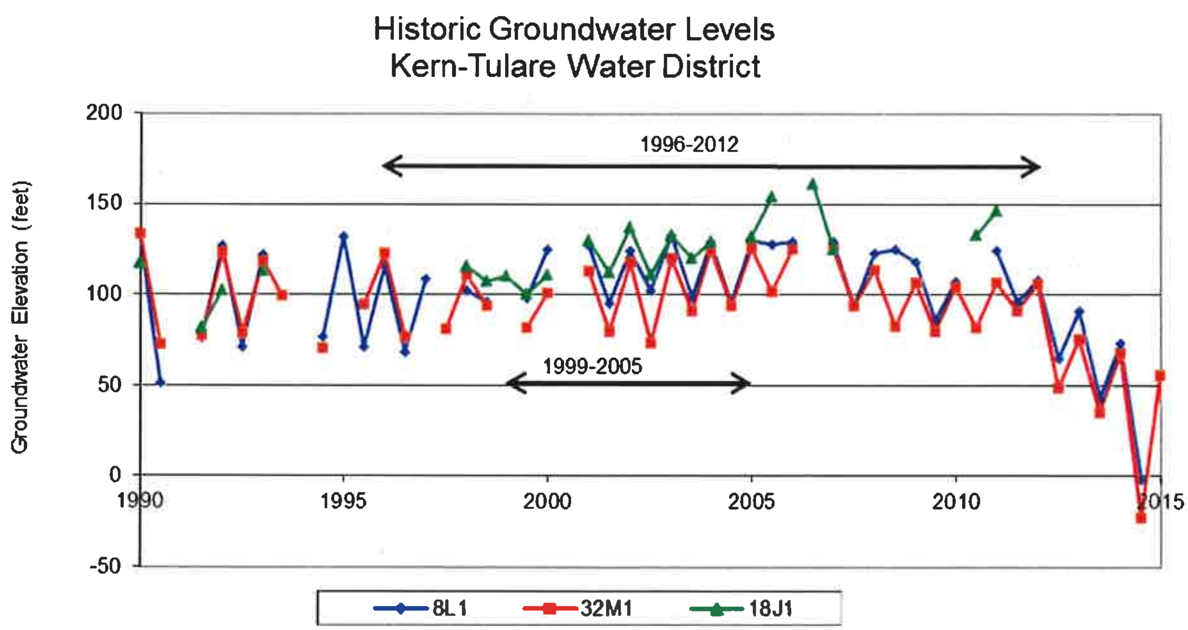
KERN-TULARE WATER DISTRICT

ANALYSIS OF GROUNDWATER RESOURCES



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INTRODUCTION

The California State legislature recently implemented the 2014 Sustainable Groundwater Management Act. The Act dictates that all local agencies within the Tulare Lake groundwater basin of the San Joaquin Valley join a local Groundwater Sustainability Agency (GSA) by 2017. Each GSA must adopt a Groundwater Sustainability Plan (GSP) by 2020 that achieves groundwater sustainability by 2040.

For purposes of the Act, groundwater basins in California are defined by the Department of Water Resources (DWR) Bull. 118 which places Kern-Tulare Water District (the District) in two sub-basins: Tule sub-basin no. 5-22.13 which includes the portion of Tulare Lake groundwater basin located in Tulare County; and Kern sub-basin no. 5-22.14 which includes the portion of Tulare Lake groundwater basin located in Kern County.

Based on examination of published reports, geophysical logs, driller's logs, groundwater level information, and water quality data, the Santa Margarita Formation and Olcese Sands aquifers which occur below the District and east of the District are hydrologically separate from the remainder of the Tulare Lake groundwater basin to the west. Water users within the District and east of the District rely primarily upon the Santa Margarita Formation and Olcese Sands for their groundwater supply. Therefore, the District is considering managing groundwater within the District and east of the District.

The purpose of this report is to describe the geohydrology related to the Kern-Tulare Water District to policy makers, governmental regulatory bodies, neighboring water districts, affected landowners, and the public as part of the basin boundary modification process. Another purpose of this report is to determine what additional information is required for the development of a thoughtful and responsible GSP.

A map indicating the location of the District, other districts, developed land outside of a district, DWR Bul. 118 boundaries, and the limits of the study area is presented in Figure 1.

