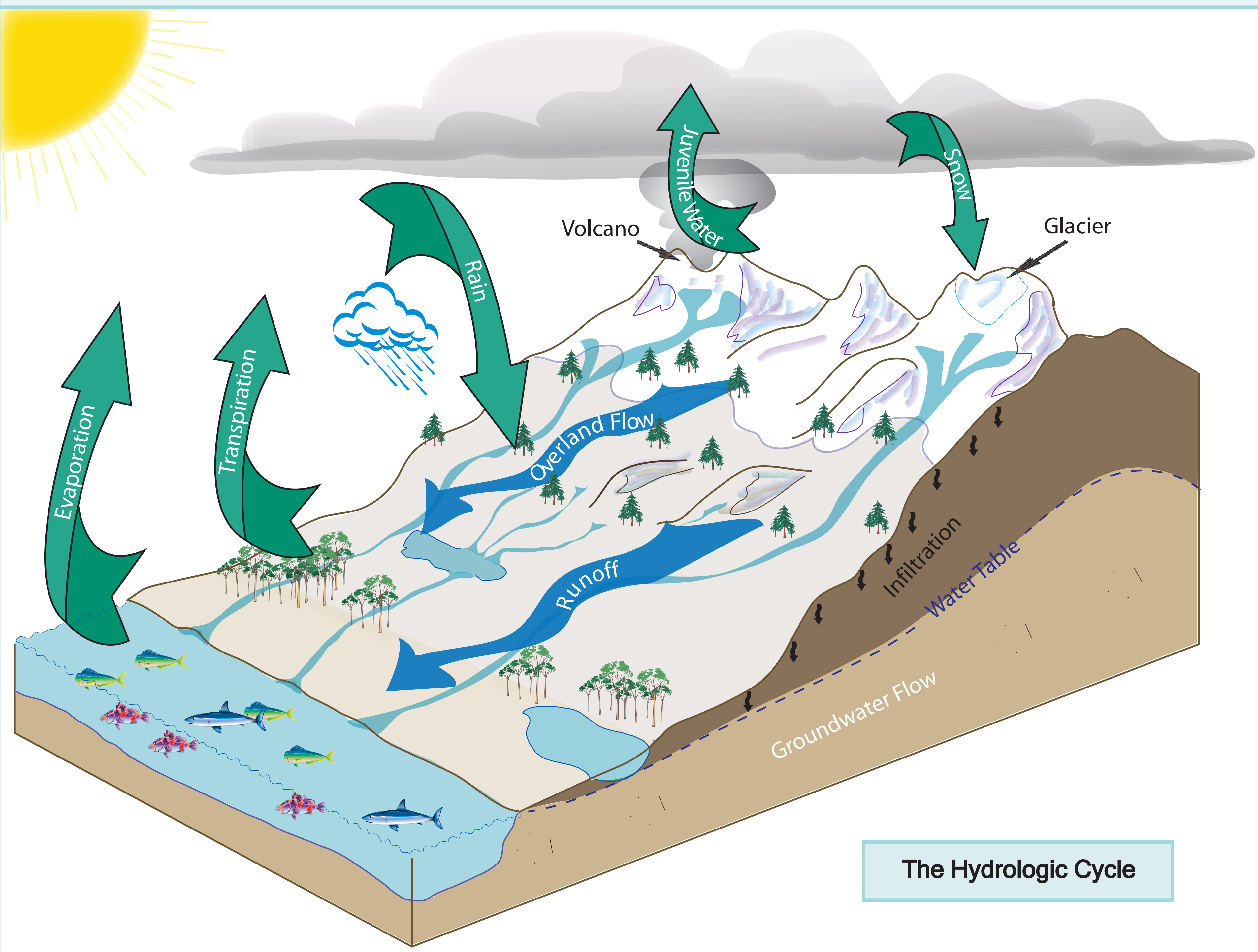


Aquifer Recharge

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.

The Future of Water Resources

The hydrologic cycle allocates a limited amount of this resource to the Oeste Hydrologic Sub-area. Human stewardship of this resource will be vital to the managed growth and quality of life in the high desert.



The Hydrologic Cycle

For definition's of above terms see Glossary.

Introduction

Groundwater Basins

Generally a ***groundwater basin*** is an area that by virtue of the unconsolidated, permeable materials it contains, is capable of substantial water storage. The real significance of any groundwater basin is its ability to provide a legitimate and useable source of water. Most groundwater basins share similar characteristics and are probably most aptly described in graphic form. The illustration below provides a basic visual overview of how materials within a basun influence groundwater behavior.

The majority of groundwater in California gathers in basins filled with ***alluvium***, that is, material deposited by streamflow (DWR Bulletin 118). ***Alluvial*** material provides the most favorable conditions for groundwater storage and movement. Though groundwater can occur in a variety of settings, groundwater within alluvium is most common in California (DWR Bulletin 118).

The basic construction of a typical groundwater basin involves a variety of materials which comprise basin aquifers. Each of these materials interact uniquely with the water that flows through and around them on its way to a ***discharge area*** (i.e. lake, creek, well or pump). The illustration below helps put these materials and their function into context.

The movement of water through a groundwater basin's constituent materials is further discussed in the Groundwater Movement section of this atlas.

The Oeste Hydrologic Sub-area is one the 108 groundwater sub-areas in the state of California (DWR Bulletin 118).

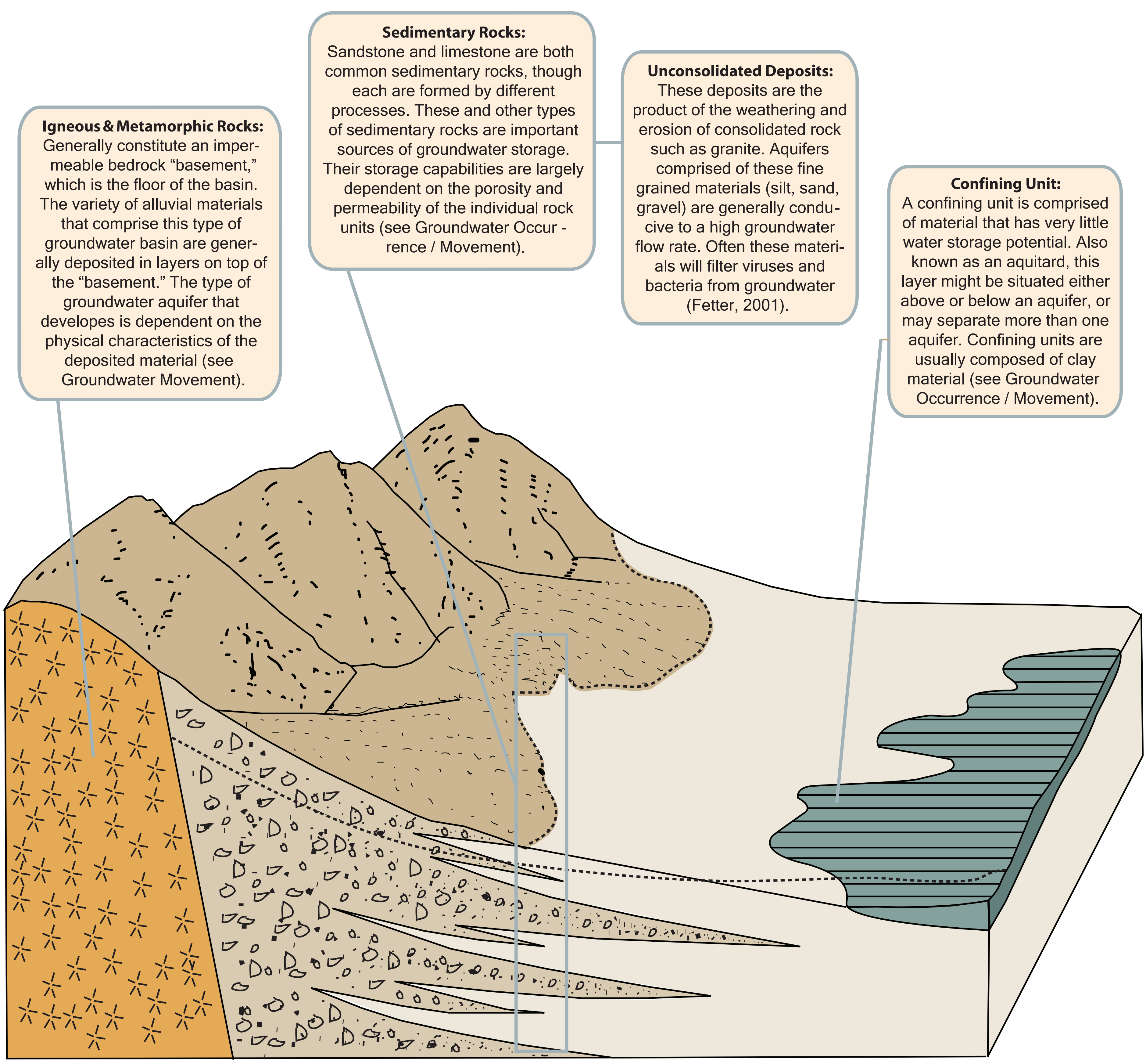
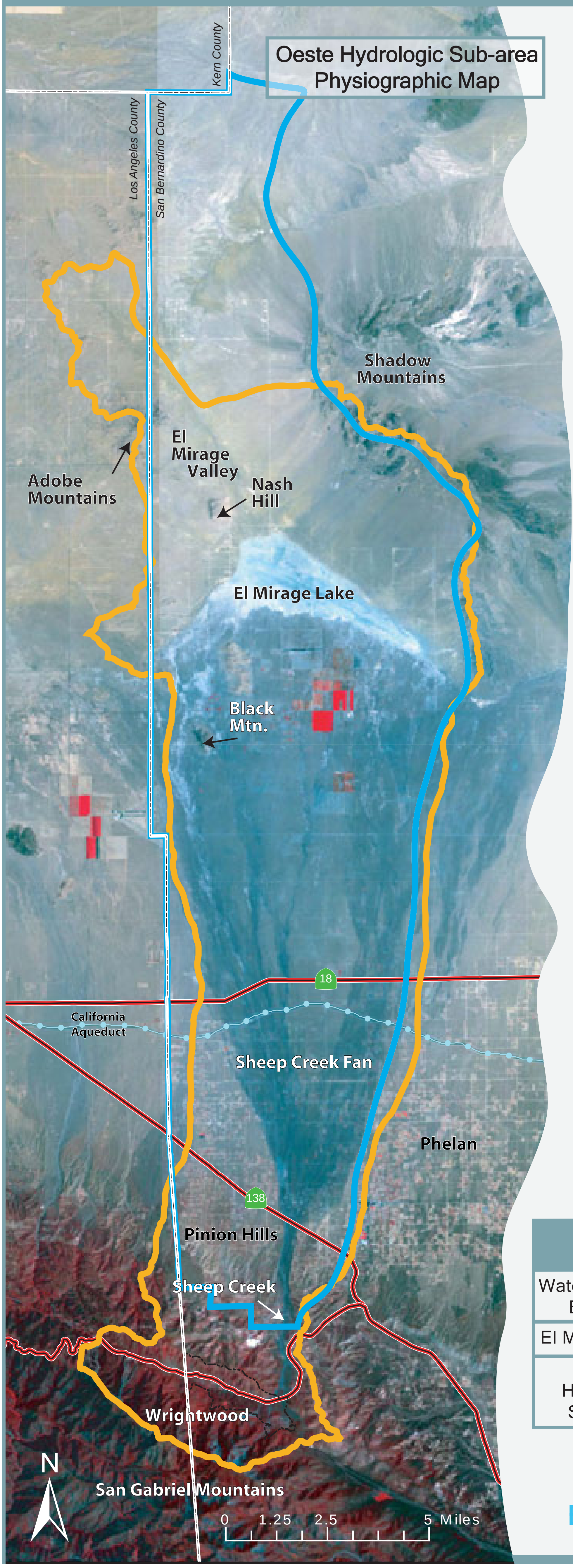
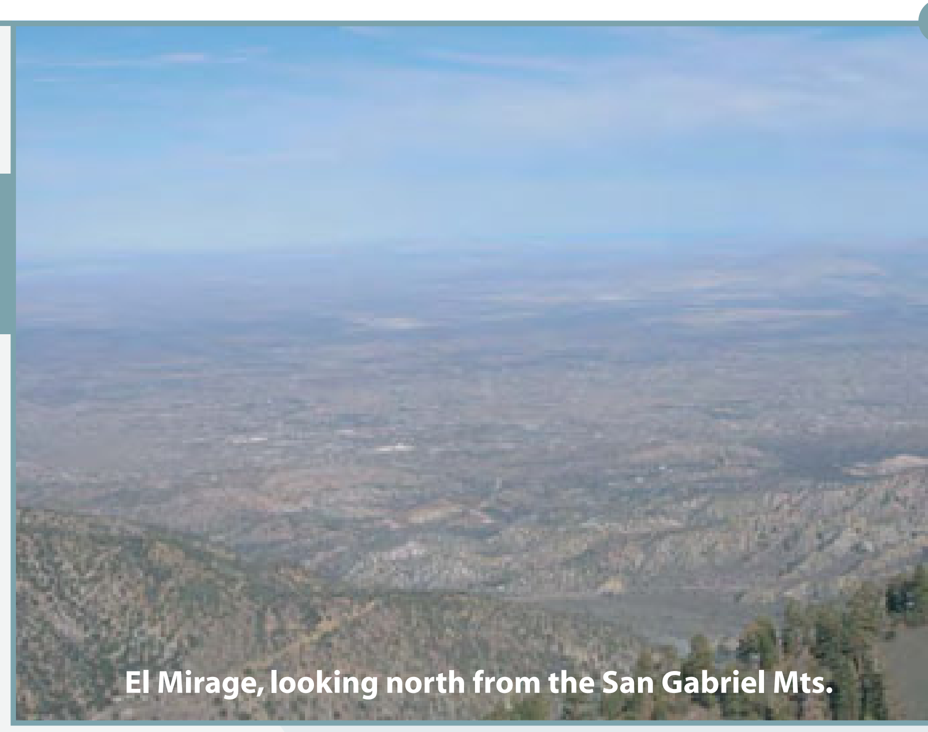


Image modified from Hamblin, W. K. (1976)

Background

Physiography




El Mirage, looking north from the San Gabriel Mts.


Sheep Creek

The El Mirage Valley ***watershed*** boundary encloses approximately 166 mi^2 (430 km^2) ranging in elevation from 2,833 ft (863 m) at El Mirage (dry) Lake, to 8,500 ft (2,591 m) in the San Gabriel Mountains (Oeste Hydrologic Sub-area Physiographic Map, El MIrage Watershed Dimensions table). 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 is conspicuous on satillite images (Oeste Hydrologic Sub-area Physiographic Map). The highly visual image of Sheep Creek Fan 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.

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

EXPLANATION

Oeste Hydrologic Sub-area Boundary

El Mirage Watershed

CalView Landsat Imagery Holdings. U.S. Geological Survey, 1999-2002.
California Spatial Information Library, 2000.

Background

Regional Climate

The southern Mojave Desert is considered "high desert." The Oeste Hydrologic Sub-area experiences over one mile of elevation ***relief*** from the approximate center of the El Mirage Valley to the top of the San Gabriel Mountains. Due to this range in elevation the region is characterized by dry hot summers and cold winters. Summer monthly maximum temperatures average ~95°F (35°C) and winter monthly maximum temperatures average ~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).

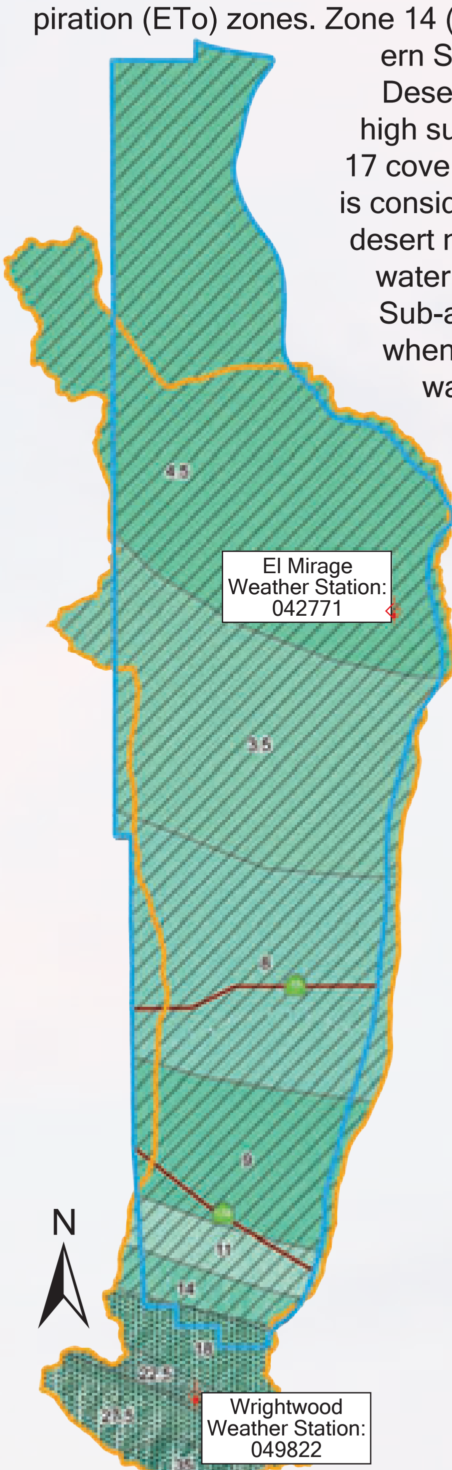
Precipitation within the Mojave Desert region is considered minimal (see Average Precipitation and Evaporation for El Mirage and Wrightwood) - deserts are defined as arid regions that receive 10 in (25 cm) or less of rain per year (CALWATER, 1997). Precipitation data from the El Mirage weather station indicate yearly rainfall through El Mirage Valley to be approximately 5.94 in (15.1 cm) (see 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. Precipitation is greater 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.

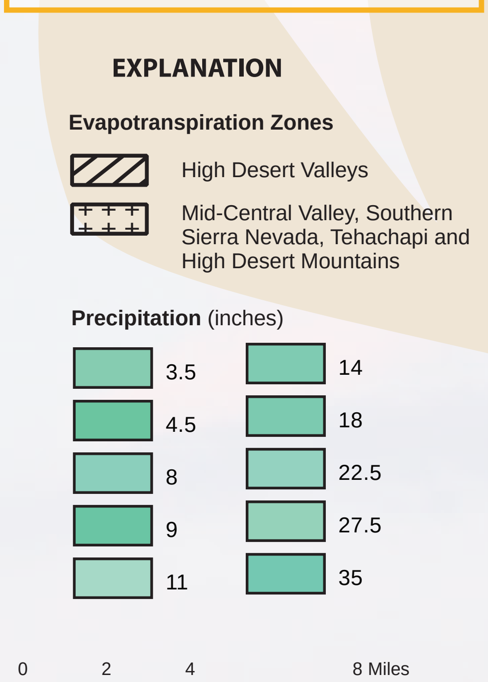
The Oeste Hydrologic Sub-area is located within two evapotranspiration (ETo) zones. Zone 14 (Mid-Central Valley and the Southern Sierra Nevada, Tehachapi, and High Desert Mountains) is characterized by high summer sunshine and winds. Zone 17 covers the "High Desert Valleys," which is considered by CIMIS (2006) 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 (Oeste Hydrologic Sub-area Precipitation and Evapotranspiration Map).

Dry Lake in the summer; mudcracks on surface

Mojave in the winter

Oeste Hydrologic Sub-area Precipitation and Evapotranspiration Map





California Precipitation. Teale GIS Solutions Group, 1997.

Average Precipitation and Evapotranspiration for El Mirage and Wrightwood, California

	El Mirage Valley		Wrightwood		Evapotranspiration	
Month	mm	in	mm	in	mm	in
Jan	16.5	0.65	202	7.96	51.40	2.02
Feb	43.2	1.7	242	9.53	66.18	2.61
Mar	14.5	0.57	213	8.38	115.94	4.55
Apr	8.9	0.35	59	2.34	157.21	6.19
May	1.5	0.059	25	0.97	185.41	7.30
Jun	0.28	0.011	7	0.26	224.13	8.85
Jul	2.5	0.1	2	0.08	248.13	9.77
Aug	11.9	0.47	7	0.29	228.42	8.99
Sep	5.6	0.22	26	1.01	165.58	6.52
Oct	17.5	0.69	39	1.54	118.37	4.66
Nov	10.9	0.43	82	3.23	68.06	2.68
Dec	17.5	0.69	121	4.78	52.17	2.05
Total	150.9	5.94	1,025	40.37	1681.2	66.19

Background

Vegetation

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 california*) 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 abundant of the local flora is the "Greasewood" or Creosote Bush (*Larrea tridentate*). Locally, the Creosote Bush occurs in the well drained soils of the inter-mountain plains. Though mostly occurring in pure stands, the Creosote Bush often coexists 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*) present on the upper elevation slopes of the Sheep Creek Fan. Creosote and Four-Winged saltbush (*Atriplex canescens*) are the dominant vegetation on the lower elevation slopes of the Sheep Creek 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 as shown in the Oeste Hydrologic Sub-area Vegetation Map. The Creosote is part of a diverse community of shrubs referred to as "desert scrub." Also evident from the Vegitation Map is the concentration of California and Western Juniper trees banding the southern border of the study area along the north-eastern slope of the San Gabriel Mountains.

Oeste Hydrologic Sub-area Vegetation Map

California Department of Forestry and Fire Protection (1999, 2004)

Creosote Bush "Greasewood"

Mixed flora

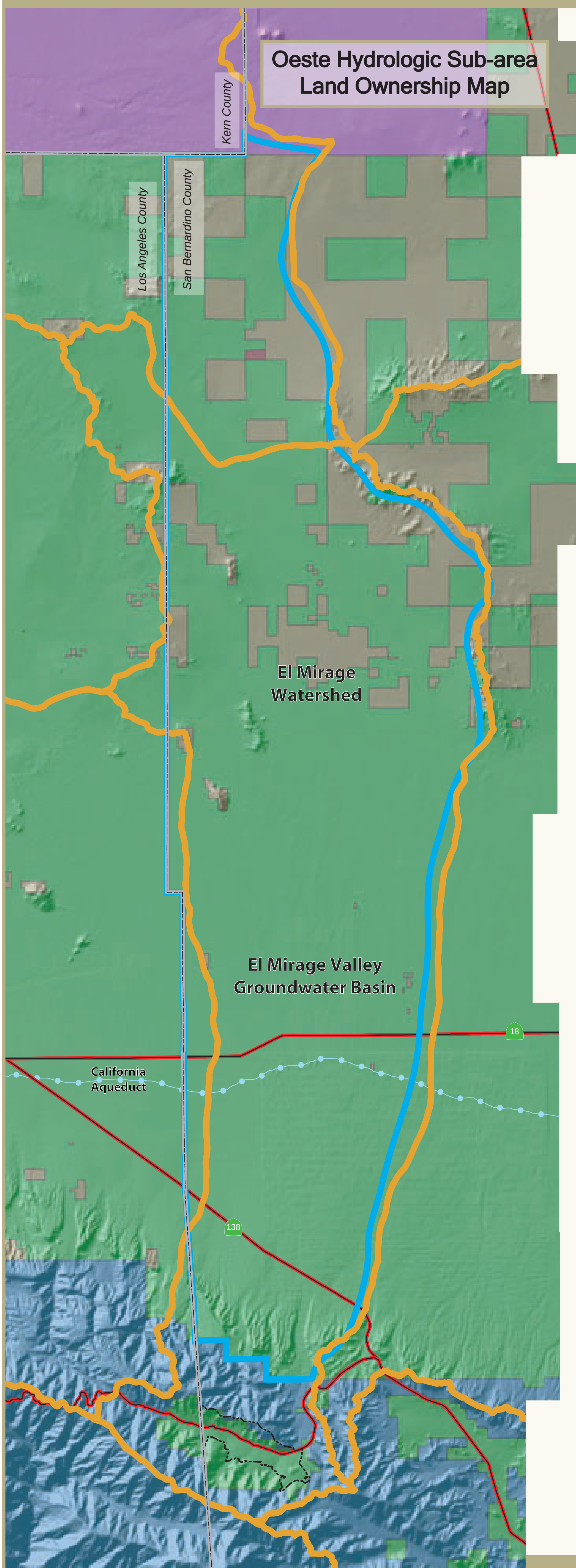
Joshua Tree

Pinyon Pine

Mixed flora

Background

Land Use




Alfalfa Fields, El Mirage Valley


Community of Phelan

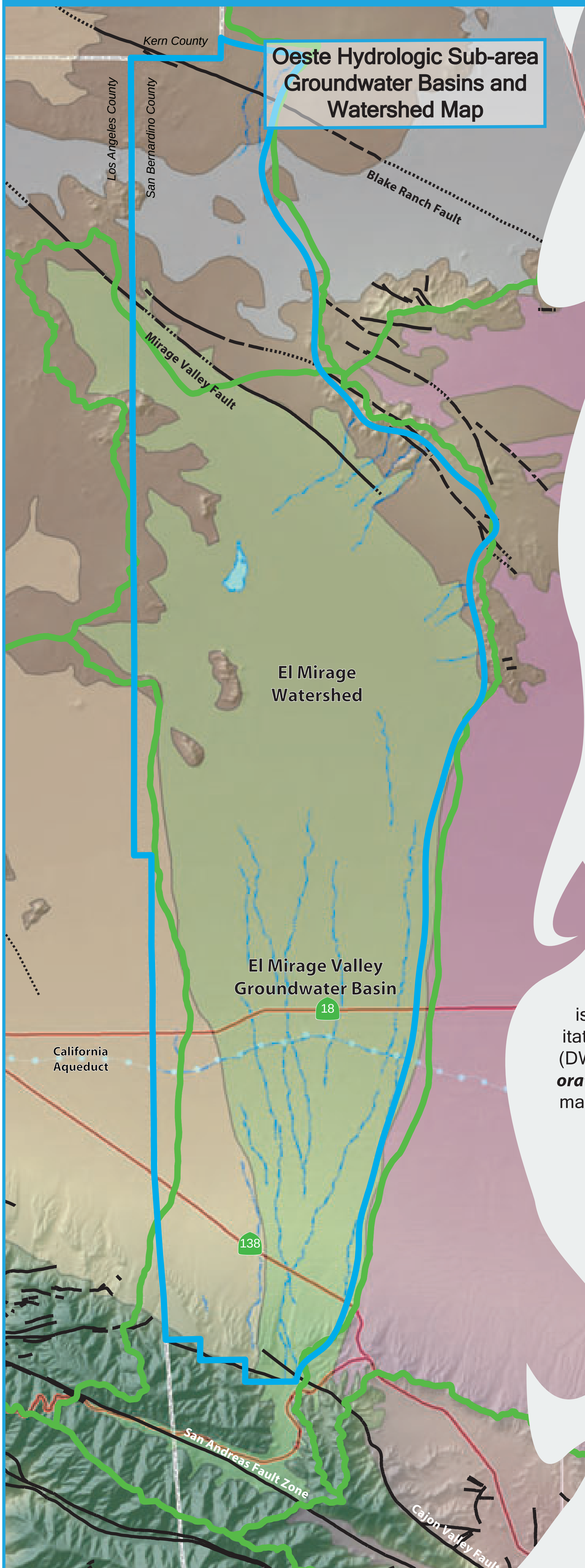
The Oeste Hydrologic Sub-area has been host to many peoples and industries throughout recorded history. More notable peoples include the Serrano Indians, Spanish missionaries, Mormon colonists, and homesteaders like the Wright family, for whom the town of Wrightwood is named (Wrightwood California, www.wrightwoodcalifornia.com).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

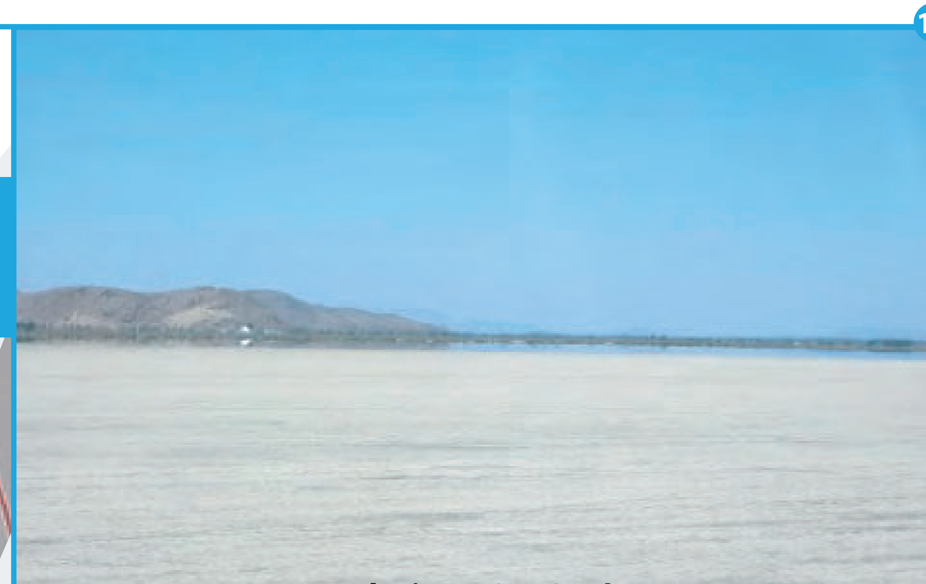
The burgeoning communities of Phelan, Pinion Hills, El Mirage and Wrightwood display diverse character and accomodate industry from agriculture to high technology (California Department of Conservation, 2002). For example, the Ducommun AeroStructures Company in El Mirage, produces aircraft parts for civilian and military aircraft (Ducommun Aerostructures, www.ducommunaero.com). Dairy farming and alfalfa farming are also thriving industries within the Oeste Hydrologic Sub-area.

Sources: Califonia County Boundaries. California Department of Forestry and Fire Protection (2004)
Oeste Hydrologic Sub-area. Apple Valley, California: Mojave Water Agency (2006)

Background

Watershed





El Mirage (Dry) Lake

El Mirage (dry) Lake, which resides at the low, distal end of the Sheep Creek Fan, is comprised of extensive brown clay deposits at the surface and deeper clay deposits which represent former lake deposits that have been slowly overlain by the Sheep Creek Fan deposits to the South.

Sheep Creek

Streams and lakes within the El Mirage Valley ***watershed*** are considered ***ephemeral***. There are no streams that are ***perennial*** upon entering or leaving the boundary of El Mirage Valley watershed. These same streams may however, be perennial at higher elevations. Surface flow into the basin is largely derived from snow melt and storm runoff from adjacent mountains. ***Runoff*** from surrounding mountains is concentrated through Sheep Creek. Lesser runoff is generally conveyed through small channels and washes that contribute to the local groundwater table, or continues to flow towards El Mirage (dry) Lake. The estimated annual runoff into El Mirage Valley from the Sheep Creek Wash is approximately 2,200 ***acre-feet*** (Izbicki et al., 2000). This runoff is derived from the approximately 28 to 32 inches of annual precipitation occurring in the southern region of the Swarthout Valley (DWR, 2003). Water collected on the dry lake surface may ***evaporate*** and/or slowly ***infiltrate*** into the underlying semi-***impermeable*** materials (Fife, 1977).

California Groundwater Basins (1997 TIGER). Teale GIS Solutions Group (1997)
California Watersheds (CALWATER 2.2). California Dept. of Forestry and Fire Protection (2004)
Oeste Ephemeral Streams and Lakes. Apple Valley, California: Mojave Water Agency (2006)

Background

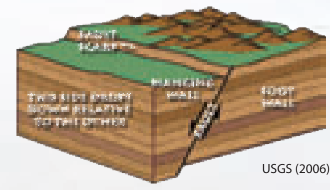
Faults & Seismic Activity

Oeste Hydrologic Sub-area Seismicity Map 1932 - 2004

Fault Type

When classifying a ***fault***, the movement of units of rock with respect to each other is the common diagnostic tool. The graphic representations below illustrate the three common fault types.

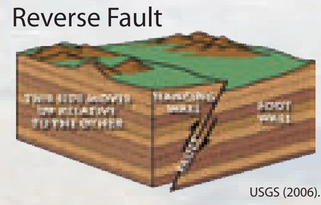
Normal Fault



Mirage Valley Fault

Normal Fault: This type fault is commonly the result of the pulling apart of two rock units (tension). In this setting the hanging wall drops below the foot wall when the units are pulled apart.

Reverse Fault



Reverse Fault: This type fault results commonly from the collision or pushing together of two rock units (compression). In this setting, when the units are pushed together, the hanging wall slides upward in relation to the footwall.

Strike-Slip Fault

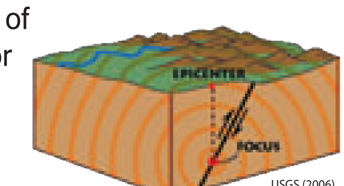
San Andreas Fault

Strike-Slip Fault: This type fault commonly results from the lateral, side-by-side movement of rock units past each other (shear). The San Andreas Fault is arguably the most popular strike-slip fault in the world.

Earthquakes and Faulting

The continents of the earth are commonly likened to moving "plates." Where these plates meet and interact through pulling apart (tension), colliding (compression) or sliding past each other (shear), faulting occurs. A fault forms when the stress placed on the earth's brittle crust builds to the point of failure. When the brittle rock gives way the resultant feature is a fault.

The abrupt movement, resulting from the failure of the brittle rock, produces an earthquake. Seismic waves propagate from a point called the ***focus***, which is the actual point of rock rupture. The focus can occur deep or shallow in the earth's crust. What we know as the ***epicenter*** of the quake, are the seismic waves that arrive at the earth's surface immediately above the focus.



Historically, the Oeste Hydrologic Sub-area is no stranger to seismic activity. Seismic activity clustered near all three fault types between 1932 and 2004 lends a general overview of the potential frequency and magnitude of earthquakes that can be produced by each fault. The most conspicuous feature of the Oeste Hydrologic Sub-area Seismicity Map is the contribution of the San Andreas Fault to the seismic history of the area.

Faulting in El Mirage

The main faults dissecting the Oeste Hydrologic Sub-area are located north of Mirage Valley (Mirage Valley fault) and near Wrightwood, within the Swarthout Valley (San Andreas fault). The San Andreas fault is an active strike-slip fault (SCEC, www.scec.org). The faults are represented by thick black lines on the Oeste Hydrologic Sub-area Geologic Map. The aforementioned faults are graphically represented at the top of this page. Conveniently, each fault can be described as one of the three common types.

General Geology

Materials which comprise the Oeste Hydrologic Sub-area are derived from the surrounding mountains and consist of ***igneous***, ***metamorphic***, and ***sedimentary rocks***. The geology depicted in the adjacent, Oeste Hydrologic Sub-area map, is based on the work of (T.W. Dibblee Jr. geologic map quadrangles: Roger and Kramer,1960; Shadow Mountains, 1960. San Bernardino 100,000 Quadrangle (Morton and Miller, 2003). The surficial and subsurface distribution, of both ***basement rock*** as well as ***Tertiary*** and ***Quaternary*** sedimentary deposits, are represented grahpically in cross-section A-A'. The geologic profile, represented in cross-section A-A', is based on research done by the CSUF Groundwater Research Group in cooperation with the Mojave Water Agency.

GEOLOGIC MAP EXPLANATION
(lithology along cross-section A-A')

QUATERNARY DEPOSITS

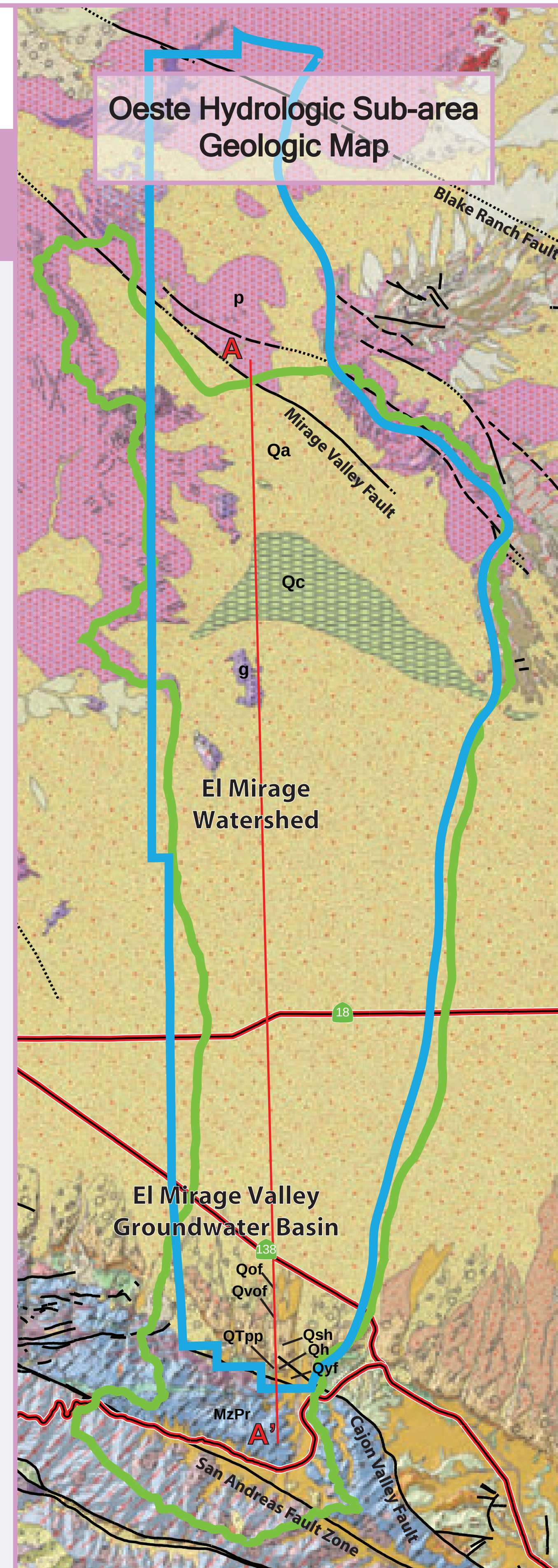
- Qa — Alluvial gravel and sand
- Qc — Playa clay
- Qyf — Young alluvial-fan deposits
- Qof — Old alluvial-fan deposits
- Qvof — Very old alluvial-fan deposits
- Qsh — Shoemaker Gravel
- Qh — Harold Formation
- QTpp — Phelan Peak deposits

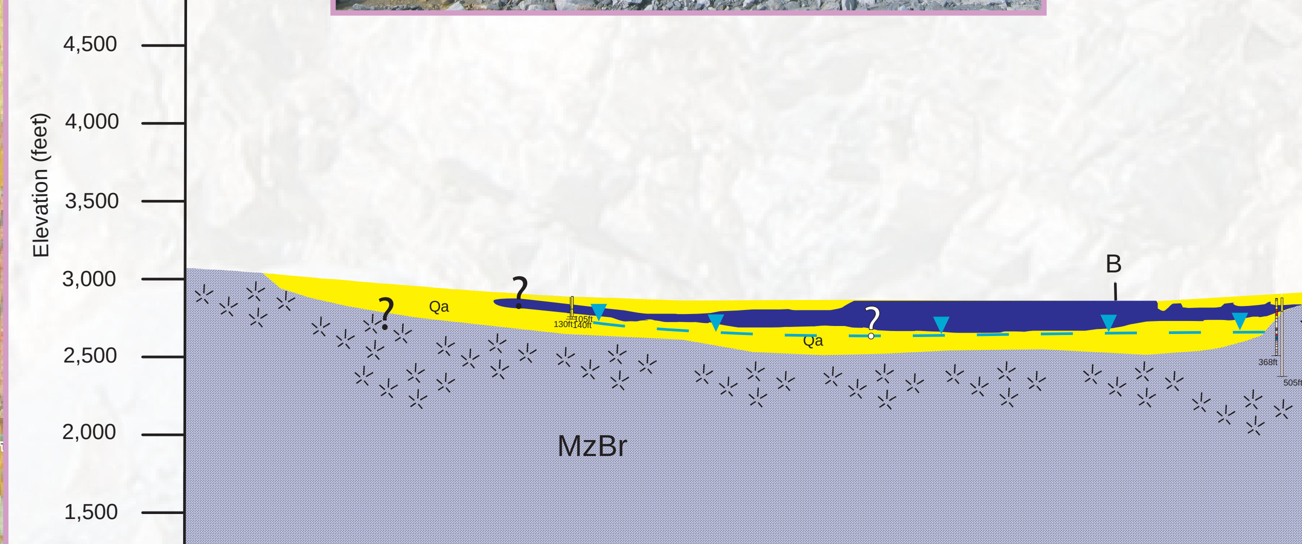
MESOZOIC PLUTONIC/METAMORPHIC ROCKS (BASEMENT ROCKS)

- p — Pegmatite and aplite dikes
- g — Granite
- MzPr — Gneiss of Pinyon Ridge

N

0 1 2 4 Miles





Surficial Sediments
The Sheep Creek Fan makes up most of the surface geology south of El Mirage (dry) Lake. The Sheep Creek Fan is very distinctive because it is almost entirely composed of Pelona Schist materials. Aeolian sand is also widespread on the Sheep Creek Fan (Miller and Bedford, 2000).