Figure 1

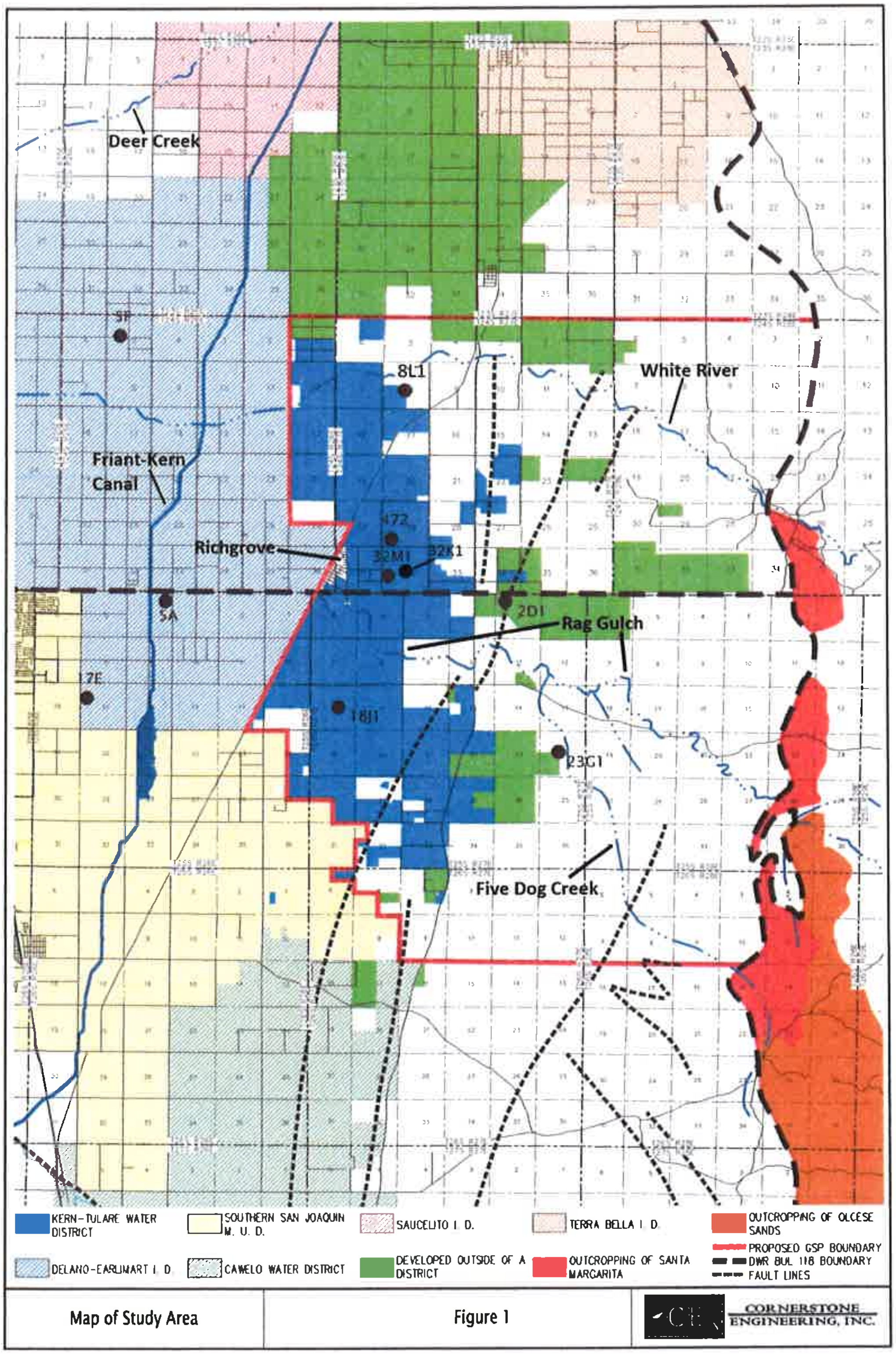


Figure 1: Map of Study Area showing the Kern Tulare Water District (bright blue) and surrounding water districts. Lighter dashed lines are mapped faults in and near the District. Important drainages are labeled and shown in blue. Labeled wells will be discussed in subsequent sections of this report.

GEOLOGIC SETTING

Throughout Miocene and Pliocene time (approximately 25 to 2 million years ago), the southern San Joaquin Valley was a marine environment. Most of the valley's major oil reservoirs and some sands that currently act as local aquifers were deposited during this time. Overlying these marine sedimentary deposits are continental deposits of Pleistocene and Holocene age (2 million years ago to present). These continental deposits form the regional aquifer (Tulare Aquifer) within the valley. All of these sedimentary deposits beneath the District have been tilted westward along with the underlying Sierra Nevada basement complex.

Stratigraphy

Table 1 illustrates the geologic units beneath the District, listed in order from youngest to oldest, and the correlation between the depositional environment, geophysical log, and general character of the strata. The geophysical log presented is from oil and gas well API no. 10700472 which is located one mile east of Richgrove, near the center of the District in the southwest corner of Section 29, T. 24 S., R. 27E as shown in Figure 1 (Well 472). Each of the geologic units identified in Table 1 are further described in the sections which follow.

Table 1

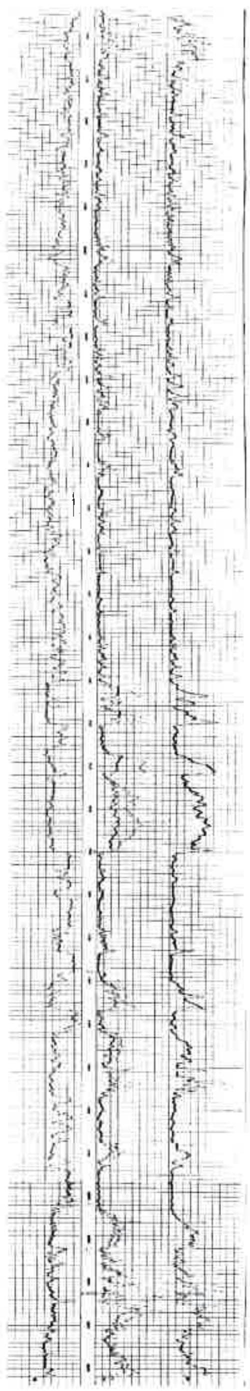
Dep. Environ.	Geophysical Log	Geologic Unit (depth)	General Character
Flood Plain		Tulare and Kern River continental deposits (0-650')	Interbedded gravel, sand, silt, and clay that become more confined with depth. Mostly de-watered beneath the District.
Marine		San Joaquin and Etchegoin Pliocene marine deposits (650-1600')	Siltstone, clayey, diatomaceous with thin lenticular sand beds. Minimal water production zone with poor quality water in thin sand layers. Clays within these sediments function as confining layers.
		Santa Margarita Formation (1,600-2,000')	Fine to coarse white sand, gravel, and sandstone. Major fresh water producing zone within and east of the District.
		Round Mountain Silt	Brown siltstone with diatomite member. Impervious water barrier.
		Olcese Sands (2,300-2,600')	Light gray sandstone with a few pebble and siltstone beds. Fresh water producing zone within and east of District.
		Freeman-Jewett Silt	Brown siltstone with interbedded light-colored ashy beds. Impervious water barrier.
		Pyramid Hills and Vedder Sands	Interbedded sandstone and siltstone. Fresh water producing zone east of the District.
Non-marine		Walker Formation	Shaly silt with some lenticular sand stringers. Limited water production near the foothills.
		Basement (3,200')	Granite or slate