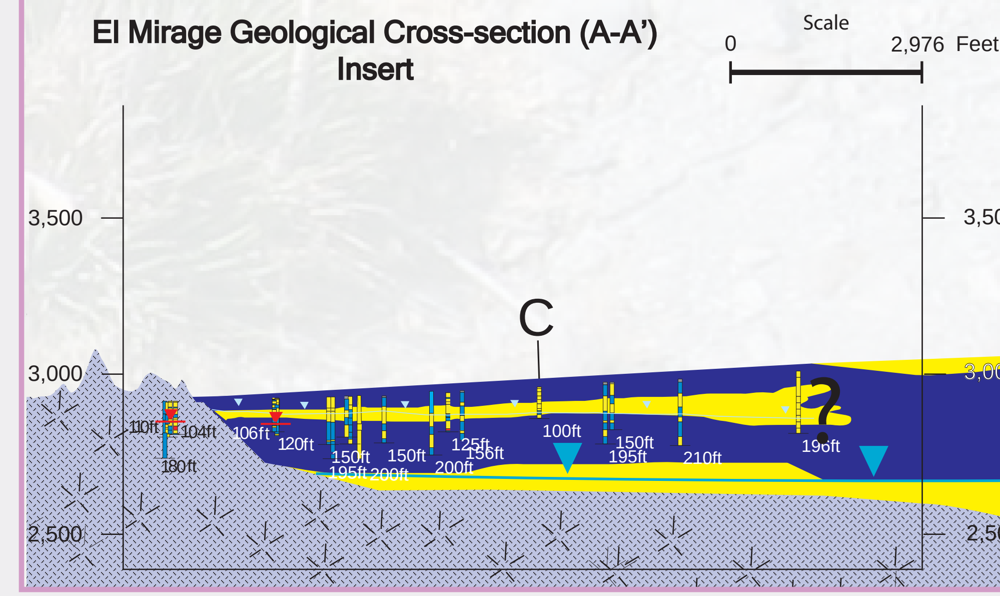
Old Aluvial Fan Deposits
The late to middle ***Pleistocene*** (Qof) fans consist of massive to poorly bedded, sand to boulder ***alluvium***. The fans are moderately consolidated and highly dissected (Miller and Bedford 2000).

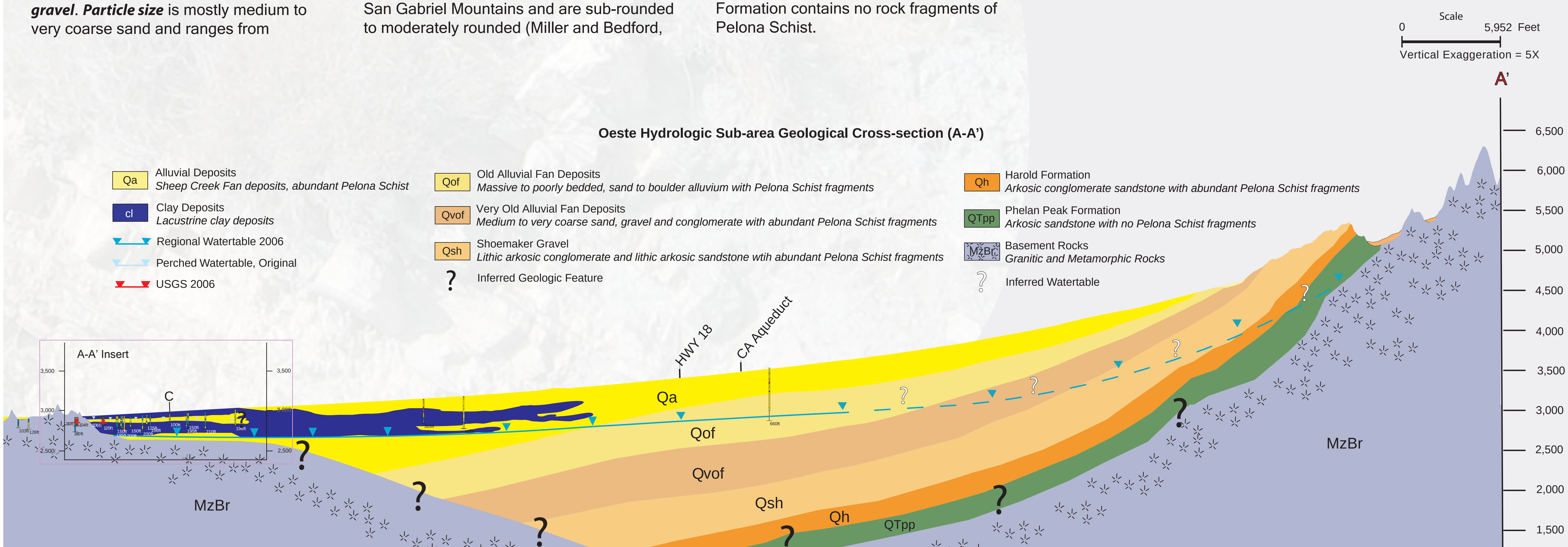
Very Old Alluvial Fan Deposits
Middle to early Pleistocene alluvial fan deposits consist of moderately to well consolidated deposits of ***silt***, ***sand***, and ***gravel***. ***Particle size*** is mostly medium to very coarse sand and ranges from sparsely to highly conglomeratic. The deposits also contain an abundance of Pelona Schist clasts (Miller and Bedford, 2000).

Shoemaker Gravel
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*** (Miller and Bedford, Foster, 2000, 1980).

Harold Formation
The Harold Formation is composed of arkosic conglomerate sandstone, with discontinuous carbonate cemented layers. The clasts are composed of Pelona Schist and other metamorphic rocks found in the main mass of the San Gabriel Mountains and are sub-rounded to moderately rounded (Miller and Bedford, Foster, 2000, 1980). The Harold Formation is Pleistocene in age and is about 150 meters thick near Sheep Creek (Miller and Bedford, 2003).

Phelan Peak Formation
The ***lithology*** of the older Phelan Peak (Tpp) consists of ***Pliocene*** age arkosic sandstone with thin beds of clayey and silty sandstone and feldspathic conglomerate (Foster, 1980; Weldon 1984). The younger Phelan Peak (QTpp³) 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 marble, granitic, volcanic and various other 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.



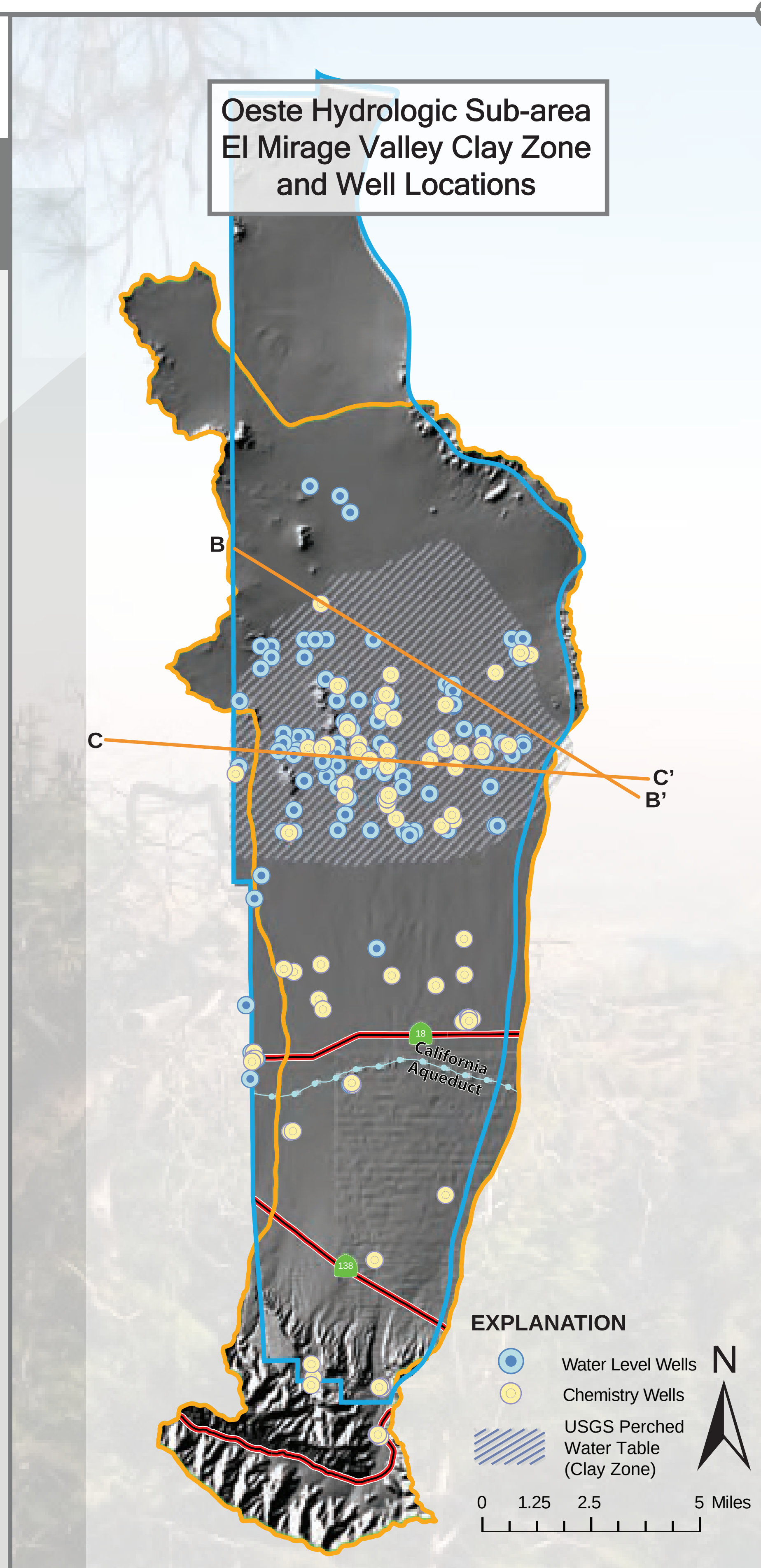


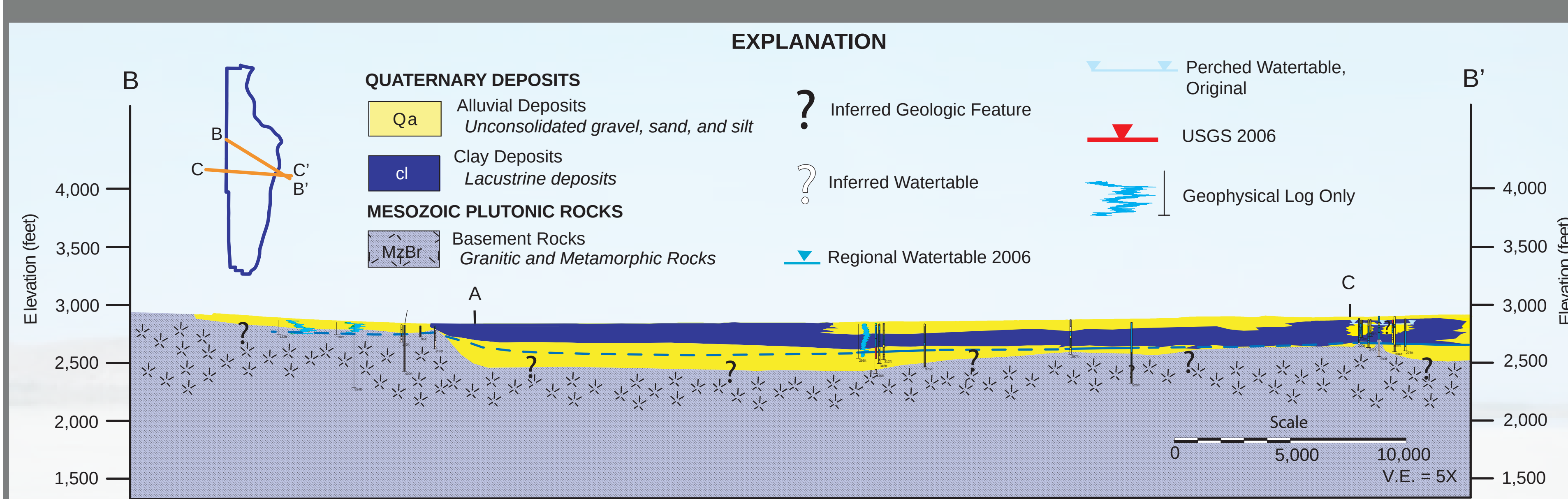
Geology

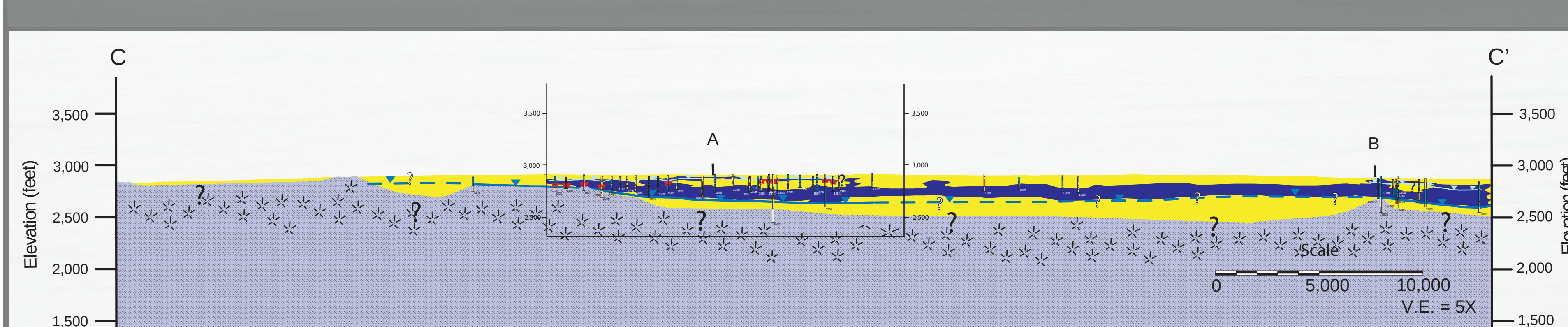
El Mirage Clay Zone

Underlying El Mirage (dry) Lake and extending southwards about 19,000+ ft (6 km) is a thick ***clay*** sequence with disconnected, but extensive ***interbedded*** lenses of sand and gravel that gradually descends into the subsurface. The sand and gravel lenses are primary sources of perched or semi-confined groundwater in the area around El Mirage (dry) Lake.

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 (90 km). 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).

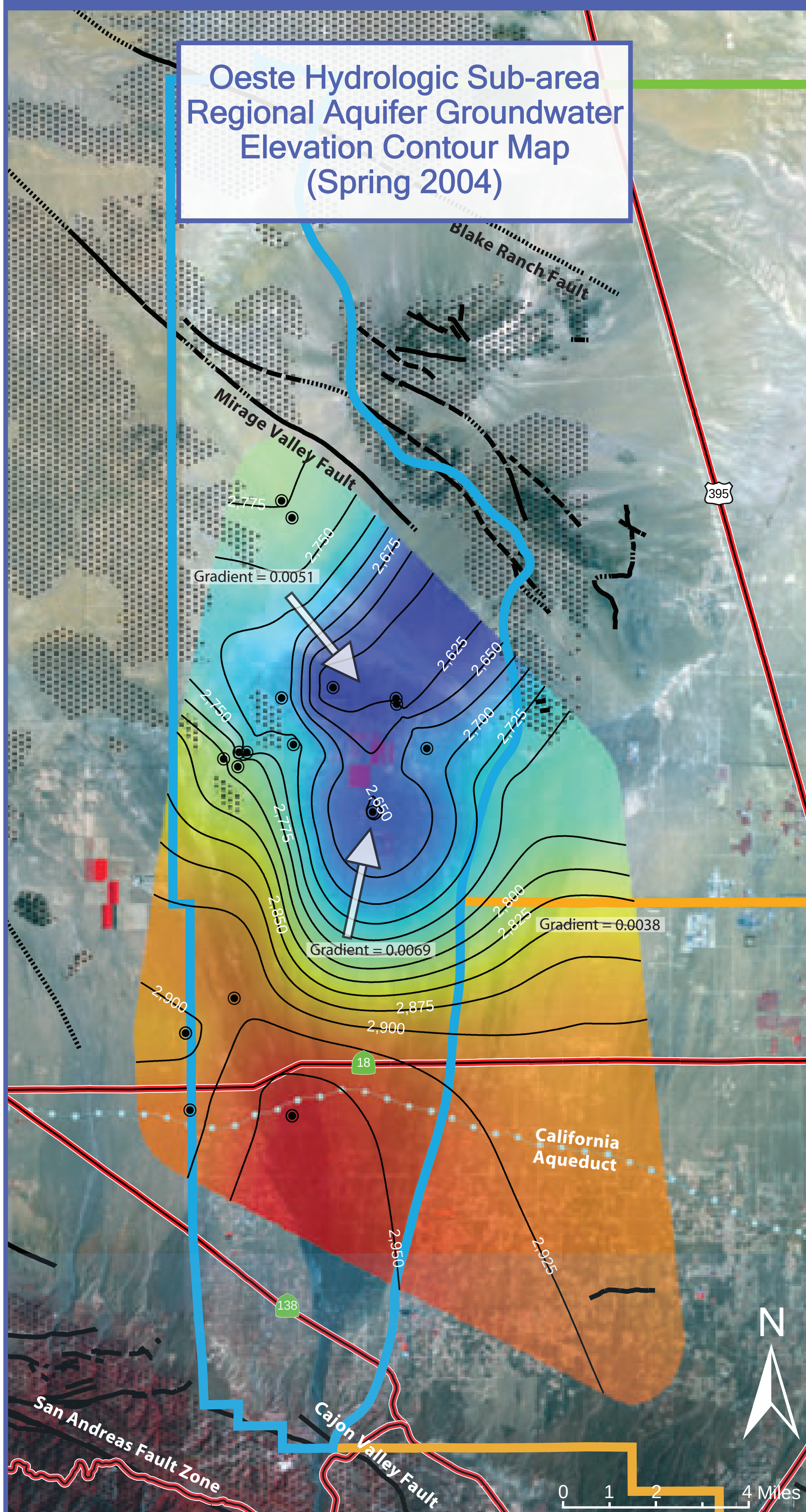






Groundwater

Groundwater Occurrence



The El Mirage Valley ***groundwater basin*** is bordered to 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. These groundwater basins typically conform to physical watershed boundaries, but in some cases are formed by geopolitical boundaries. This case 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 most likely extensive across all of the defined boundaries (Horne, 1989; Stamos et al., 2001).

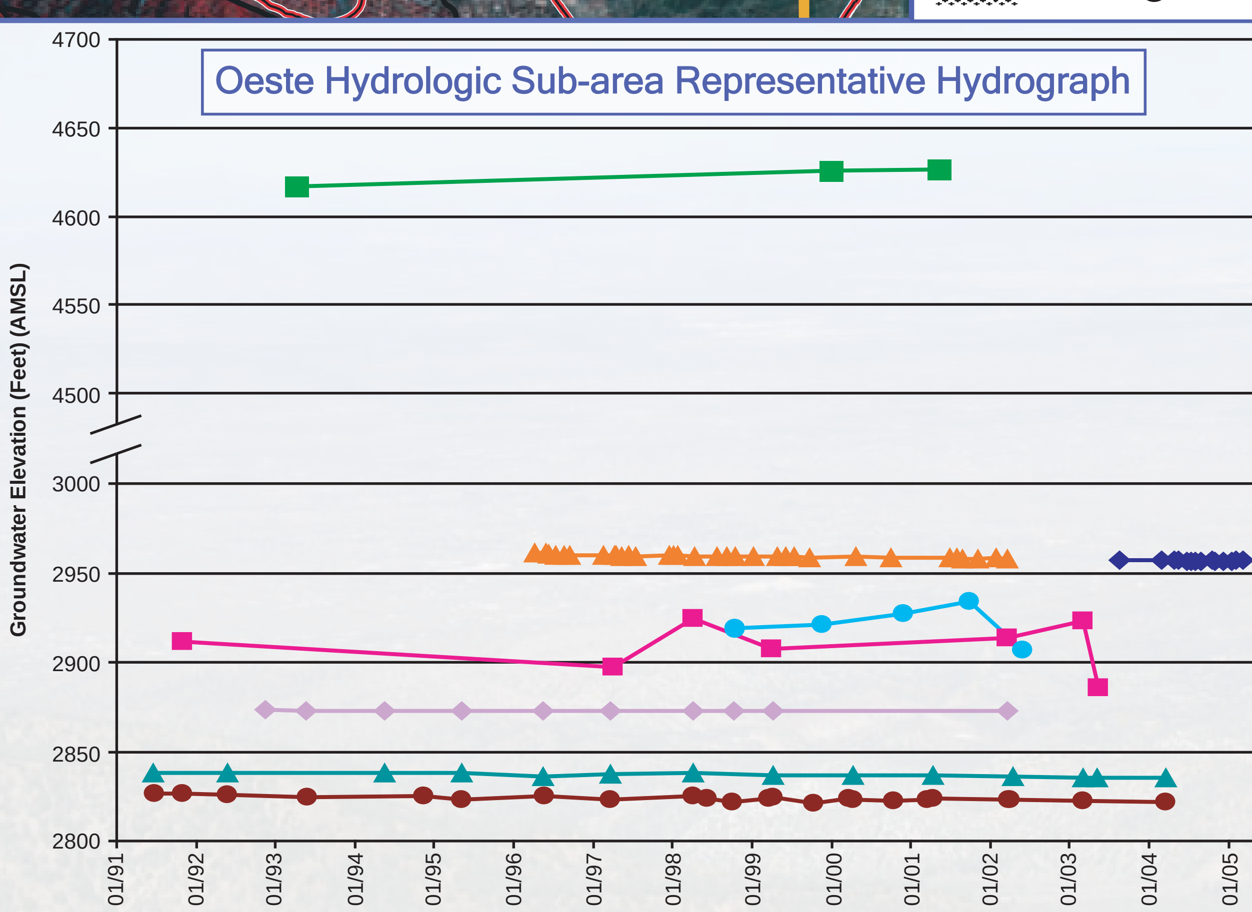
The El Mirage Valley groundwater basin has two principle groundwater aquifers (Smith and Pimentel, Izbicki, et al., 2000, 2003). A lower regional aquifer extends from the southern portion of Sheep Creek to El Mirage (dry) Lake in the north. This aquifer extends from the Los Angeles county line in the west to the community of Phelan in the east. 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). DWR (2003) reports well yields averaging 230 gallons/minute (gpm) with a high of 1,000 (gpm).