Table 1: Type log showing hydrostratigraphic units with the study area. For the location of well 472 see Figure 1.

Continental Deposits from the Sierra Nevada

The land surface of the study area is underlain by unconsolidated continental deposits (Tulare/Kern River formations) derived from the Sierra Nevada. These deposits consist chiefly of alluvial, lacustrine, and flood-plain deposits which thicken from east to west (Lofgren and Klausing, 1969). The lacustrine Corcoran Clay is an important confining layer within these deposits. This clay layer occurs west of the District and is not present within the District.

This shallow aquifer system within the District can be separated into two units: (1) a shallow, highly permeable zone that occupies the uppermost 100 to 300 feet and forms a semi-confined aquifer; and (2) a deep zone that is hydraulically continuous with the shallow zone but in which confinement increases with depth. The deep zone ranges in thickness from 400 to 1,000 feet (Lofgren and Klausing, 1969).

During the early years of agricultural development, water for irrigation was pumped almost exclusively from the shallow, highly permeable zone. As water levels declined, deeper wells were drilled and many of the shallow wells were abandoned or restricted to domestic and stock use (Lofgren and Klausing, 1969).

Pliocene Marine Deposits

Underlying the unconsolidated continental deposits is a thick section of marine strata, chiefly siltstone, of Pliocene age (San Joaquin and Etchegoin formations). The partially cemented clayey siltstone contains thin, lenticular sand beds. This siltstone is differentiated from the overlying continental deposits by a marked change in lithology which is recognized in electric logs throughout the study area (Lofgren and Klausing, 1969).

The thin sandstone beds in this Pliocene marine siltstone sequence are tapped by a few wells, but the overall transmissibility of the siltstone unit is very low; thus it contributes little groundwater to wells and acts as a confining unit over most of the area. The thin sand beds contain saline water that is unusable for ordinary purposes (Lofgren and Klausing, 1969). Only a few wells within the District produce low yields of fresh water from these thin sands.

Santa Margarita Formation

Below the Pliocene marine deposits lay permeable sandstones of the Santa Margarita Formation. The average thickness of permeable sediments in the formation is 200 feet (Boyle 1974). The Santa Margarita Formation is confined above and below by impervious silt and shale layers. The main Santa Margarita sand body lies beneath the District and can be fully penetrated by wells 2200-2400 feet deep (Reynolds 1955).

The sands in this formation were originally deposited in a nearshore marine environment and contained salt water. The observation that they are now filled with fresh water is evidence that groundwater recharge has occurred. Rainfall and stream seepage have fed fresh water into these sands east of the District where they crop out at the surface at a sufficient elevation to exert a westward hydraulic gradient in the sands. These waters have moved westward down-structure displacing the original saline waters westward into the deeper parts of the basin (Reynolds 1955).

Geophysical logs from over 200 oil wells were reviewed and the depth of each geological unit, elevation of ground surface, and depth to base of fresh water was input into a three-dimensional computer mapping program. Based upon this mapping, contours showing the depth to the top of the Santa Margarita Formation and the approximate western limit of fresh water (approximately 2000 mg/l total dissolved solids) were determined and are presented in Figure 2. As shown in Figure 2, the boundaries of the area underlain by the confined aquifer of the Santa Margarita Formation are in the vicinity of the District and the limit of fresh water closely approximates the District's western boundary.

Figure 2

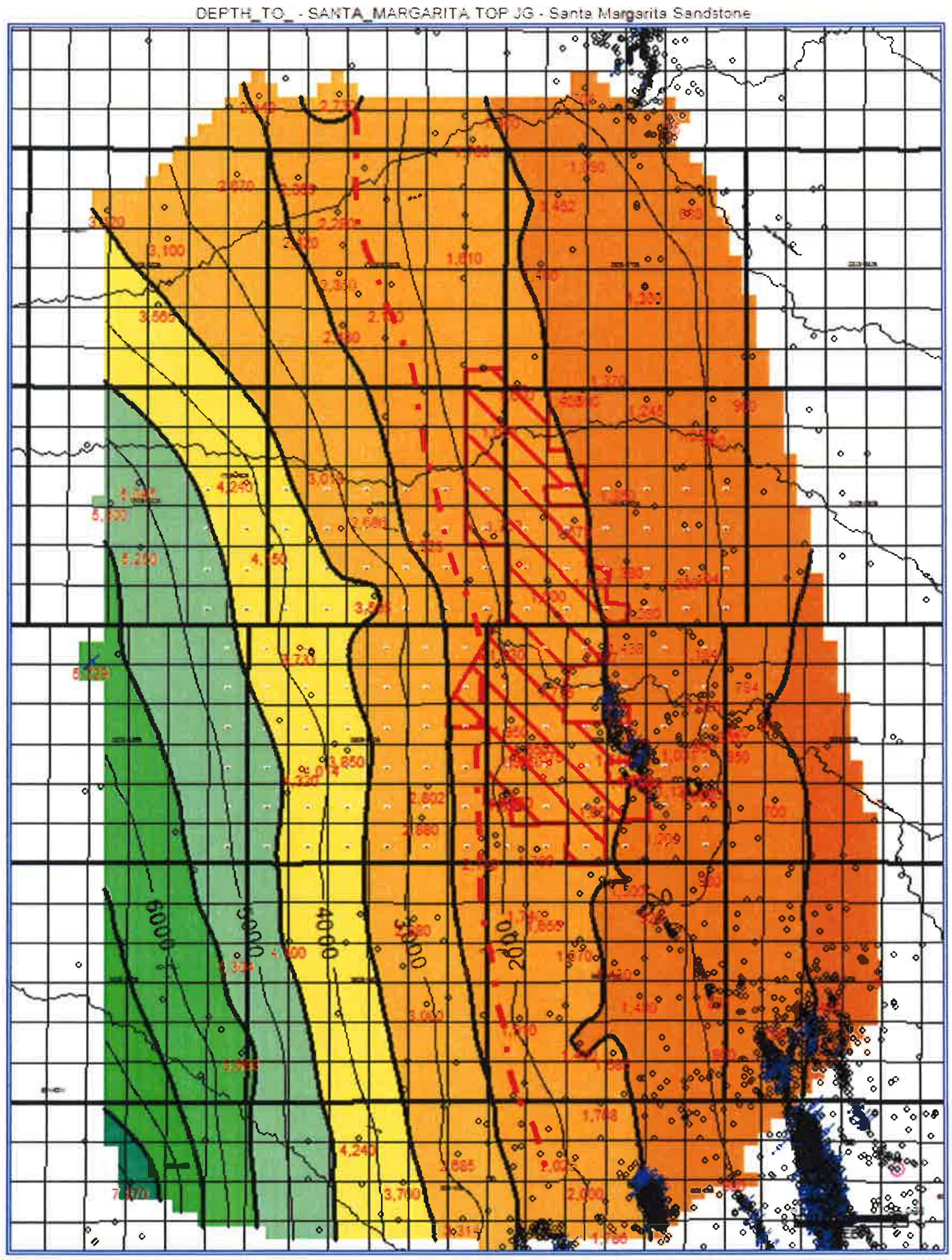


Figure 2: Depth to the top of Santa Margarita Formation. Dashed heavy red line shows approximate location of 2000 mg/l salinity as determined from geophysical logs in oil wells. West of this line, water salinity exceeds 2000 mg/l. All depths are in feet relative to ground surface.

Round Mountain Silt

The Round Mountain Silt is an impervious siltstone and shale section approximately 200 feet thick that was deposited in an offshore marine environment. It is an effective groundwater flow barrier between the overlying Santa Margarita Formation and the underlying Olcese sands. This siltstone extends continuously over the entire area, but thins eastward (Reynolds 1955).

Olcese Sands

The nearshore marine Olcese sands are present throughout the District and have good porosity and permeability (Reynolds 1955). The average thickness of permeable sediments in the formation is 180 feet (Boyle 1974). The Olcese sands are a secondary source of fresh water within the District. Like the Santa Margarita Formation, this aquifer is recharged by rainfall and streamflow where the sands crop out east of the District.

Subsurface data including geophysical and drillers logs were used to construct a contour map showing the depth to the top of the Olcese Sands and the approximate western limit of fresh water (Figure 3). The map indicates that the boundaries of the area underlain by the confined aquifer of the Olcese Sands are in the vicinity of the District and the limit of fresh water (approximately 2000 mg/l TDS) closely approximates the District's western boundary.

Freeman-Jewett Silt

Below the Olcese Sands is the offshore marine Freeman-Jewett silt which is about 350 feet thick in the west and thins to the east. It is primarily impervious silt although sands are locally present. It forms an effective groundwater flow barrier (Reynolds 1955).