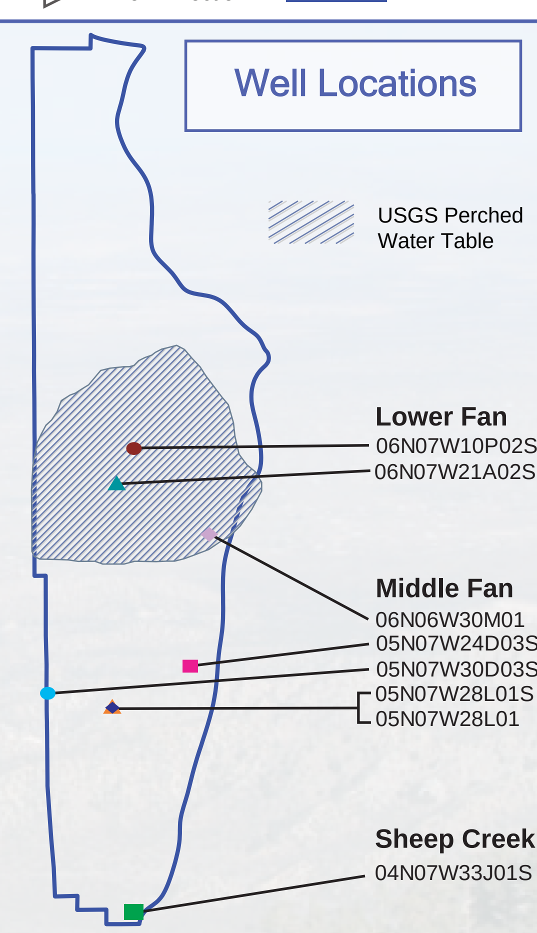
The upper ***perched aquifer*** is isolated near the dry lake area and is typically less then 250 ft (75 m) in depth (Horne, 1989). However, in several places, the depth of the perched layer may be deeper and is interbedded with sands, silts, and gravels. The upper perched aquifer is principally used by single family dwellings and small businesses.

EXPLANATION

Oeste Hydrologic Sub-area Boundary
Alto Hydrologic Sub-area (Transition Zone) Boundary
Alto Hydrologic Sub-area Boundary
Bedrock
Wells
Water Flow Direction

Groundwater Contours
25 Feet Interval (AMSL)
High : 2957.2
Low : 2609.3





Groundwater

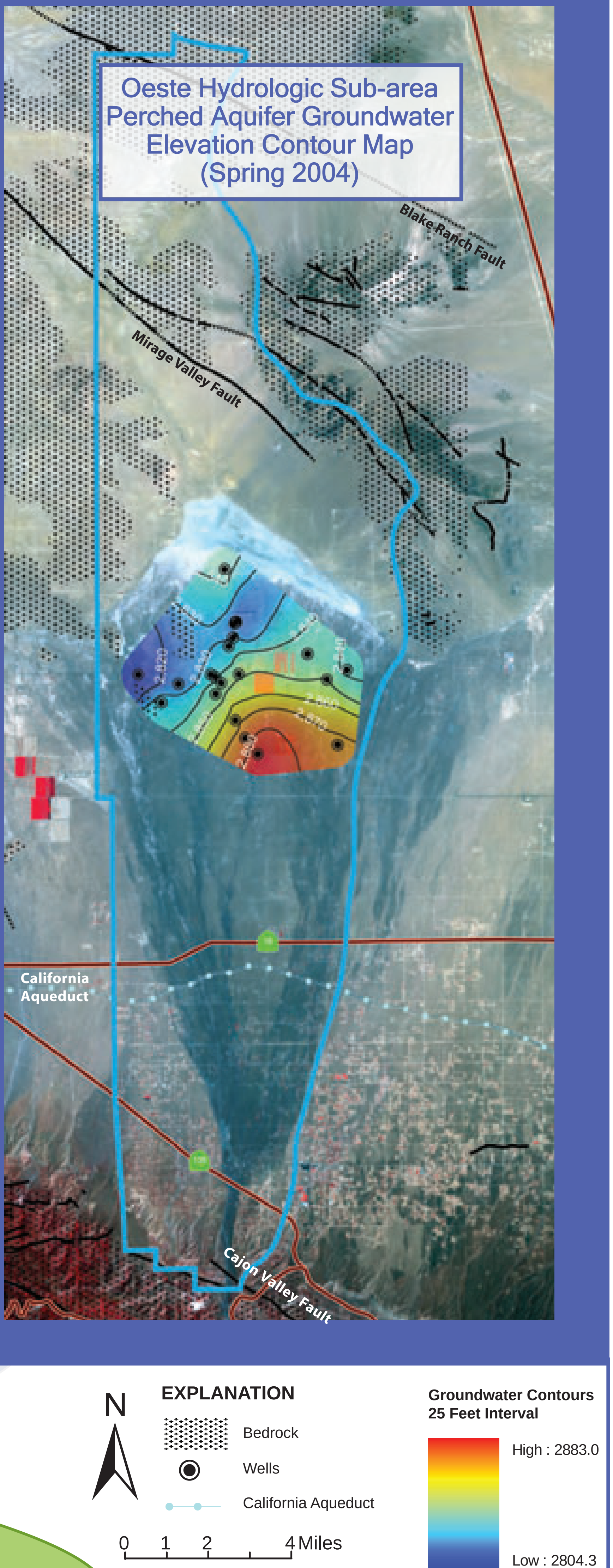
Groundwater Movement

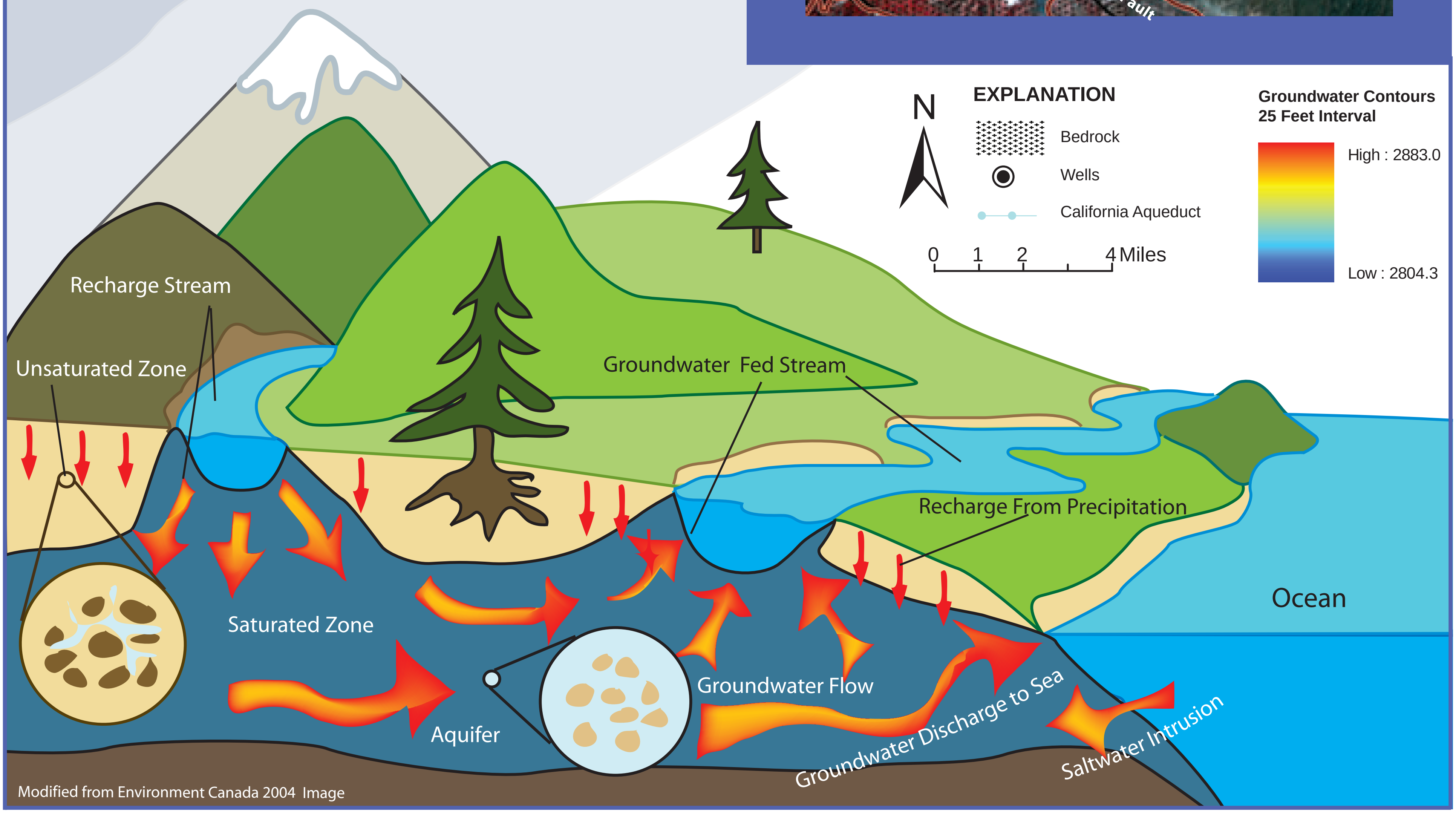
The basic scheme of groundwater movement begins with precipitation falling to earth. When for example, rain or snow falls to the earth, it is either immediately absorbed by the ground or forms ***runoff***. Runoff is not immediately absorbed and manifests itself as streams that flow overland. Sometimes these streams find their way to other bodies of water such as lakes; often though, this flowing water is absorbed by the ground. As water makes its way through the ground (***infiltration***), it encounters two primary zones. The first zone is known as the ***unsaturated*** or ***vadose zone***. In the vadose zone the small spaces between the grains of soil or rock (***pore spaces***) are occupied by both water and air. As the water infiltrates further it encounters the ***saturated zone*** in which all pore spaces are occupied by water.

Groundwater movement is highly dependent on a few factors two of which are the size of the pore spaces and the interconnectedness of these spaces. The larger the pore spaces and the more open pathways between them, the greater the volume of water flowing through. Just as water runs downhill on the surface, water flows downhill or gradient in the subsurface (groundwater movement). Thus, gravity is another key factor in groundwater movement with faster movement on steeper slopes. Compared to swift moving surface streams, groundwater moves slowly, On the order of inches to feet per year.

In the case of the Oeste Hydrologic Sub-area, ***groundwater flow*** slows as it approaches El Mirage (dry) Lake due to a more moderate slope, decreasing pore size and interconnectedness. The chemistry of the groundwater also undergoes many alterations as it flows to the dry lake area. Some of these alterations occur as a result of the water's contact with the byproducts of land use, other alterations are due to changing chemistry of geologic materials encountered by the groundwater.

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-feet/year 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.





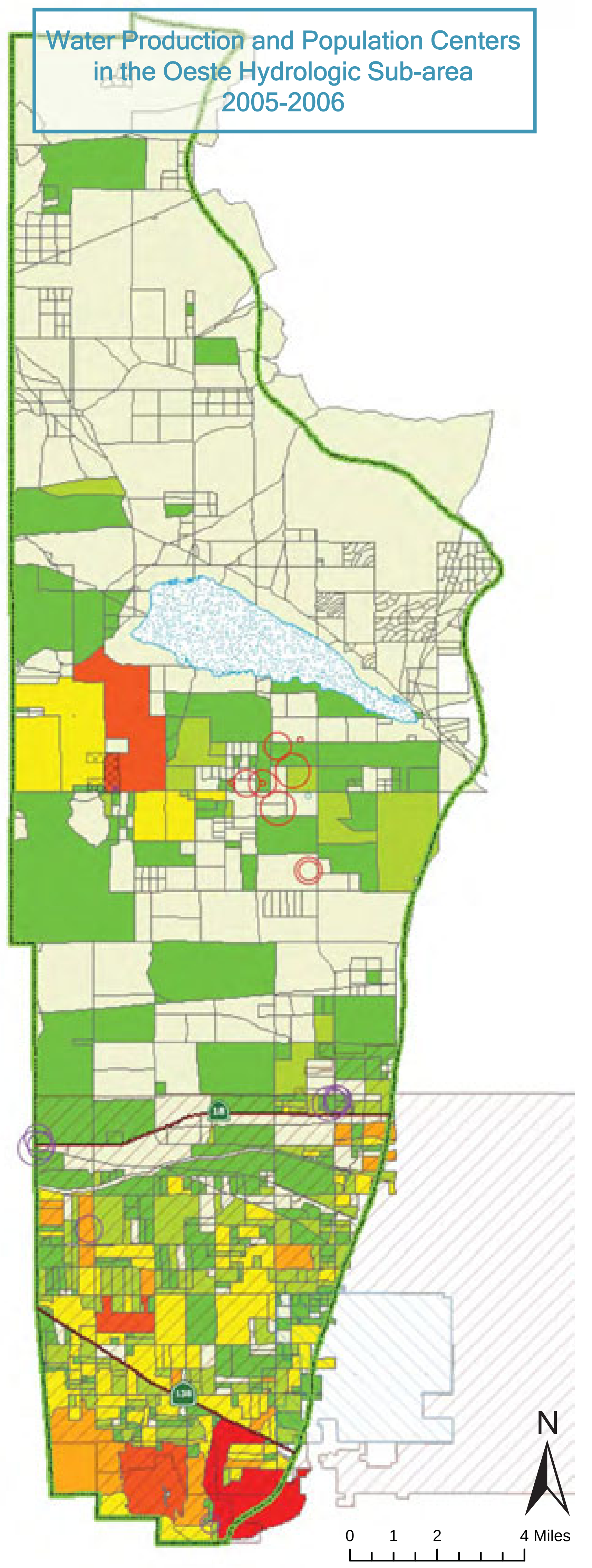
Groundwater

Production / Usage

Historically, groundwater production in the Oeste Hydrologic Sub-area has primarily been for agricultural purposes. Over the last 20 years, housing development and municipal production in the region has increased, replacing agricultural production. Farming in the “High Desert” has slowed over the last few decades and is expected to follow current downward trends in the Oeste Hydrologic 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 producers 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 Hydrologic 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 Hydrologic 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.

The table below (Groundwater Production in the Oeste Hydrologic Sub-area) shows monitored groundwater production in the Oeste Hydrologic Sub-area from 1993 to 2006. Production data is provided by the Mojave Basin Area Watermaster. The adjacent map (2005-2006 Water Production and Population Centers in the Oeste Hydrologic Sub-area). shows areas and volumes of groundwater production for major producers (>10 acre-ft groundwater production per year). The majority of minimal producers (untracked groundwater producers <10 acre-ft/yr,) are located in the community of El Mirage.



EXPLANATION

Production in ac/ft by type

Dairy/Agriculture	Industrial	Municipal
0-20	0-20	0-20
21-50	21-50	21-50
51-100	51-100	51-100
101-500	101-500	101-500
501-1000	501-1000	501-1000
1001-1500	1001-1500	1001-1500

Water Companies

- Chamisal Mutual Water Co.
- County Service Area 70L
- Sheep Creek Water Co.

Population (Census 2000)

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

Groundwater Production in the Oeste Hydrologic 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).

Mojave Basin Area Watermaster

Groundwater

Groundwater Budget

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. The most practical purpose of an accurate ***groundwater budget*** is to maintain a favorable balance between what goes in (***groundwater recharge***) and what comes out (***groundwater production***).

Water budgets for the Oeste Hydrologic Sub-area were calculated using a general water budget equation (see Water Budget Equations Table). Based on the relatively stable groundwater levels in evidence (see hydrograph p.17), 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 within the Oeste Hydrologic Sub-area; these values 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 ***throughflow*** (under flow) through the Sheep Creek wash area. This atlas 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).

Based on the previous water budget calculations, a surplus of water should be present in the Oeste Hydrologic Sub-area. ***Hydrograph*** analysis suggests that water levels have only fluctuated slightly over the past 15 years with a slight trend downwards (see hydrograph p.17). 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.

Water Budget Equations

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

Fetter (2001). For definition of above terms see Glossary.

Oeste Hydrologic Sub-area Watershed Groundwater Inputs

Annual Average (acre-ft)	DWR, (1967)	Horne, (1989)	GeoConsultants, (2005)	Stamos, et al., (2001)	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

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	2,392	350
Consumptive use	-	4,300	532	2,196	2,700
Total	NA	6,000	-	4,588	3,050

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

Oeste Hydrologic Sub-area Groundwater Budget Calculations

Annual Average (acre-ft)	Horne, (1989)	Stomos, 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)	(1,500)

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

County Service Area 70 Zone L.

County Service Area 70 Zone L.

Water Chemistry

Aquifer Water Quality

Groundwater is just one part of the water cycle. However, in areas such as the Oeste Hydrologic Sub-area where surface waters are limited, groundwater becomes the primary source of water. Groundwater has a variety of uses including: drinking, irrigation and agriculture. Natural waters such as groundwater acquire their chemical compositions from a variety of sources. Primarily, they accumulate dissolved and suspended constituents through contact with the gases, liquids, and solids they encounter during their passage through the ***hydrologic cycle***.

As these waters move along hydrologic flow paths, that bring them into contact with a variety of geologic materials and biological systems, the composition of surface and groundwater continuously evolves and changes on time scales of minutes to years. Rain and snow supply most ***terrestrial surface water*** and groundwater systems, as is the case in the Oeste Hydrologic Sub-area. Precipitation is not pure water, but contains dissolved substances that vary in amount and composition according to location and season. Under natural conditions, rain is usually ***acidic***, because of reactions with atmospheric carbon dioxide (CO_2) and naturally occurring gaseous sulfur and nitrogen compounds. Naturally occurring organic acids may also contribute to the acidity of rain. Anthropogenic emissions (air pollution) to the atmsphere tend to significantly increase rain acidity, creating "acid rain."

Two physical factors: the ***residence time*** and the pathways or routes along which water moves through the hydrologic system, are particularly important to the relative chemical composition of the water.

1. The longer the residence time in a particular environment, the more opportunity there is for reactions between water and the materials with which it is in contact. Groundwater is particularly impacted by residence time. One positive outcome of this situation is that subsurface sediments can filter out many impurities.

2. Water pathways determine which materials water contacts during its passage through the hydrologic system. In general, waters that follow shallow pathways contact more weathered and consequently less reactive materials than waters that move along deeper pathways.

Therefore, the physical mechanisms that determine the travel time of water, and the pathways along which the water moves can strongly affect the chemical composition of water.

Water quality within the Oetse Hydrologic Sub-area was evaluated based on the lower, more regional aquifer and a separate perched, or shallow groundwater system surrounding El Mirage (dry) Lake. *Water chemistry associated with the shallow, perched aquifer will be represented in italics for the remainder of the atlas.* Water quality deeper than approximately 500 ft (152 m) was not reviewed due to lack of sufficient data.

Oeste Hydrologic Sub-area Water Chemistry
Lower Aquifer

Constituent	Minimum Reading (mg/L)	Maximum Reading (mg/L)	Average Reading (mg/L)
Magnesium (Mg)	0.07	49	15.16
Sodium (Na)	14	280	69.95
Calcium (Ca)	4.6	188	65.92
Chloride (Cl)	1.41	200	20.24
Sulfate (SO_4)	1.67	638	198.78
Nitrate (NO_3)	0.1	20	7.35
Arsenic (As)	0.3 µg/L	12 µg/L	3.83 µg/L
Chromium (total Cr)	2.5 µg/L	59.3 µg/L	20.91 µg/L
Hardness (as $CaCO_3$)	14	530	223.32
Total Dissolved Solids (TDS)	44.58	1,134	435.09
pH	6.71	8.7	7.79

Oeste Hydrologic Sub-area Water Chemistry
Upper Aquifer

Constituent	Minimum Reading (mg/L)	Maximum Reading (mg/L)	Average Reading (mg/L)
Magnesium (mg)	0.74	12	5.46
Sodium (Na)	1.22	94.1	58.95
Calcium (Ca)	9.41	54	33.55
Chloride (Cl)	1.1	42	5.08
Sulfate (SO_4)	14.7	229	163.26
Nitrate (NO_3)	0.3	4.7	1.72
Arsenic (As)	1 µg/L	5.2 µg/L	2.43 µg/L
Chromium (total Cr)	2 µg/L	15 µg/L	7.7 µg/L
Hardness (as $CaCO_3$)	73	180	110.36
Total Dissolved Solids (TDS)	46.9	1,190	345.39
pH	6.1	8.7	7.84

Water Quality Standards & Ion Water Chemistry

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), represented in the table below, 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. 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. The Drinking Water Quality Standards table below, 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.

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.

Primary Drinking Water Quality Standards

MCL's, DLR's and PHG's for Regulated Drinking Water Contaminants (mg/L)
MCL (Maximum Contamination Level)
DLR (Detection Limit for purpose of Reporting)
PHG (Public Health Goal)

Contaminant	MCL	DLR	PHG	Date of PHG
Chemicals with MCL's 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, Division of Drinking Water and Environmental Management - Updated December 22, 2006.
For definitions of above terms see Glossary.

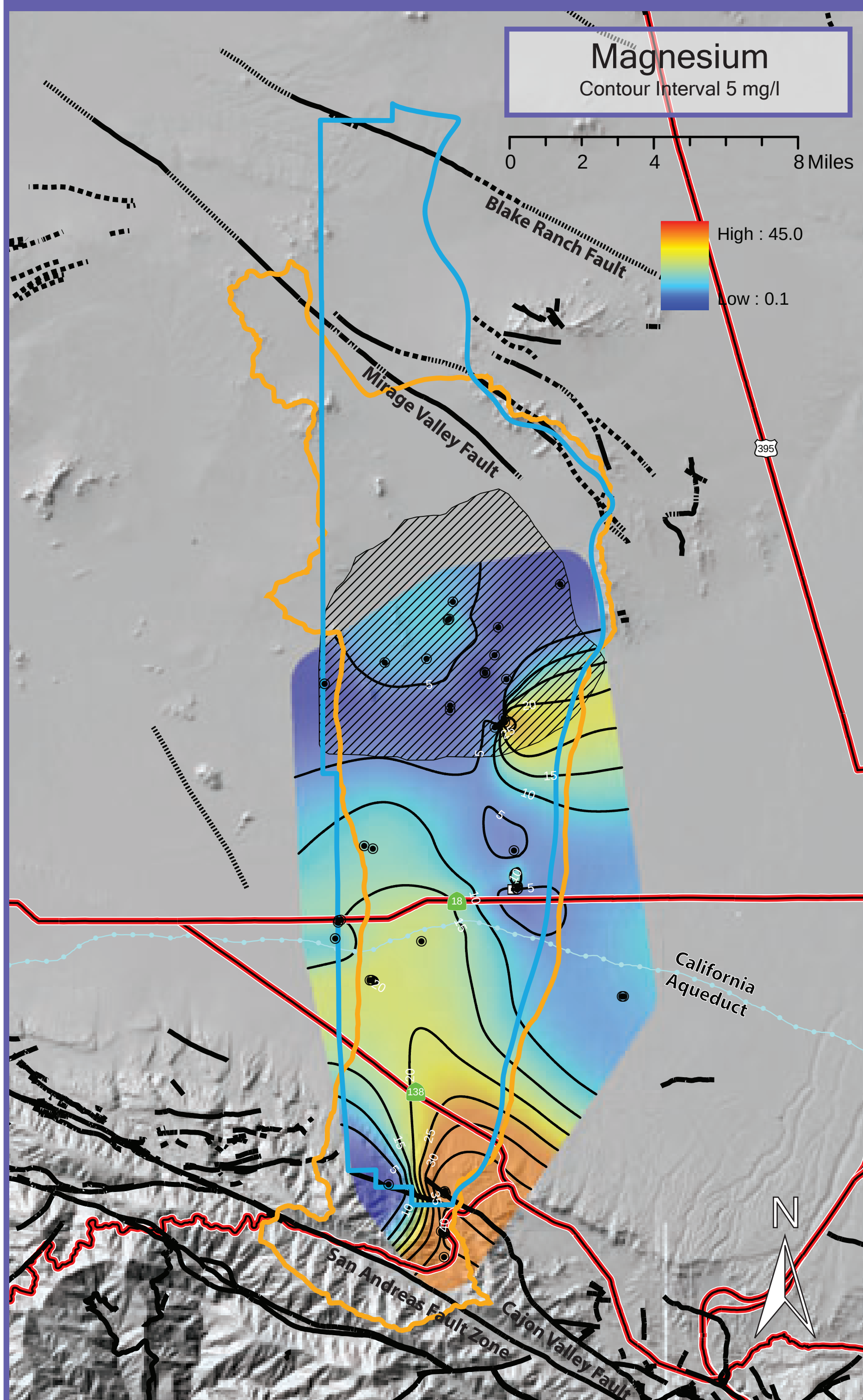
Secondary Drinking Water Quality Standards

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)	250	500	600
Total Dissolved Solids (TDS)	500	1,000	1,500

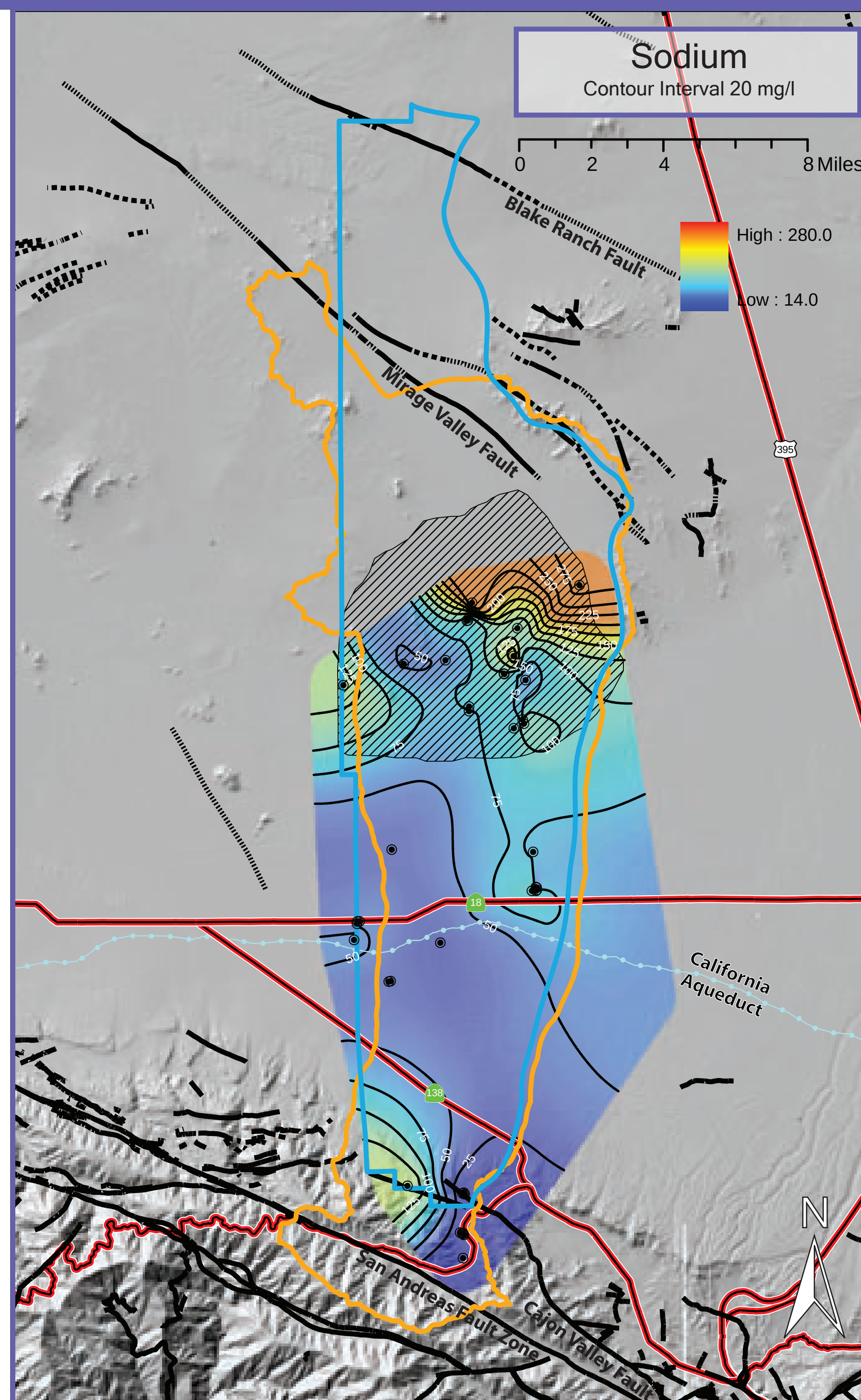
Source: CDHS (2003).

Water Chemistry

Ion Water Chemistry



Magnesium



Sodium

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.

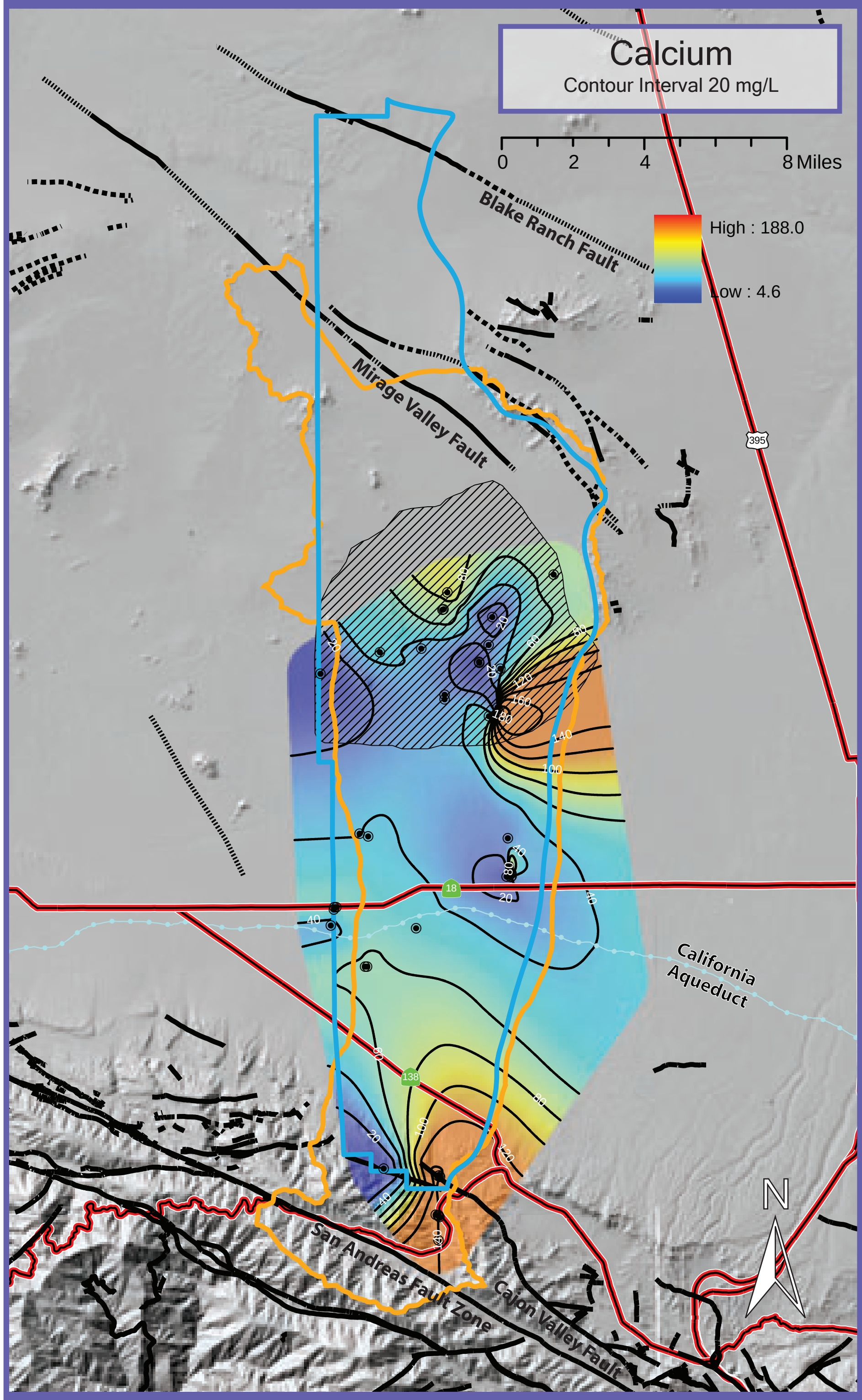
The average regional lower aquifer magnesium concentration in the Oeste Hydrologic Sub-area is 15.16 mg/L. The highest groundwater concentrations appear to be at the ***discharge area*** of Sheep Creek. As groundwater moves north towards the center of the basin, magnesium levels decline.

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. Sources of excess sodium are primarily from septic systems.

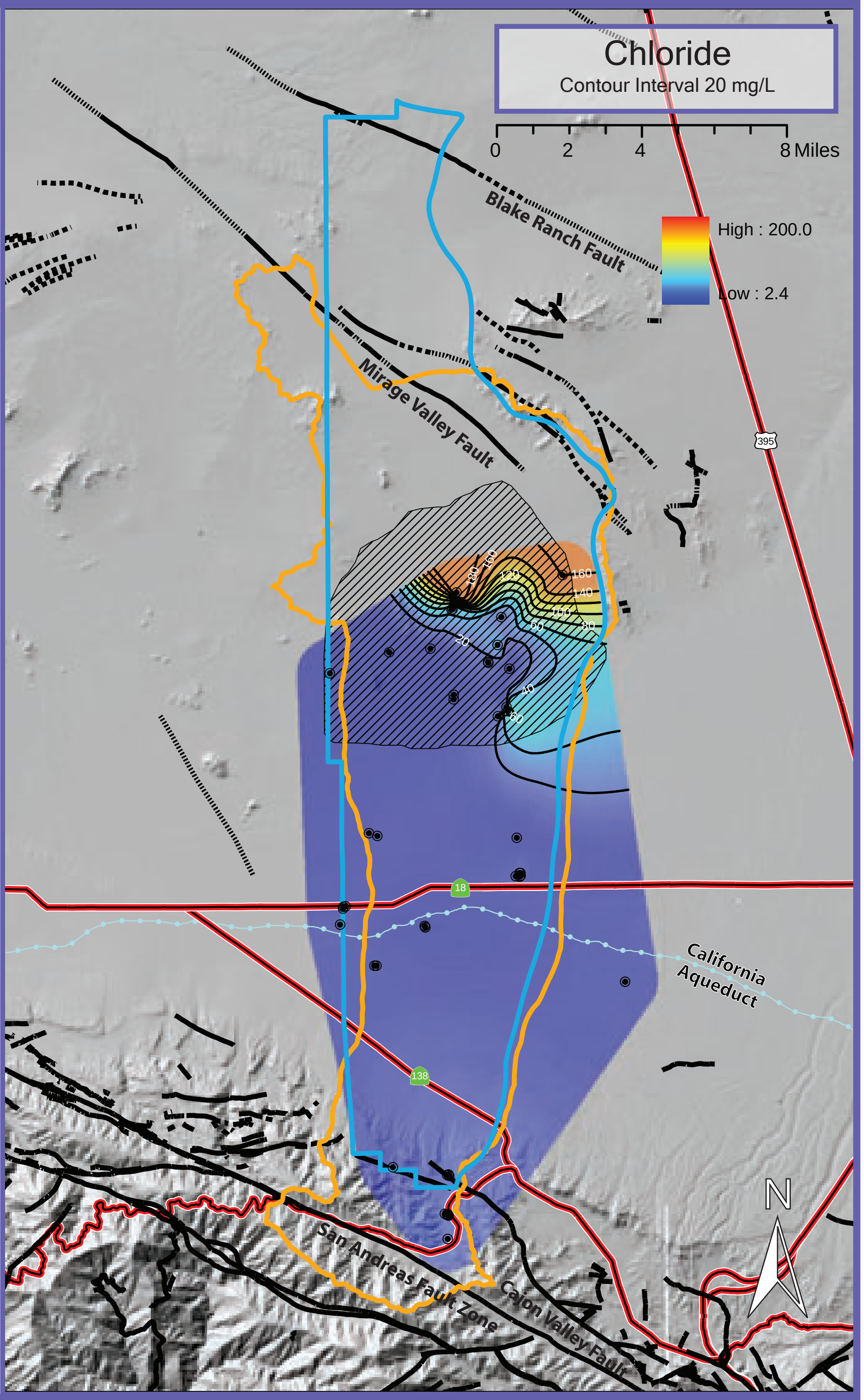
The average regional lower aquifer sodium concentration in the Oeste Hydrologic Sub-area is 69.95 mg/L. Generally, sodium is high towards El Mirage (dry) Lake. High regional aquifer concentrations exist near the northeastern portion of the basin and appear to be associated with the El Mirage (dry) Lake.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

Water Chemistry

Ion Water Chemistry



Calcium



Chloride

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. Generally, calcium is high towards El Mirage (dry) Lake. Groundwater exiting 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; it appears that elevated calcium concentrated water is being drawn into the basin from the east. *The upper perched aquifer has calcium concentrations rang ing from a low of 9.41 mg/L to a high of 54.0 mg/L.*

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

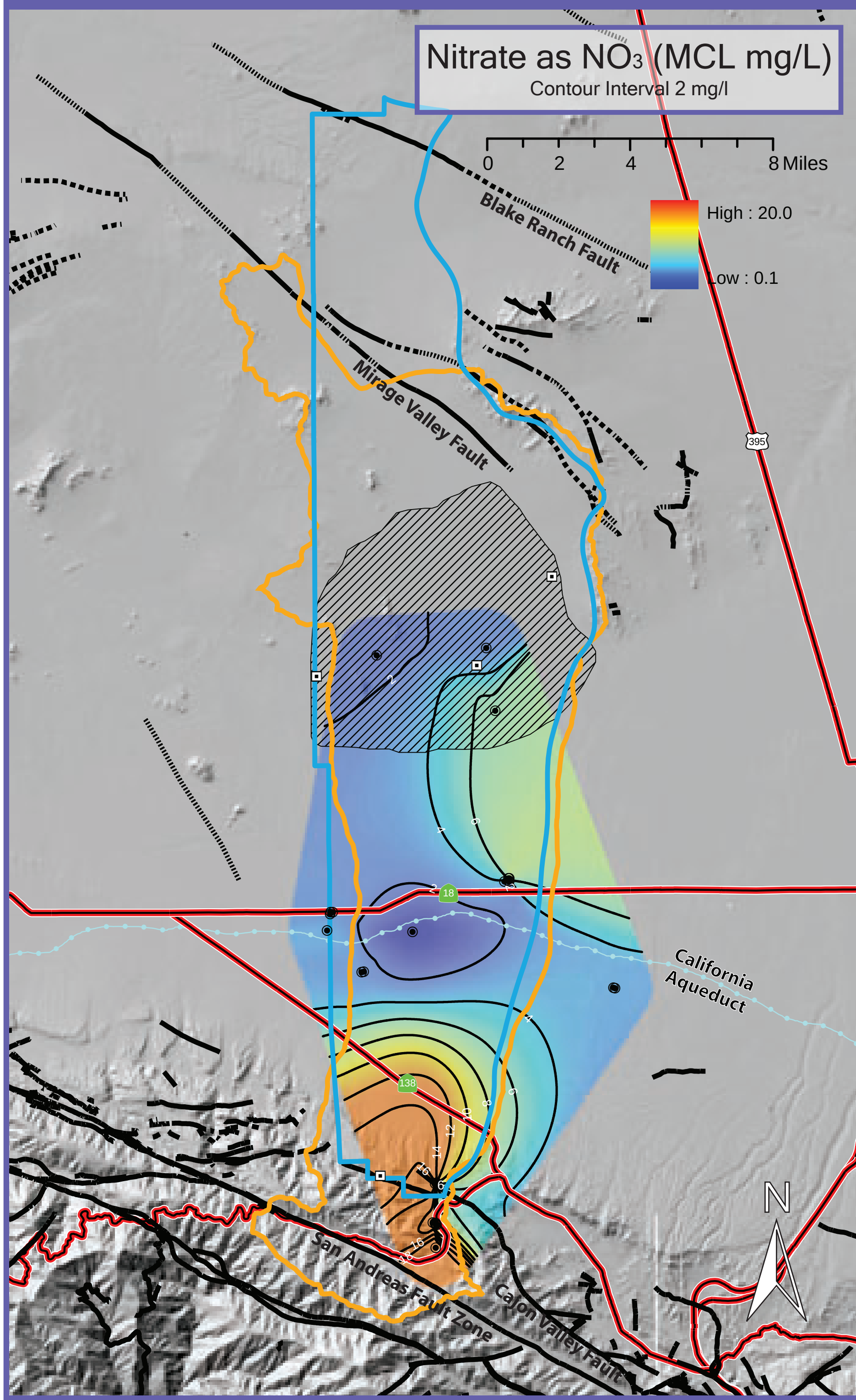
Source: CDHS (2003).