Figure 3

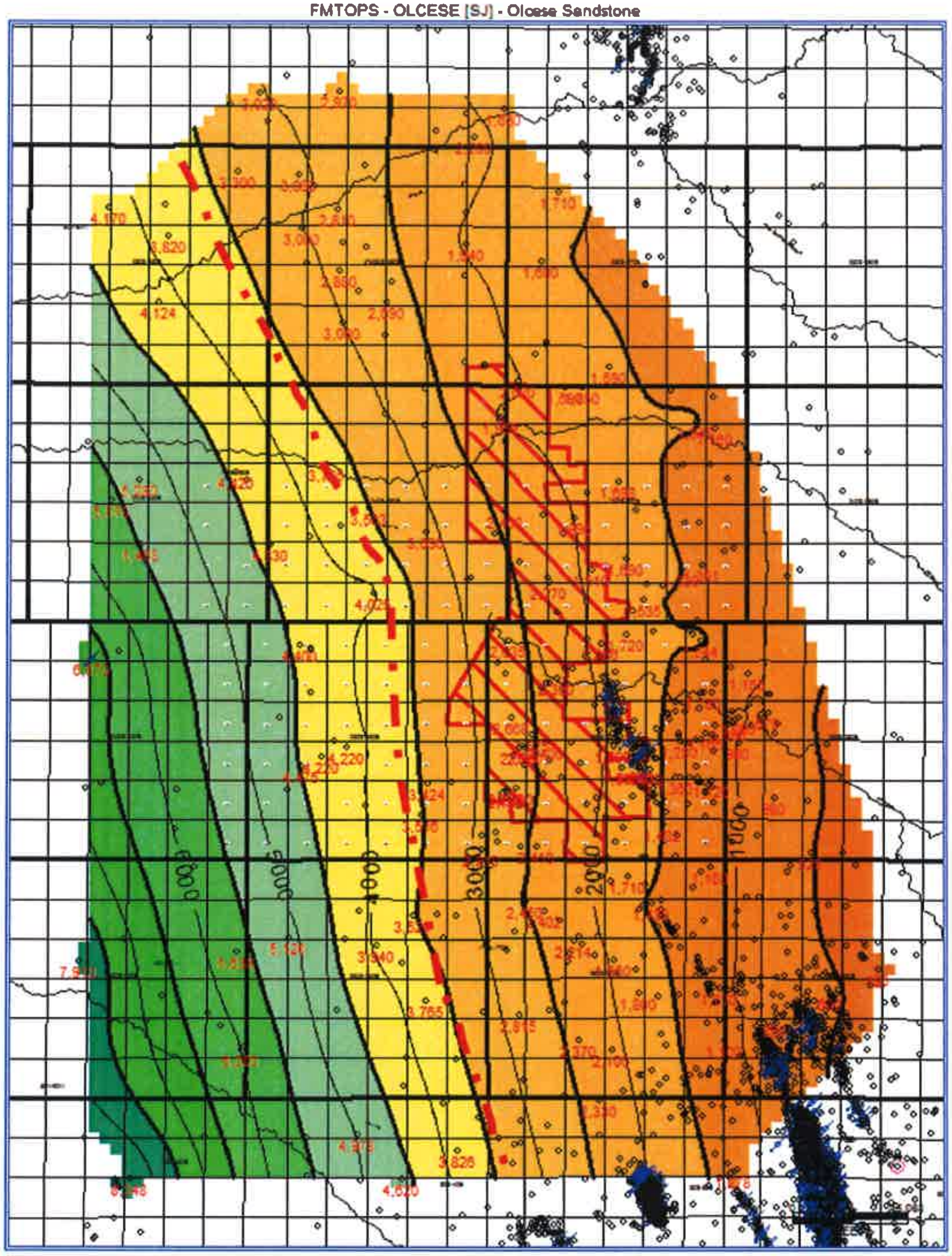


Figure 3: Depth to the top of Olcese Sands. Dashed heavy red line shows approximate location of 2000 mg/l salinity as determined from geophysical logs in oil wells. West of this line, water salinity exceeds 2000 mg/l. All depths in feet relative to ground surface.

Pyramid Hills and Vedder Sands

The marine Pyramid Hill and Vedder Sands may be treated as a single unit varying in thickness from 100 feet to over 400 feet (Reynolds 1955). Both are potential sources of groundwater, however, potable water from these sands are limited to a narrow belt east of the District (Lofgren and Klausing, 1969). These sands produce oil in the Jasmin field which is located near the eastern boundary of the District.

Walker Formation

The Walker Formation is the non-marine equivalent of the Pyramid Hill and Vedder sands and lies below them and to the east. East of the District, the Walker Formation exists as a continental deposit composed principally of shaly silt with some lenticular sand stringers. The thickness of the Walker varies erratically through the area from 30 feet to nearly 200 feet (Reynolds 1955). The non-marine sedimentary rocks generally are poorly permeable and yield only small quantities of water. Groundwater in and near the outcrop area generally is fresh, but further west and at moderate depths it becomes brackish to highly mineralized (Hilton et al., 1963).

Basement Complex

The basement complex is encountered directly below the Walker and gets increasingly deeper to the west, due to the westward tilting of the Sierra Nevada basement complex and overlying sedimentary rock layers (Reynolds 1955). The dominant rock types are igneous rocks ranging in composition from granite to gabbro and metamorphic rocks consisting largely of quartzite, schist, gneiss, and marble (Lofgren and Klausing, 1969). Although the rocks of the basement complex are relatively impermeable, they may yield sufficient water from fractures for domestic and stock use. They are present at great depth beneath the intensively cultivated area of the valley, and are of no importance as a source of water except around the margins of the valley (Hilton et al, 1963).

Localized Faulting

The location of faults in the study area is presented in Figure 1 (fault locations from Bakersfield 1:250,000 map http://www.quake.ca.gov/gmaps/GAM/bakersfield/bakersfield.html, accessed

1/30/2016). Tectonic activity in the area is expressed by moderate westward tilting and by minor displacement along two nearly vertical sub parallel north-northeast-trending faults that transect the District from north to south. The westernmost of the two northerly trending faults is believed to have had vertical displacement down to the west of 50 to 80 feet (Boyle 1974). Displacement on the easternmost fault cannot be determined from available data. It is not known if these faults influence the continuity of aquifers in the subsurface. Long-term water level measurements and well-performance data will be necessary before the influence of faulting on subsurface conditions can be determined with certainty (Boyle 1974).

Geologic Cross Section

Figure 4 is a representative cross section prepared from inspection of geophysical logs and driller's logs from oil and water wells. This cross section is located along County Line Road from Highway 99 in the west to the Sierra mountain front in the east.

Oil well shallow resistivity logs are shaded yellow where shallow resistivity is greater than 5 ohm-m to highlight the presence of sandstone (shown in yellow) and shale/clay. Driller's logs are shaded yellow for sand and brown for clay.

TDS values were estimated using the Humble variant of the Archie Equation of Winsauer et al. (1952) to determine that the salinity increases to over 2,000 mg/l just west of the boundary between the District and DEID (shown in dark blue). The Archie Equation provides an approximation of salinity and is imprecise. This method is useful for distinguishing differences in salinity at about the 10^3 range in these aquifers depending upon the salinity and the quality of the logs, but cannot distinguish between values with a precision of 10^2.

West of the District, groundwater wells tap the continental deposits of the Tulare/Kern River formations, and are drilled to a depth of 800 to 1,200 feet. These wells typically yield 1,000 to 1,500 gpm. The Santa Margarita Formation is about 2,400 feet deep at the District's western boundary and is progressively deeper to the west. As the depth increases, the water quality becomes increasingly poor and wells west of the District are typically not completed in the Santa Margarita Formation.

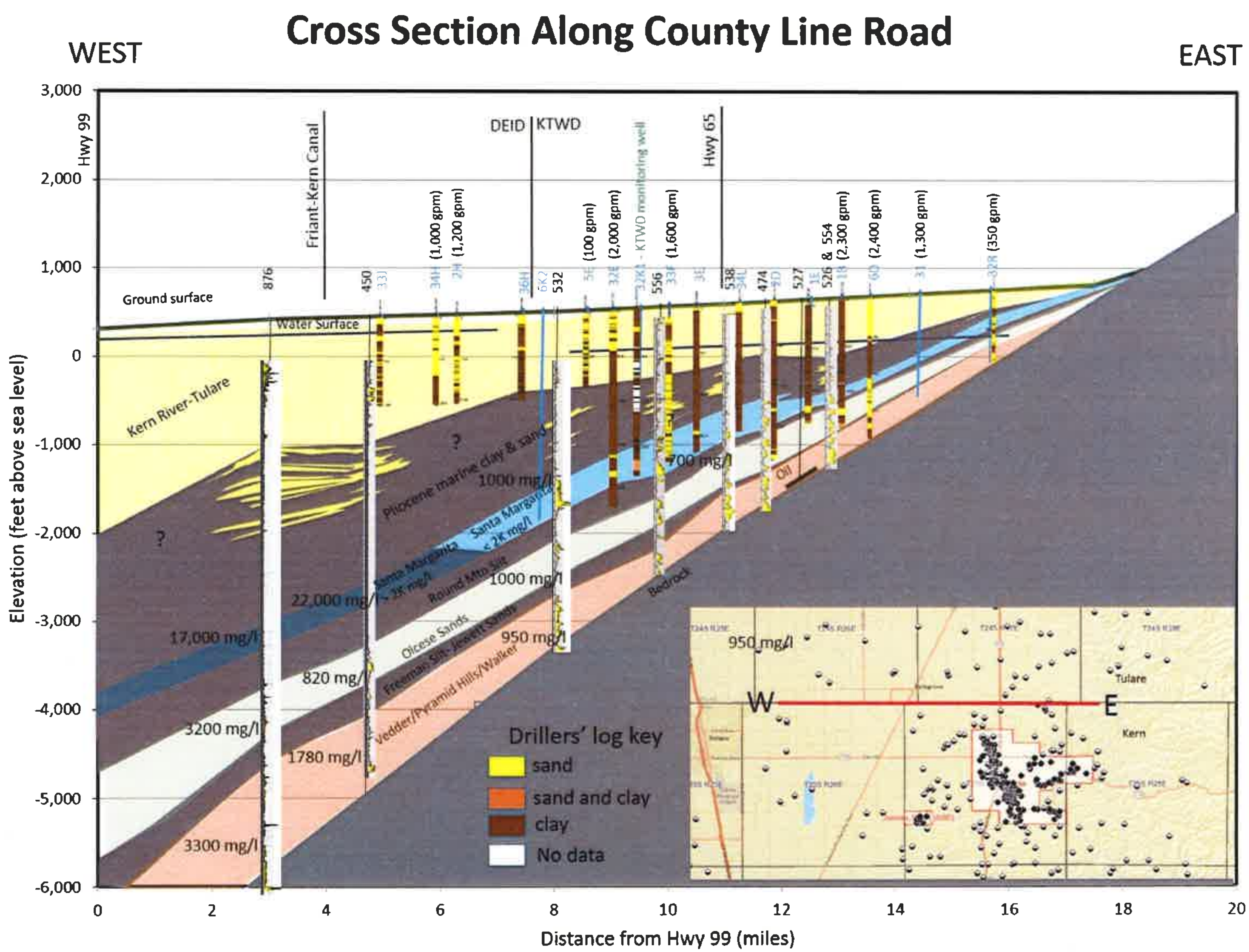


Figure 4: East-west structural cross section along the Kern-Tulare county line from the Sierra mountain front in the east to California Highway 99 in the west. Electric logs are from oil wells and are denoted at the surface by black numbers representing the last three digits of the API number. The shallow resistivity curve is shaded in yellow at values over 5 ohm-m to emphasize the presence of sands. Resistivity becomes increasingly suppressed to the west indicating the presence of higher salinity zones. Drillers logs from water wells are denoted at the surface by blue numbers/letters. Described sands are in yellow and clays in brown. Measured yields in gallons per minute (GPM) are noted above water wells at their surface location where available. Salinity values calculated from geophysical logs in oil wells are noted at the deph at which they were calculated.