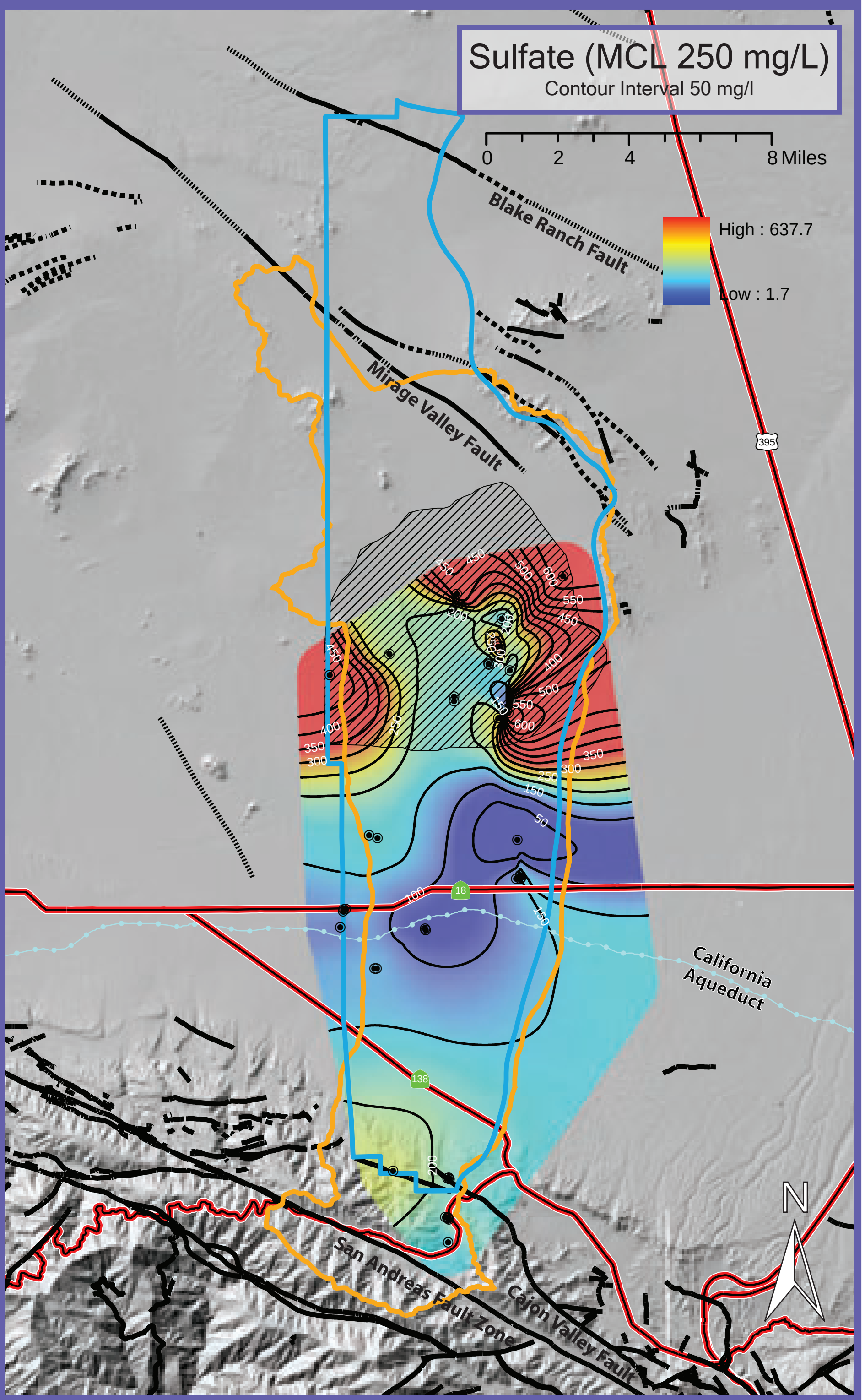
Chloride is regulated as a secondary contaminant in drinking water by the USEPA and State of California. The secondary maximum contaminant limit (Secondary MCL) for chloride is 250 mg/L. Risks or effects include high blood pressure, salty taste, corroded pipes, blackening of fixtures and appliances, 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. El Mirage (dry) Lake has on average the highest concentration, where as the remaining portion of the basin is generally under 25 mg/L.

Water Chemistry

Ion Water Chemistry





Nitrate

Primary MCL (mg/L)	MCL 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 found in 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 central portion of the basin. Groundwater exiting Sheep Creek have nitrate (as NO_3) concentrations between 1.0-2.0 mg/L. *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.*

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

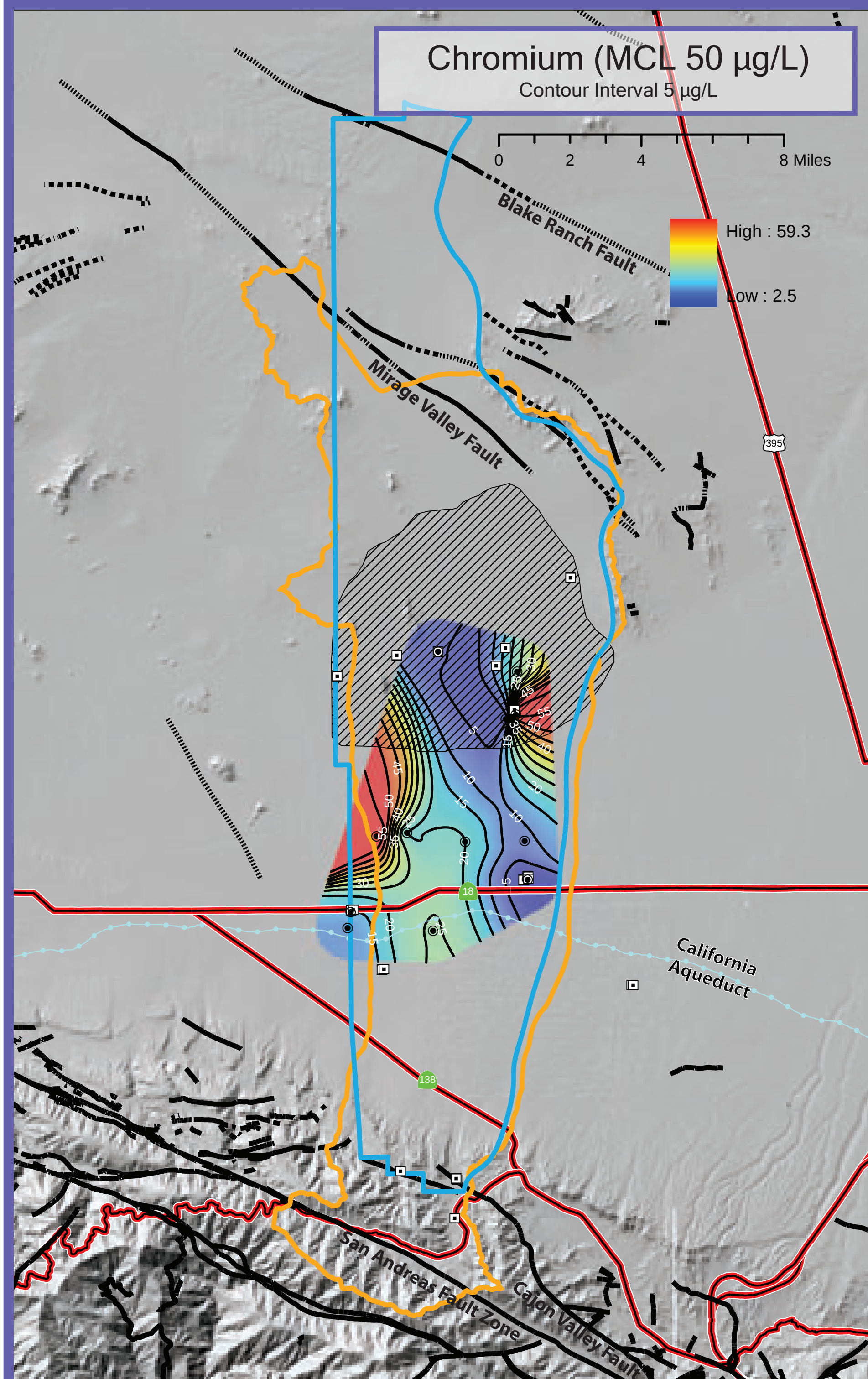
Source: CDHS (2003).

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 amount 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 upper perched aquifer shows sulfate readings between 14.7 mg/L to a high of 229.0 mg/L.*

Water Chemistry

Regional Water Chemistry



The average regional lower aquifer chromium (total) concentration in the Oeste Hydrologic Sub-area is 0.021 mg/L (21.0 µg/L). Groundwaters along the Phelan side of the basin have concentrations less than 0.006 mg/L (6.0 µg/L). Samples collected near the dry lake area also have low concentrations of chromium (total). Several research projects have been undertaken by the USGS to evaluate the higher than expected concentrations of chromium (total) exiting from Sheep Creek [Ball and Izbicki, 2004; Khachikian et al., 2004].

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; USGS NWIS Database].

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, an 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 an MCL for chromium VI.

Chromium

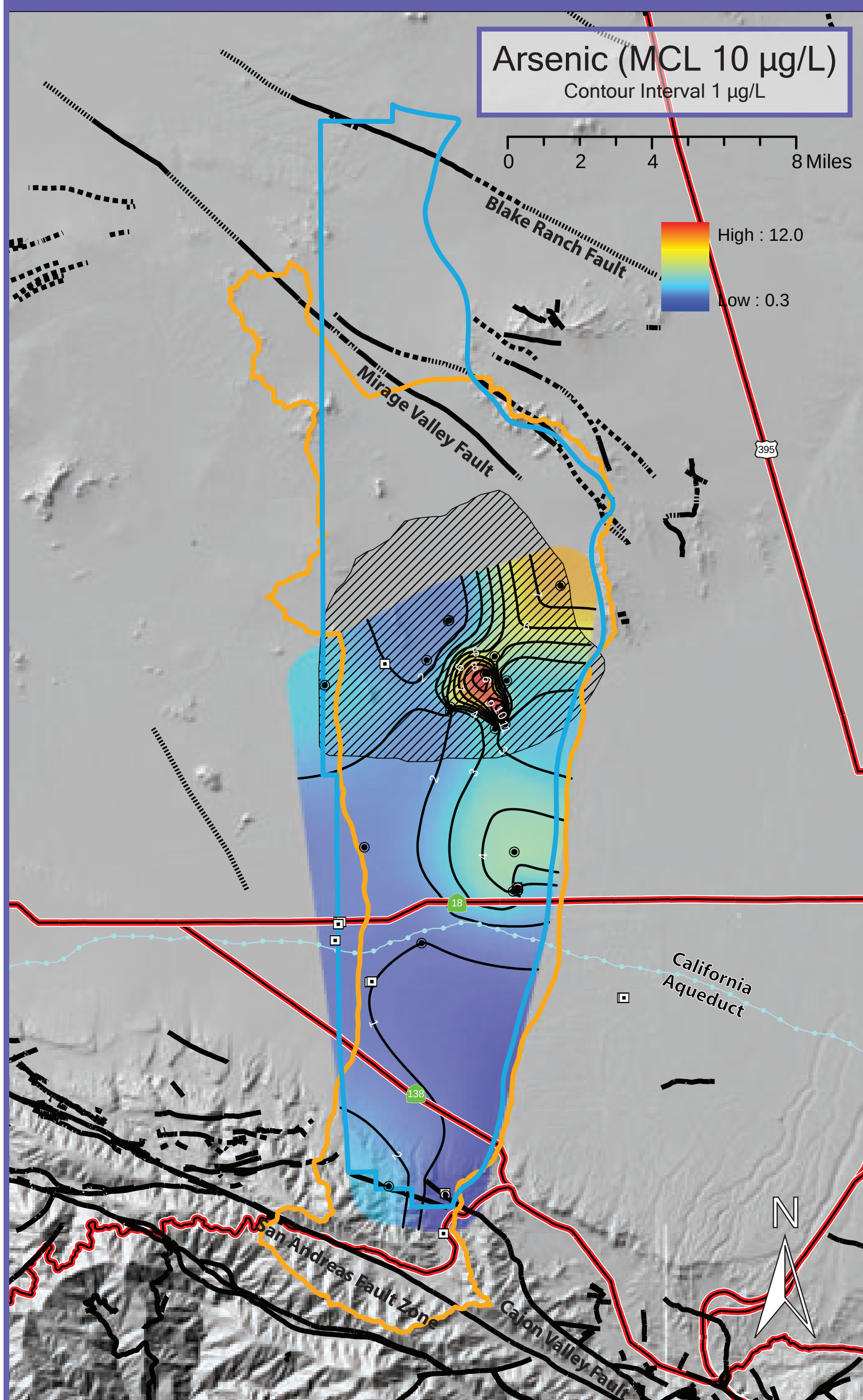
Primary MCL (mg/L) for Chromium (total)	Potential health effects from ingestion of water	Sources of contaminant in drinking water
0.05 (50.0 µg/L)	Allergic dermatitis	Discharge from planting facilities, steel and pulp mills and erosion of natural deposits

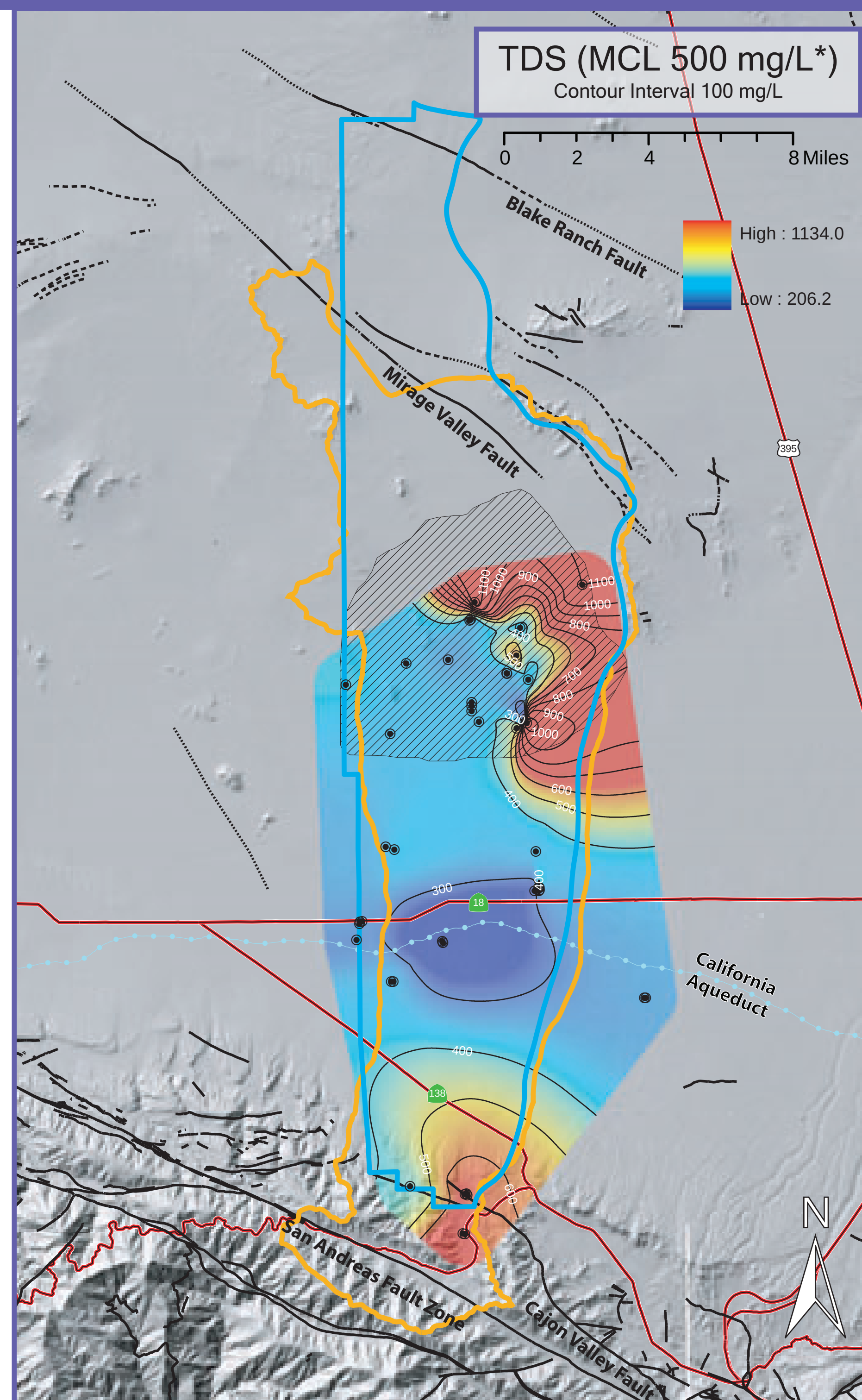
Source: CDHS (2006).

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.

Water Chemistry

Regional Water Chemistry





Arsenic

Primary MCL (mg/L)	MCLG (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 electonics production wastes.

Table 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 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.*

Total Dissolved Solids (TDS)

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 tast

Table Source: CDHS [2003].

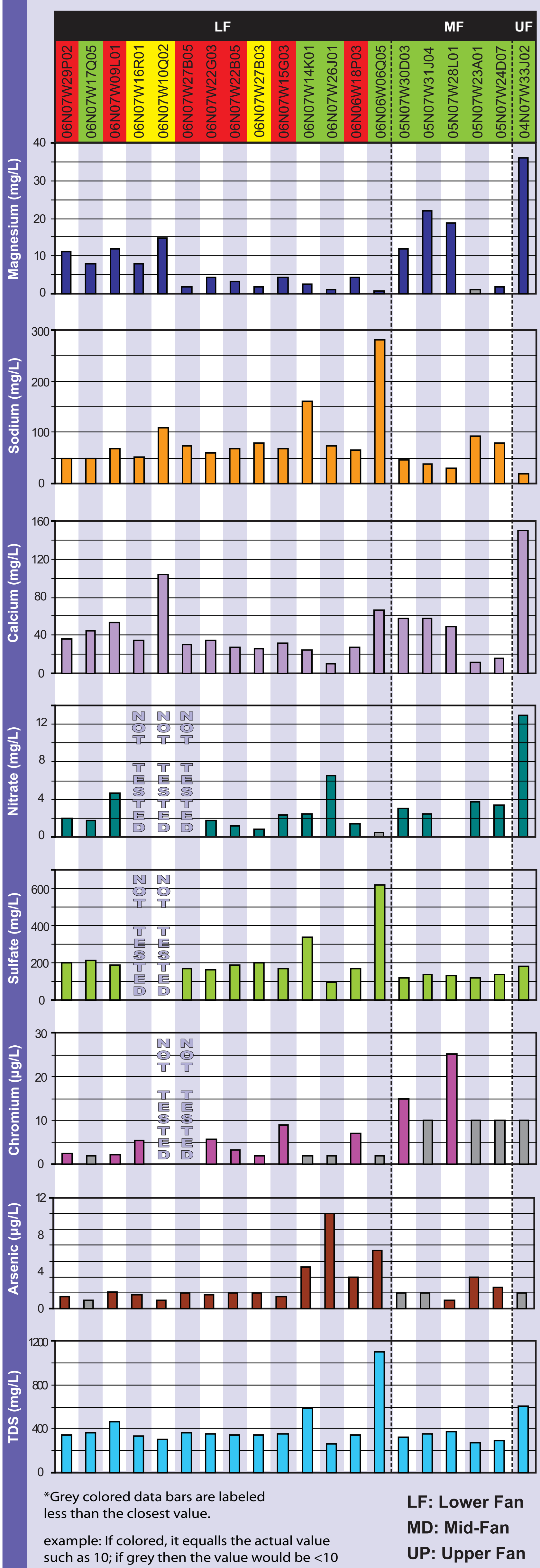
Total dissolved solids (TDS) is regulated as a secondary contaminant. The secondary MCL for TDS is 500 mg/L. A high TDS results in hard, salty, colored water that stains and produces deposits on or in pipes and faucets.

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 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.*

Water Chemistry

Regional Water Chemistry

Constituent Totals from Oeste Hydrologic Sub-area Wells (in order from west to east)

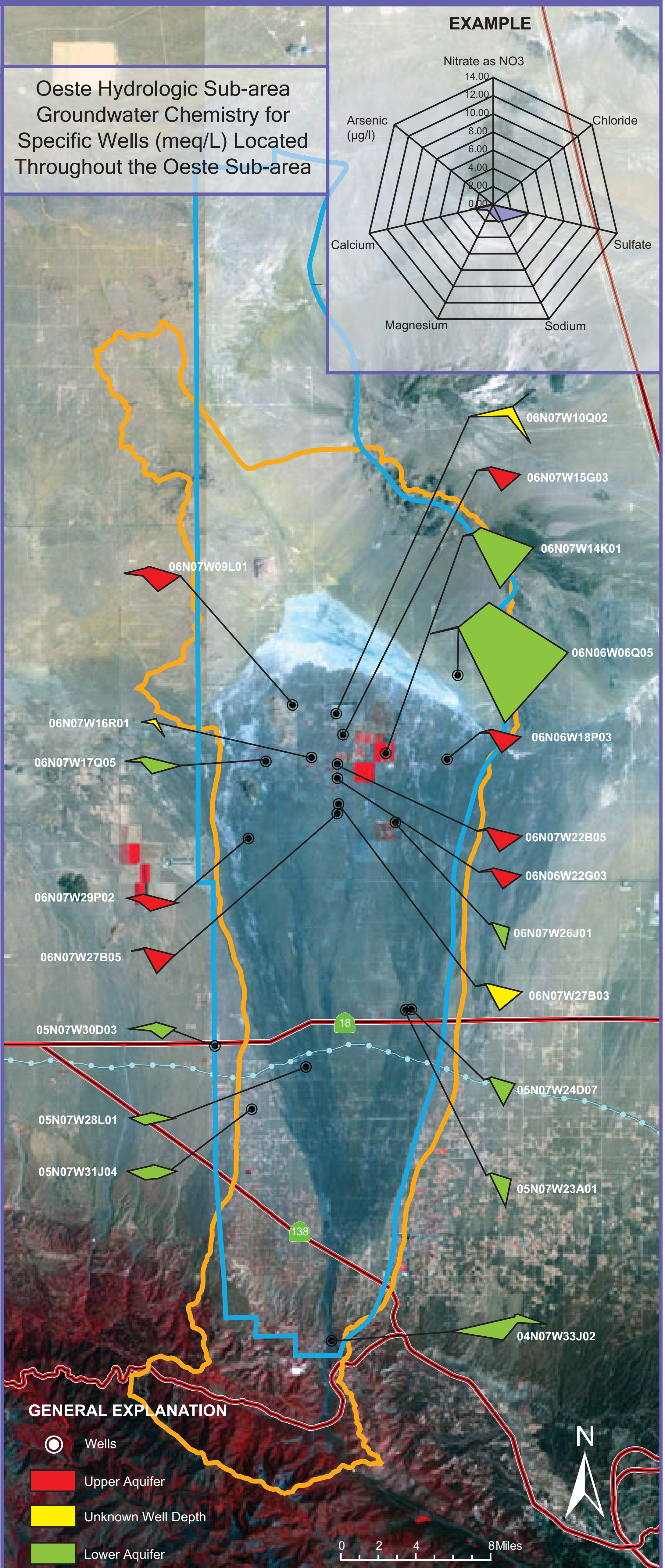


*Grey colored data bars are labeled less than the closest value.

example: If colored, it equalls the actual value such as 10; if grey then the value would be <10

LF: Lower Fan
MD: Mid-Fan
UP: Upper Fan

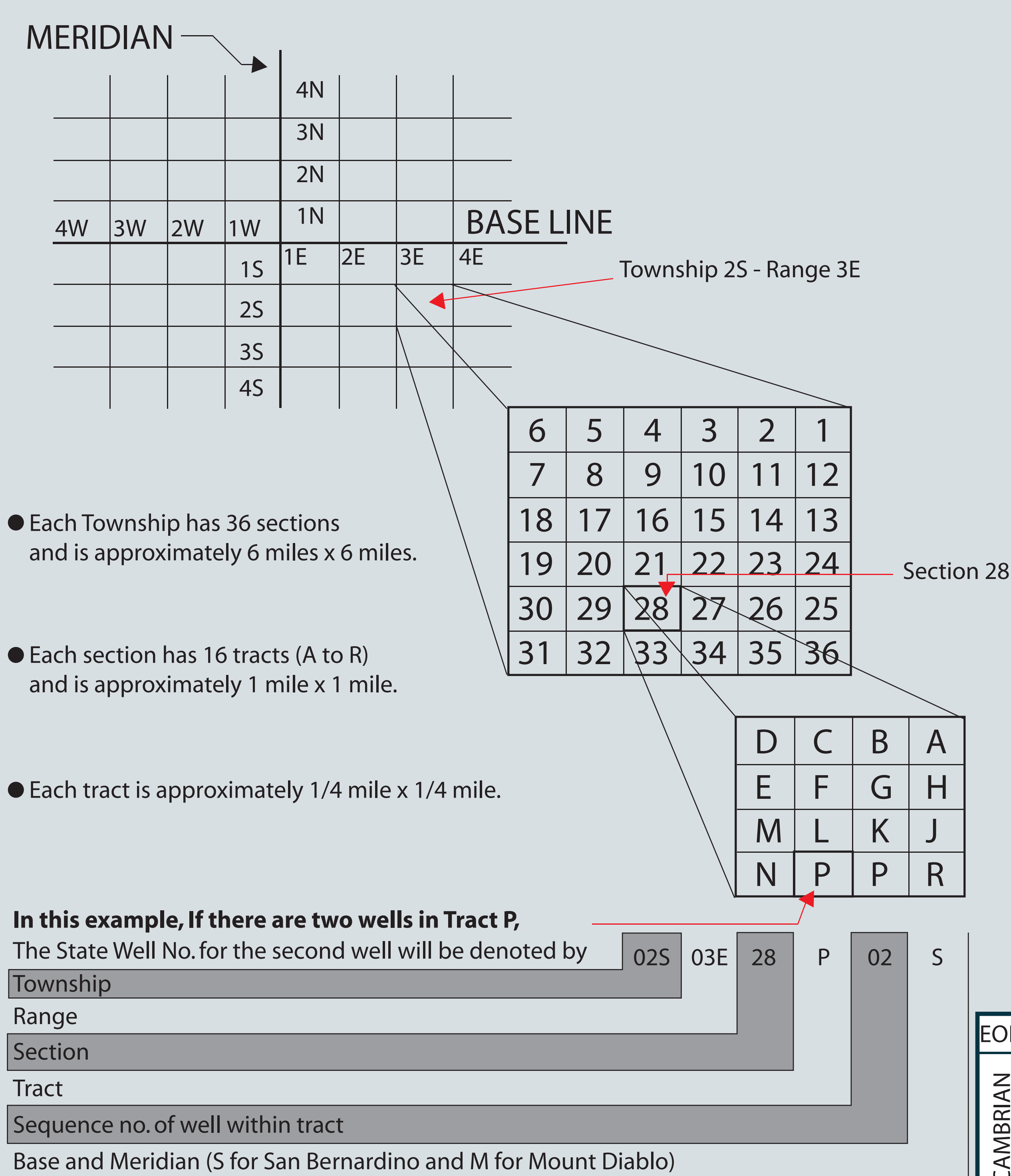
Oeste Hydrologic Sub-area Groundwater Chemistry for Specific Wells (meq/L) Located Throughout the Oeste Sub-area



Glossary

Information Tables

STATE WELL-NUMBERING SYSTEM



Geologic Time Scale

EON	ERA	PERIOD		EPOCH	MA
	CENOZOIC	Quaternary		Holocene	
				Pleistocene	1.8
		Tertiary	Neogene	Pliocene	
				-5-	
				Miocene	
				-24-	
			Paleogene	Oligocene	
				-34-	
				Eocene	
				-55-	
				Paleocene	65
	MESOZOIC	Cretaceous			144
		Jurassic			206
		Triassic			248
	PALEOZOIC	Permian			290
		Pennsylvanian			323
		Mississippian			354
		Devonian			417
		Silurian			443
		Ordovician			490
		Cambrian			540
PRE-CAMBRIAN	Proterozoic				2,500
	Archean				3,800
	Azoic				4,700

Unit Conversions

units to convert	units converting to	formula for conversion
inch (in)	millimeter (mm)	# in x 25.4 = # mm
foot (ft)	mm	# ft x 304.8 = # mm
mile (mi)	kilometer (km)	# mi x 1.609344 = # km
acre-foot (acf)	gallon (gal)	# acf x 325,851 = # gal
cubic-foot (ft^3)	acre-foot (acf)	# ft^3 x 0.000023 = # acf
pound (lb)	gram (g)	# lb x 453.59 = # g
degree Farenheit (°F)	degree Celcius (°C)	(°F - 32) x 5°C/9°F = °C
part-per-billion (ppb)	microgram-per-liter (μg/L)	# ppb = # μg/L
part-per-million (ppm)	milligram-per-liter (mg/L)	# ppm = # mg/L
gallon (gal)	liter (L)	# gal x 3.79 = # L
microgram (μg)	gram (g)	# μg x 10^{-6} = # g

OVERALL MAP GENERAL EXPLANATION

- Ephemeral Streams
- Fault - Solid where known, dashed where approximate, dotted where inferred
- Major Highways
- Oeste Hydrologic Sub-area Boundary
- El Mirage Watershed
- City Boundary
- County Boundary
- California Aqueduct
- Wells
- Well location ND (non-detect); below laboratory reporting limit

Glossary

A

abandoned well – A well that has been permanently disconnected. Most US states have regulations or guidelines for abandoned wells to ensure that contamination cannot move from the surface into the aquifer. [18]

absorption - The entrance of water into the soil or rocks by all natural processes, including the infiltration of precipitation or snowmelt, gravity flow of streams into the valley alluvium into sinkholes or other large openings, and the movement of atmospheric moisture. [11]

acidic - The condition of water or soil that contains a sufficient amount of acid substances to lower the pH below 7.0. [18]

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. [20]

adsorption -The adherence of ions or molecules in solution to the surface of solids. [11]

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. [19]

advection - The process by which solutes are transported by the bulk of flowing fluid such as the flowing ground water. [11]

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). [17]

aerobic -A condition in which free (atmospheric) or dissolved oxygen is present in the water. [17]

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. [17]

alkaline soil - Soil with a pH value greater than 7.0. [3]

alkalinity - The capacity of water for neutralizing an acid solution. [20]

alluvial - Pertaining to, or composed of, alluvium or deposited by a stream or running water. [9]

alluvial fan - A fan-shaped deposit of generally coarse material created where a stream flows out onto a gentle plain; a geomorphologic feature characterized by a cone or fan-shaped deposit of clay, silt, sand. [9]

alluvium - A general term for all sediment deposited in land environments by streams. [9]

anaerobic - A condition in which "free" (atmospheric) or dissolved oxygen is NOT present in water. [18]

anion - A negative ion. [9]

anoxic - Denotes the absence of oxygen, as in a body of water. [9]

anthropogenic – Compounds created by human beings, often relatively resistant to biodegradation. [10]

aqueous - (1) Relating to, similar to, containing, or dissolved in water; watery (2) Formed from matter deposited by water, as certain sedimentary rocks. [9]

aquiclude - (confining bed) A formation which, although porous and capable of absorbing water slowly, will not transmit water fast enough to furnish an appreciable supply for a well or spring. [9]

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. [9]

- **confined** - An aquifer that is bounded above and below by formations of distinctly lower permeability than that of the aquifer itself. An aquifer containing confined ground water. [7]
- **leaky** - An aquifer overlain and/ or underlain by a thin semipervious layer through which flow into or out of the aquifer can take place. [10]
- **perched** - Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater. [7]
- **unconfined** - An aquifer which is not bounded on top by an aquitard. The upper surface of an unconfined aquifer is the water table. [7]
- **aquifer system** - A body of permeable and relatively impermeable materials that functions regionally as a water yielding unit. [9]

aquifer test - A test to determine the hydraulic properties of an aquifer, involving the withdrawal of measured quantities of water from, or the addition of water to a well and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition (recharge). [9]

aquitard - A confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. [9]

area of influence – The area surrounding a pumping or recharging well within which the water table or potentiometric surface has been changed due to the well's pumping or recharge. [9]

argillic paleosol - A buried soil horizon of the geologic past containing increased amounts of clay minerals. [3]

arroyo - A water-carved channel or gully in an arid area, which is usually rather small, with steep banks and is dry much of the time due to infrequent rainfall and the shallowness of the cut. It does not penetrate below the level of permanent ground water. [11]

artesian aquifer - An artesian aquifer is an aquifer which is bounded above and below by formations of impermeable or relatively impermeable material. [9]

Glossary

A-C
artificial recharge - conjunctive use

artificial recharge - The addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells. [7]

attenuation – The process of diminishing contaminant concentrations in groundwater, due to filtration, biodegradation, dilution, sorption, volitilization and other processes. [9]

available soil moisture - Soil or *Vadose Water* that is available for use by plants. [9]

average linear velocity – The rate of movement of fluid particles through porous media along a line from one point to another. [8]

B

background level – In toxic substances monitoring, the average presence of a substance in the environment, originally referring to naturally occurring phenomena. [9]

banking (water) - A water conservation and use optimization system whereby water is reallocated for current use or stored for later use. Water banking may be a means of handling surplus water resources and may involve aquifer recharge or similar means of storage. [9]

basalt - A fine-grained, dark-colored igneous rock which is generally of extrusive origin. [9]

baseflow – Sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural base flow is sustained largely by ground-water discharges. [20]

basement rock - The oldest rocks in a given area; a complex of metamorphic and igneous rocks that underlies the sedimentary deposits. Usually Precambrian or Paleozoic in age. [15]

basin - A geographic area drained by a single major stream; consists of a drainage system comprised of streams and often natural or man-made lakes. [9]

bedrock-The solid rock beneath the soil and superficial rock. A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material. [20]

biological contaminants – Living organisms or derivates (e.g. viruses, bacteria, fungi, and mammal and bird antigens) that can cause harmful health effects when inhaled, swallowed, or otherwise taken into the body. [18]

bolson- An alluvium-filled basin, depression, or wide valley mostly surrounded by mountains and drained by a system that has no surface outlet; an undrained or internally drained intermontane basin. [10]

C

caliche - A soil layer near the surface, more or less cemented by secondary carbonates of calcium or magnesium precipitated from the soil solution. It may occur as a soft, thin soil horizon, as a hard, thick bed just beneath the Solum, or as a surface layer exposed by erosion. [9]

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. [9]

capillary action - Movement of water through very small spaces due to molecular forces called capillary forces. [17]

capillary fringe - The zone above he water table within which the porous medium is saturated by water under less than atmospheric pressure. [17]

carbonate - A sediment formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron. [11]

cation - A positively charged ion in an electrolyte solution, attracted to the cathode under the influence of a difference in electrical potential. Sodium ion (Na+) is a cation. [18]

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. [11]

clay - One type of soil particle with a diameter of approximately one ten-thousandth of an inch. [18]

coarse - Composed of or constituting relatively large particles; e.g. “coarse sandy loam”. [3]

combined sewer overflow –Wastewater flow that consists of storm water and sanitary sewage. [10]

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. [18]

compaction -(1) Compaction process is to change the ground soil voids by means of mechanical devices in order to reduce the settlement, hydraulic conductivity, and to increase the shear resistance; (2) Also called Densification. [10]

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 an electrical current. [18]

conductivity - A measure of the ability of a solution to carry an electrical current. [18]

cone of depression - The depression, roughly conical in shape, produced in the water table by the pumping of water from a well. [18]

confining bed - A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. [3]

conglomerate - A sedimentary rock made of rounded rock fragments, such as pebbles, cobbles, and boulders, in a finer-grained matrix. To call the rock a conglomerate, some of the constituent pebbles must be at least 2 mm (about 1/13th of an inch) across. [21]

conjunctive use -The coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply. [7]

Glossary

C-E

consolidation - extraction well

consolidation - (Soil Mechanics)- Adjustment of a soil in response to increased load; involves squeezing of water from the pores and a decrease in void ratio (pore space). [9]

consumptive use – Water removed from available supplies without direct return to a water resource system for uses such as manufacturing, agriculture, and food preparation. [22]

contaminant – Any substance or property preventing the use or reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing, washing, recreation, and cooling. Any solute or cause of change in physical properties that renders water unfit for a given use. (Generally considered synonymous with pollutant). [9]

cosmetic effects - Effects of physical changes in a person from the water, such as, discoloration of teeth. [19]

cross contamination - The intermixing of two water streams which results in unacceptable water quality for a given purpose. [22]

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. [20]

D

Darcy's Law – The equation for velocity of flow of groundwater which states that in material of given permeability, velocity increases as slope of groundwater table increases. [9]

deep percolation - Water that percolates below the lower limit of the *root zone* of plants into a groundwater aquifer and cannot be used by plants. [9]

depression storage - (1) Water contained in natural depressions in the land surface such as puddles. (2) Water that is temporarily detained on the surface of the earth in puddles and cavities that have little or no surface outlet. [9]

detection limit-The lowest concentration of a chemical that can reliably be distinguished from a zero concentration. [2]

dike -(1) A low wall that can act as a barrier to prevent a spill from spreading. (2) A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks. [9]

direct runoff - Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes. [9]

discharge – The flow of surfacewater in a stream or the flow of groundwater from a spring, ditch or flowing artesian well. [9]

- **mean discharge** - Arithmetic mean of discharges over a given time period. [9]
- **instantaneous discharge** - The discharge at a particular instant of time. [9]

discharge area - An area in which groundwater is discharged to the land surface, surface water or atmosphere. [9]

dissolved oxygen (DO) - Concentration of oxygen dissolved in water and readily available to fish and other aquatic organisms. [9]

dissolved solids - The dissolved mineral constituents or chemical compounds in water or solution; they form the residue that remains after evaporation and drying. Excessive amounts of dissolved solids make the water unfit to drink or use in industrial processes. [9]

divide – (1) The line of separation between drainage systems; (2) The highest ridge line of a mountain chain. [10]

domestic consumption – Water used for household purposes such as washing, food preparation, toilets and showers. [9]

downgradient - The direction that groundwater flows; similar to "downstream" for surface water. [9]

drainage basin - Area from which surface runoff is carried away by a single drainage system. [10]

drawdown - Vertical distance the free water elevation is lowered or the reduction of the pressure head due to the removal of free water due to pumping test. [10]

drinking water equivalent level – The lifetime exposure level at which adverse health effects are not anticipated to occur, assuming 100% exposure from drinking water. [10]

drought - An extended period of dry weather, which, as a minimum, can result in a partial crop failure or an inability to meet normal water demands. [10]

E

effective porosity – The ratio of the volume of the voids of a soil mass that can be drained by gravity to the total volume of the mass. [10]

effluent stream – See glossary term *stream*.

electroneutrality principle - The principle expresses the fact that all pure substances carry a net charge of zero. [4]

EPA - The Environmental Protection Agency. Federal agency created by the Executive Reorganization Plan No.3 in 1970 to consolidate federal regulatory authority over pollution. [10]

ephemeral stream – See glossary term *stream*.

epicenter - A point or line directly above the focus or point at which an earthquake occurs. [10]

equilibrium - A state of balance or rest. [10]

equipotential line - The line along which water will rise to the same elevation in piezometric tubes. [10]

erosion - A general term that describes the physical and mechanical breaking down, chemical solution, and movement of broken-down and dissolved rock materials. [10]

evaporation - The conversion of liquid water to water vapor. [10]

evaporite - A non-elastic sedimentary rock whose constituent minerals were precipitated from water solution as a result of evaporation. [10]

evapotranspiration - Water withdrawn from the soil by evaporation and plant transpiration. [10]

extraction well - A well employed to extract fluids from the subsurface. [10]