Within the District, most wells drilled in the 1950's and 1960's are perforated from the top of first encountered water to the bottom of the well. These older wells are typically perforated in the continental deposits (Tulare/Kern River) and the Pliocene marine deposits (San Joaquin/Etchegoin formations), as well as the Santa Margarita Formation. Newer groundwater wells are drilled to a depth of 1,800 to 2,400 feet, completed in the Santa Margarita Formation and typically yield 2,000 to 2,500 gpm. More recent wells tend to be perforated only in the deeper zones because the shallower continental deposits are substantially dewatered under the District and the Pliocene marine deposits have low permeability. Currently, the only significant source of water is the Santa Margarita Formation and Olcese Sands.

Only a few wells less than 1,800 feet deep tap the continental deposits near the western border of the District in proximity to Rag Gulch (location in Figure 1). One of these wells, well 5E, completed to a depth of 806 feet, taps the continental and Pliocene marine deposits exclusively. This well has a very low yield (estimated at 100 gpm). Nearby well 32E, completed to a depth of 2,020 feet, taps the Santa Margarita Formation and has a yield of 2,000 gpm. Comparison of these two wells demonstrates the low yield of the dewatered continental and the Pliocene marine deposits compared to the underlying Santa Margarita Formation.

East of the District, wells are drilled to a depth of 1,500 to 1,800 feet and predominately tap the Santa Margarita Formation and the Olcese Sands. Wells located further east also tap the Pyramid Hills, Vedder, and Walker Formations.

Well 32R encountered sand and gravel nearly all the way to bedrock but has a low yield (350 gpm) because it has only 90 feet of saturated thickness. This well demonstrates that groundwater yields are reduced closer to the mountain front as the saturated thickness of the aquifer is reduced. The presence of sand and gravel from the ground surface to the water table demonstrates the recharge capability to the confined aquifers below.

GROUNDWATER QUALITY

All available water quality records within the study area were collected from Kern County Water Agency and from the District's files. Additionally, all available driller's logs were obtained from DWR. Water quality records available in the study area are summarized in Table 2 for all wells for which a driller's log was available and the perforated interval was known.

Table 2

Water Quality Data					
Well Number	25S26E1A2	25S26E1J3	25S26E1Q1	25S27E4C1	25S27E8H1
Geologic Unit Tapped	Continental Deposits	Continental Deposits	Continental Deposits	Santa Margarita	Santa Margarita
Perforated Interval (ft)	595-863	?-905	714-1025	?-1860	1604-2003
Date of Sample	5/27/58	5/27/58	8/6/79	6/20/63	4/18/56
Specific Conductance (EC)	632	779		455	661
pH	8	8.1		8.1	7.9
Sodium (mg/L)	79	89		90	80
Chloride (mg/L)	53	65		50	26
Boron (mg/L)			0.01	0.2	0.12
Bicarbonate (mg/L)					
Nitrate (mg/L)			46	0.2	0.1
TDS (mg/L)			620	305	
Well Number	25S27E11Q1	25S27E20C	25S27E27G1	25S27E28G	26S27E6B
Geologic Unit Tapped	Santa Margarita	Marine & Santa M.	Santa M. & Olcese	Santa Margarita	Continental Deposits
Perforated Interval (ft)	?-1060	500-2000	996-2000	730-1880	600-800
Date of Sample	8/15/67	8/5/15	8/19/67	8/5/15	8/5/15
Specific Conductance (EC)	423	760	610	570	830
pH	8.2	7.93	7.8	8.75	8.91
Sodium (mg/L)	41	88	76	100	160
Chloride (mg/L)	22	63	54	63	130
Boron (mg/L)	0.1	0.19	0.1	0.32	0.75
Bicarbonate (mg/L)		99		110	170
Nitrate (mg/L)	0.8	6.7	0.4	<2.00	<2.00
TDS (mg/L)	241	460	384	360	500

Continental Deposits from the Sierra Nevada

Based upon water quality records available from two wells which tap the continental deposits near the western boundary of the District, fresh water produced from sediments in the continental deposits is uniformly calcium-sodium bicarbonate type with dissolved solids concentrations from 500 to 620 ppm. Water with a TDS of greater than 500 ppm is of marginal quality for irrigation.

Pliocene Marine Deposits

Limited water quality data is available for the Pliocene marine deposits because they are mostly clay and there is little production from this zone. Wells that are completed in this zone are also completed in the Santa Margarita Formation. Low resistivity values observed in oilfield geophysical logs suggest that the thin sand beds contain saline water.

Based upon water quality records available from one well located within the District which taps both the Santa Margarita Formation and the Pliocene marine deposits, the TDS is 460 ppm. This TDS value is probably more representative of the Santa Margarita Formation than the Pliocene marine deposits because the sands of the Santa Margarita Formation are thicker and have a higher transmissivity.