Glossary

F-H
fault - hydrochemical facies

F

fault - A fracture, or large crack, in the Earth's crust where one side moves up/down/sideways relative to the other. [15]

- **normal fault** - Vertical fault where one slab of the rock is displaced up and the other slab down. It is created by tensional forces acting in opposite directions. [14]
- **reverse fault** - This vertical fault develops when compressional force causes the displacement of one block of rock over another. [14]
- **strike-slip fault** - Fault that primarily displays horizontal displacement. [14]

field capacity - The maximum amount of water that a soil can retain after excess water from saturated conditions has been drained by the force of gravity. [12]

flow rate –The rate, expressed in gallons-or liters-per-hour, at which a fluid escapes from a hole or fissure in a tank. [12]

focus (hypocenter) - Point of stress release in an earthquake. [14]

footwall - The bottommost surface of an inclined fault. [14]

friable - Said of a rock or mineral that crumbles naturally or is easily broken, pulverized or reduced to powder, such as soft or poorly cemented sandstone. [3]

G

geophysical log (well log) – A graphic record of the measured or computed physical characteristics of the rock section encountered in a well, plotted as a continuous function of depth. [3]

gneiss - A foliated rock formed by regional metamorphism, in which bands or lenticles of granular minerals having flaky or elongate prismatic habits predominate. [3]

granodiorite - A group of coarse-grained plutonic rocks intermediate in composition between quartz diorite and quartz monzonite. [3]

gravel - A term used to describe unconsolidated sediments composed of rock fragments. These rock fragments have a size that is greater than 2 millimeters. [14]

grey water - Wastewater other than sewage, such as sink drainage or washing machine discharge. [18]

groundwater - The supply of fresh water found beneath the Earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants or leaking underground storage tanks. [17]

groundwater barrier - Rock, clay or other natural or artificial materials with relatively low permeability that occurs 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. [9]

groundwater basin - A subsurface basin in which groundwater collects or is retained or from which groundwater may flow. [9]

groundwater budget - A quantitative description of the recharge, discharge and changes in storage of an aquifer or system of aquifers. [9]

groundwater discharge - The flow of water from the zone of saturation. [9]

groundwater divide - A ridge in the water table, or potentiometric surface, from which groundwater moves away at right angles in both directions. [9]

groundwater flow - Water that moves through the subsurface soil and rocks. [9]

groundwater mound - Raised area in a water table or other potentiometric surface, created by groundwater recharge. [9]

groundwater production - See glossary term *production*.

groundwater recharge - The natural or intentional infiltration of surface water into the zone of saturation. [7]

H

hanging wall - The topmost surface of an inclined fault. [14]

hard water - Water which forms a precipitate with soap due to the presence of calcium, magnesium or ferrous ions in solution. [9]

hardness (of water) - A property of water causing formation of an insoluble residue when the water is used with soap. It is primarily caused by calcium and magnesium ions. [9]

headwater(s) - The source and upper reaches of a stream; also the upper reaches of a reservoir. [9]

homogeneity - Characteristic of a medium in which material properties are identical throughout. [9]

hydraulic barrier - Modifications to a groundwater flow system that restrict or impede movement of water and contaminants. [9]

hydraulic conductivity (K) - The rate of flow of water in gallons per day through a cross-section of one square foot of medium under a unit hydraulic gradient. [9]

hydraulic diffusivity - In groundwater, the transmissivity divided by the storage coefficient or T/S. [3]

hydraulic gradient (I) - The slope of the water surface. [9]

hydraulic head (h) - The height of the free surface of a body of water above a given point beneath the surface. [9]

hydraulic radius (R) - The cross-sectional area of a channel divided by its wetted perimeter. [3]

hydrochemical facies - The diagnostic chemical character of groundwater solutions occurring in hydraulic systems. [3]

Glossary

H-M

hydrocompaction - maximum residual disinfectant level

hydrocompaction - The settling and hardening of land due to application of large amounts of water for irrigation. [9]

hydrogeologic - Those factors that deal with subsurface waters and related geologic aspects of surface waters. [9]

hydrogeology - The geology of ground water, with particular emphasis on the chemistry and movement of water. [17]

hydrograph - A graph of the rate of runoff plotted against time for a point on a channel. [18]

hydrologic budget - An accounting of the inflow to, outflow from and storage in, a hydrologic unit such as a drainage basin, aquifer, soil zone, lake or reservoir. [3]

hydrologic cycle - Movement or exchange of water between the atmosphere and the earth. [17]

hydrologic unit - A geographic area representing part or all of a surface drainage basin or a distinct hydrologic feature. [9]

hydrology - The study of the occurrence, distribution and circulation of the natural waters of the earth. [18]

hydrostratigraphy - A geologic framework consisting of a body of rock having considerable lateral extent and composing a reasonably distinct hydrologic system. [7]

I

igneous rock - Rocks formed by the solidification of molten materials (magma or lava). [9]

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. [16]

infiltration - The flow of fluid into a substance through pores or small openings. [9]

infiltration capacity - The maximum rate at which the soil, when in a given condition, can absorb falling rain or melted snow. [9]

infiltration gallery - A subsurface groundwater collection system, typically shallow in depth, constructed with open jointed or perforated pipes that discharge collected water into a watertight chamber. From this chamber the water is pumped to treatment facilities and into the distribution system. Usually located close to streams or ponds. [9]

infiltration rate - Rate of downward movement or flow of water from the surface into the soil. [9]

inflow - The act or process of flowing in or into. [9]

influent stream - See glossary term *stream.*

injection well - Refers to a well constructed for the purpose of injecting treated wastewater directly into the ground. [9]

interbedding - A bedding, usually thin, of one kind of rock material occurring between or alternating with beds of another kind. [9]

interflow - Lateral movement of water in the upper layer of soil. [9]

intermittent stream - See glossary term *stream.*

intrinsic permeability - The relative ease with which a porous medium can transmit a liquid under a hydraulic or potential gradient. [1]

ion - An element or compound that has gained or lost an electron, so that it is no longer neutral electrically, but carries a charge. [9]

isotope - Alternate form of an element. Elements having the same number of protons but different numbers of neutrons in their nuclei. Isotopes have the same atomic number, but different atomic weights. [9]

isotropy - The condition in which a medium has the same properties in all directions. [9]

J

juvenile water - Water brought to the surface or added to underground supplies from magma. [9]

L

lacustrine - Pertaining to, produced by or inhabiting a lake. [9]

leachate - Liquid which has percolated through the ground, such as water seeping through a sanitary landfill, waste, pesticides or fertilizers. [9]

leaching - The washing out or flushing of a soluble substance from an insoluble one. [9]

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. [9]

leaky aquifer - An artesian or water table aquifer that loses or gains water through adjacent semi-permeable confining units. [9]

lithic arkose - Containing appreciable rock fragments; specificaly a sandstone containing fine grained rock fragments, feldspar, quartz, quartzite and chert. [3]

lithology- The scientific study of rocks, usually with the unaided eye or with little magnification. [9]

losing stream - See glossary term *stream.*

M

matrix - Solid framework of a porous material or system. [9]

maximum contaminant level (MCL) - The highest level of a contaminant that is allowed in drinking water. [5]

maximum contaminant level goal (MCLG) – The level of a contaminant in drinking water below which there is no known or expected risk to health. [5]

maximum residual disinfectant level (MRDL) - The maximum permissible level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap without an unacceptable possibility of adverse health effects. [16]

Glossary

M-P

maximum residual disinfectant level goal - production

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. [6]

metamorphic rock - A rock that forms from the recrystallization of igneous, sedimentary or other metamorphic rocks through pressure increase, temperature rise, or chemical alteration. [14]

milligram (mg) - One-thousandth of a gram. [9]

milligrams per liter (mg/l) - A measure of concentration of a dissolved substance. A concentration of one mg/L means that one milligram of a substance is dissolved in each litter of water. [10]

million gallons per day (Mgd) - A measure of water flow. [9]

mitigation- Actions designed to lessen or reduce adverse impacts; frequently used in the context of environmental assessment. [9]

monitoring well - A well used to obtain water quality samples or measure groundwater levels. Wells used to collect groundwater samples for analysis to determine the amount, type and spread of contaminants in groundwater. [9]

N

non-point source pollution - Pollution discharge over a wide land area, not from one specific location. [9]

non-potable - Water that may contain objectionable pollution, contamination, minerals or infective agents and is considered unsafe and/or unpalatable for drinking. [9]

O

orographic uplift - Uplift of an air mass because of a topographic obstruction. Uplift also causes the cooling of the air mass. If enough cooling occurs condensation can occur and form into orographic precipitation. [14]

outfall - The place where a sewer, drain or stream discharges; the outlet or structure through which reclaimed water or treated effluent water is finally discharged to a receiving water body. [9]

outflow - Process of flowing out; includes all water that leaves a hydrologic system. [9]

overdraft - A condition that occurs in a groundwater basin when pumping exceeds recharge over an extended period of time. [9]

overland flow - The flow of rainwater or snowmelt over the land surface toward stream channels. [9]

oxygen demand - The need for molecular oxygen to meet the needs of biological and chemical processes in water. [9]

P

particle size - The diameter, in millimeters, of suspended sediment or bed material determined by either sieve or other sedimentation methods. [9]

Particle-size classification - The particle size classification is as follows: [9]

- 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, gently sloping rock surface at the base of a steeper slope, often covered with alluvium, formed primarily by erosion. [10]

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 and frequently supplies a hillside spring. [9]

percolating water - Water that passes through soil or rocks under the force of gravity along the path of least resistance. [9]

percolation - The slow seepage of water into and through the ground. [9]

perennial stream - See glossary term *stream*.

permeability - The capacity of soil, sediment or porous rock to transmit water; the property of soil or rock that allows passage of water through it. [9]

permeability coefficient - The 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° C. [9]

pH - An index of the acidity (below 7) or alkalinity (above 7) of a soil. [10]

phosphates - General term used to describe phosphorus-containing derivatives of phosphoric acid. [9]

phreatic water - Synonymous with the zone of saturation. [9]

playa - Generally, a dry or intermittently dry lakebed in the lowest spot of a closed valley. A dry bed of an ephemeral shallow lake in a nearly level area on the floor of a desert basin. [9]

plume - A space in air, water or soil containing pollutants released from a point source. [9]

point source pollution - Pollution originating from any discrete source. [9]

pollution - Harmful substances deposited in the air, water, land, leading to a state of dirtiness, impurity or unhealthiness. [9]

pore space - That portion of rock or soil not occupied by solid mineral matter and which may be occupied by groundwater. [9]

porosity - Degree to which soil, gravel, sediment, or rock is permeated with pores or cavities through which water or air can move. [17]

potable water - Water that is drinkable; water that is safe and satisfactory for drinking and cooking. [9]

precipitation - The process by which atmospheric moisture falls onto a land or water surface as rain, snow, hail or other forms of moisture. [9]

preliminary wastewater treatment - The removal of metal, rocks, rags, sand, eggshells and similar materials which may hinder the operation of a treatment plant. [9]

production - The act of extracting groundwater by pumping or otherwise. [13]

Glossary

P-S

Public Health Goal - specific yeild

Public Health Goal (PHG)- The level of a contaminant in drinking water below which there is no known or expected risk to health. [5]

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. [9]

R

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). [9]

rain shadow – A dry region on the leeward side of a topographic barrier, usually a mountain range, where rainfall is noticeably less then the windward side. [9]

recharge - The process by which water is absorbed and added to the zone of saturation, thus replenishing it. [9]

recharge area - An area where absorbed water eventually reaches one or more aquifers in the zone of saturation. [9]

recharge basin - A surface facility, often a large pond, used to increase the infiltration of surface water into a groundwater basin. [9]

recharge boundary - An aquifer system boundary that adds water to the aquifer. Streams and lakes are typical recharge boundaries. [9]

recharge rate - The quantity of water per unit of time that replenishes or refills an aquifer. [9]

redox potential - The potential is an intensity measurement. It measures the availability rather than the quantity of electrons. [10]

relief - The difference in elevation between the highest and lowest points in an area. [10]

reservoir - A pond, lake or basin either natural or artificial, for the storage, regulation and control of water. [9]

residence time - The average amount of time a particular substance spends within a designated earth system. The residence time is inversely proportional to the rate of movement within the system and directly proportional to the size of the system. [3]

return flow - The amount of water that reaches a ground or surface water source after release from the point of use and thus becomes available for further use. [9]

runoff - The water that runs off or flows over the land surface. That portion of precipitation that moves from land to surface water bodies. [9]

S

safe water - Water that does not contain harmful bacteria or toxic materials or chemicals. Water may have taste and odor problems, color and certain mineral problems and still be considered safe for drinking. [9]

safe yield - The rate at which water can be withdrawn from supply, source or an aquifer over a period of years without causing eventual depletion or contamination of the supply. [9]

saline water - Water that contains significant amounts of dissolved salts. Parameters for saline water: [20]

- 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 - Combinations of common earth elements and compounds. Sufficiently diluted, salts are usually harmless for most water uses and are even necessary for plant growth. Excessive amounts of dissolved mineral salts, however, are detrimental to practically all water uses, including agriculture and domestic uses. [9]

sand - See glossary term *Particle-size classification*.

saturated zone - The area below the water table where all open spaces are filled with water. [9]

saturation - In water chemistry, means the state of a solution (water) when it holds the maximum equilibrium quantity of dissolved matter at a given temperature and pressure. The limit when no more of a given substance will dissolve. [22]

schist - A medium to coarse grained metamorphic rock with well developed bedding planes derived from the foliated recrystrallization of platy like minerals like mica. [14]

sediment - Topsoil, sand, and minerals washed from the land into water, usually after rain or snow melt. [17]

sedimentary rock - Rock that results from the consolidation of layers of loose sediment made up of various kinds of organic and inorganic matter. [22]

seepage - Percolation of water through the soil from unlined canals, ditches, laterals, watercourses, or water storage facilities. [17]

semi-arid - A type of climate in which there is slightly more precipita-tion (25-50 cm) than in an arid climate, and in which sparse grasses are the characteristic vegetation. [9]

semi-confined aquifer - An aquifer partially confined by soil layers of low permeability through which recharge and discharge can still occur. [17]

silt - See glossary term *Particle-size classification*.

soft water - Any water that does not contain a significant amount of dissolved minerals such as salts of calcium or magnesium. [17]

soil moisture - Water diffused in the upper part of the unsaturated zone of the soil, from which water is discharged by transpiration of plants, evaporation or interflow. [9]

specific storage (Ss) - The volume of water removed or added within the unit volume of an aquifer per unit change in head. [9]

specific yield (Sy) - The amount of water a unit volume of saturated permeable rock will yield when drained by gravity. [17]

Glossary

S-V
spring - vadose zone

spring - Ground water seeping out of the earth where the water table intersects the ground surface. [17]

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. [17]

static water level - (1) Elevation or level of the water table in a well when the pump is not operating. (2) The level or elevation to which water would rise in a tube connected to an artesian aquifer or basin in a conduit under pressure. [17]

storage (groundwater) - The storage of water in groundwater reservoirs. [9]

storage coefficient - (1) For surface water, the relation of storage capacity in a reservoir to the mean annual flow of a stream above the dam forming the reservoir. (2) For groundwater, a measure of the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. [9]

storativity (S) - The amount of water an aquifer will release from storage per unit surface area per unit change in head. [9]

stratigraphy - The science of rocks that is concerned with the original succession and age relations of rock strata and their form, distribution, lithologic composition, fossil content, geophysical and geochemical properties, all characteristics and attributes of rocks as strata, and their interpretation in terms of environment and mode of origin and geologic history. [7]

stream - A long narrow channel of water that flows as a function of gravity and elevation across the Earth's surface. Many streams empty into lakes, seas or oceans. [14]

- **effluent stream (gaining stream)** - A stream in which flow is maintained during the dry season by groundwater seepage into the channel. [10]
- **ephemeral stream** - A stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table. [3]
- **influent stream (losing stream)** - A stream or reach of a stream that contributes water to the zone of saturation and develops bank storage; its channel lies above the water table. [3]
- **intermittent stream** - A stream or reach of a stream that flows only at certain times of the year, as when it receives water from springs or from some surface source. [3]
- **perennial stream** - A stream or reach of stream that flows continuously throughout the year and whose upper surface generally stands lower than the water table in the region adjoining the stream. [3]

subwatershed- Topographic perimeter of the catchment area of a stream tributary. [17]

surface water - All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.). [17]

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. [17]

T

tertiary wastewater treatment - Selected biological, physical and chemical separation processes to remove organic and inorganic substances that resist conventional treatment practices. [9]

throughflow - The roughly horizontal flow of water through soil or loose layers of rocky material overlying bedrock. [14]

total dissolved solids (TDS) - All of the dissolved solids in water. TDS is measured on a sample of water that has passed through a very fine mesh filter to remove suspended solids. The water passing through the filter is evaporated and the residue represents the dissolved solids. [9]

total suspended particles (TSP): A method of monitoring particulate matter by total weight of a sample of water. [9]

total suspended solids (TSS) - Solids found in waste water or in a stream, which can be removed by filtration. [9]

transmissivity (T) - The ability of an aquifer to transmit water. [9]

transpiration - The movement of water from the soil or groundwater reservoir via the stomata in plant cells to the atmosphere. [9]

turbidity - The cloudy appearance of water caused by the presence of suspended and colloidal matter. [18]

U

unconfined - Conditions in which the upper surface of the zone of saturation forms a water table under atmospheric pressure. [9]

unconfined aquifer - An aquifer in which the uppermost groundwater surface is at atmospheric pressure. [9]

underflow - The downstream flow of water through the permeable deposits underlying a stream. [9]

underground sources of drinking water (USDW)– An aquifer that is currently being used as a source of drinking water or those potentially capable of supplying a public water system. [9]

unsaturated zone - The area between the land surface and water table in which the pore spaces are only partially filled with water. [9]

urban runoff - Storm water from city streets and gutters that usually contains a great deal of litter and organic and bacterial wastes, which eventually flows into sewer systems and receiving waters. [9]

V

vadose zone - The zone containing water under pressure less then that of the atmosphere, including soil water, intermediate vadose water and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table. [9]

Glossary

W-Z

water quality - zone of transport

W

water quality - Description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use. [7]

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. [17]

watershed - The land area from which water drains into a stream, river, or reservoir. [7]

water table - (1) The top of the zone of saturation in the ground; (2) Upper surface of the ground water; (3) The subsurface elevation at which water will usually be present; (4) Free water elevation; (5) Also called groundwater level or groundwater table. [10]

water table aquifer - An unconfined aquifer within which the water table is found. [9]

water use - The usage of surface and/or groundwater for a specific purpose, such as for domestic use, irrigation, or industrial processing. [20]

water well - An excavation where the intended use is for location, acquisition, development, or artificial recharge of groundwater. [9]

watershed area - A topographic area within a line drawn connecting the highest points uphill of a drinking water intake into which overland flow drains. [9]

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. [9]

well efficiency - The ratio of the drawdown in the formation adjacent to the well divided by the drawdown in the well. [10]

well field - One or more wells producing water from a subsurface source. Area containing one or more wells that produces a usable amount of water. [9]

wellhead - The top level of a well, from which water pumped from the well is allowed to flow freely. [9]

well interference - The effect of neighboring pumping wells on the discharge and drawdown at a particular pumping well. [9]

well monitoring - Measurement by on-site instruments or laboratory methods of well water quality and levels. [9]

well screen - A filtering device used to keep sediment from entering a water well. [9]

well yield - The volume of water discharged from a well in gallons per minute or cubic meters per day. [9]

wilting point - The soil moisture content at which the permanent wilting of plants occurs. [9]

withdrawal - Water diverted from the ground or surface-water source for use. [9]

X

xerophyte - A drought resistant plant; a plant which grows in arid areas. [9]

Y

yield – The quantity of water (expressed as a rate of flow - GPM, GPH, GPD, or total quantity per year) that can be collected for a given use from surface or groundwater sources. The yield may vary with the use proposed, with the plan of development, and also with economic considerations. [18]

Z

zone of capture - The zone around the well contributing water to the well; the area on the ground surface from which a well captures water. [9]

zone of contribution (ZOC) - The area surrounding a pumping well that encompasses all areas or features that supply groundwater recharge to the well. [9]

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. [9]

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. [9]

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California State University Fullerton
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Associate Professor of Hydrogeology
John Foster, PhD.
Professor of Engineering Geology

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Michael Blazevic, MSc
Michael Cruikshank, BS
Veva Ebbs, MSc
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California State University Fullerton
Department of Geological Sciences

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