Santa Margarita Formation

Fresh water produced from sediments of the Santa Margarita Formation is uniformly sodium chloride in character with dissolved solids concentrations greater than 300 ppm (Boyle 1974).

Based upon water quality records available from three wells located within the District which tap the Santa Margarita Formation, the TDS ranges from 241 to 360 ppm, which indicate very good water quality. Geophysical log data indicate that the salinity increases to the west as the depth to the formation increases.

As shown previously in Figure 4, a saline-fresh water contact exists along the western border of the District.

Extreme caution should be exercised in the location and drilling of wells near the salt water interface to avoid eastward migration of the salt water interface and producing water with a harmful salt content (Reynolds 1955).

Olcese Sands

Less data is available regarding the groundwater quality of the Olcese Sands. Only one well located within the District is completed in both the Santa Margarita Formation and the Olcese Sands. In this well the TDS is 384 ppm, which indicates water quality is very good. Based upon examination of resistivity signatures in electric logs from oil exploration, the salinity distribution of water within the Olcese Sands is probably similar to that of the Santa Margarita Formation (Boyle 1974) and probably becomes increasingly saline west of the District. As shown previously in Figure 4, just west of the town of Richgrove, water within the Olcese aquifer does become increasingly saline. However, electric logs suggest that the fresh-saline water boundary may lie slightly west of that estimated for the Santa Margarita.

MOVEMENT AND OCCURENCE OF GROUNDWATER

Source of Recharge

The confined aquifers of the Santa Margarita Formation and Olcese Sands rise eastward and grade into sandy formations which outcrop at elevations of approximately 700-1,000 feet. These outcrops are areas where the aquifers are replenished by surface waters, displacing the original marine waters farther to the west in the deeper parts of the basin (Reynolds 1955). The map in Figure 1 shows the outcrop area of the Santa Margarita Formation and Olcese Sands (outcrop locations from Bakersfield 1:250,000 map http://www.quake.ca.gov/gmaps/GAM/bakersfield/bakersfield.html, accessed 1/30/2016).

The well log for well no. 32R in Figure 4 (located about 2 miles west of the basement outcrops along the mountain front) shows sand and gravel with very little clay from the ground surface to the groundwater surface. Surface water percolating into these sands and gravels is the source of recharge to the underlying sands of the Santa Margarita Formation and Olcese Sands.

Table 3 presents a summary of annual precipitation at Woody and peak annual flow in Rag Gulch near Richgrove. As presented in Table 3, 28 out of 39 (72%) of the years from 1976 through 2004 show no flow through Rag Gulch. Rainfall from the watershed does not create runoff that reaches Richgrove except in very wet years or under extremely intense rainfall events. This is evidence that recharge is occurring at the mountain front into the Santa Margarita and Olcese Formations. Therefore, the median annual net recharge (rainfall minus evaporation and transpiration in the watershed) is a reasonable estimate of Rag Gulch watershed's contribution to groundwater recharge from infiltration at Rag Gulch (Cornerstone 2015).

Table 3

Water Year	Annual Peak Flow Rag Gulch Near Richgrove (cfs)	Annual Precipitation at Woody (in)
1976	0	9.4
1977	0	9.4
1978	2,800	22.2
1979	0	13.2
1980	0	14.0
1981	0	12.4
1982	0	13.4
1983	180	15.1
1984	130	7.9
1985	0	7.7
1986	0	11.6
1987	80	11.3
1988	0	11.6
1989	0	10.2
1990	0	8.4
1991	180	8.9
1992	70	13.0
1993	0	16.3
1994	0	13.0
1995	53	20.3
1996	0	13.0
1997	0	14.0
1998	1450	25.0
1999	46	13.0
2000	40	12.0
2001	0	12.0
2002	0	10.0
2003	0	12.0
2004	0	10.0
2005	0	18.0
2006	0	12.0
2007	0	9.0
2008	0	9.0
2009	0	13.0
2010	0	13.0
2011	92	21.5
2012	0	11.4
2013	0	8.1
2014	0	6.6

Historical Groundwater Use

The first water well to produce agricultural water from the Santa Margarita Formation was the H. M. Holloway, Inc. Water Well #1 in Section 8, T.25S., R.27E. which was converted to a water well from an exploratory oil well drilled by the Western Gulf Oil Company in the early 1950's (Reynolds 1955).

During the 1950's, wells drilled to depths of 1,800 to 2,400 feet in the vicinity of Richgrove first tapped artesian water-bearing sands of the Santa Margarita Formation; they proved to be a valuable source of groundwater supply. By 1957, about 20 large irrigation wells were taking water from the Santa Margarita. Most of these wells are perforated in overlying strata as well as in the Santa Margarita (Lofgren and Klausing, 1969).

As water levels declined, deeper wells were drilled within the District which tapped the Santa Margarita Formation and many of the shallow wells which tapped only the continental deposits were abandoned or restricted to domestic and stock use (Lofgren and Klausing, 1969). By 1959, pumping from the continental deposits had created a pumping trough south of Richgrove along the Richgrove-Famoso Highway, which is approximately the western border of the District (Lofgren and Klausing, 1969).

Historical Groundwater Levels

Figure 5 is a hydrograph showing spring groundwater levels from 1960 to 2015 for wells 32K1 and 32M1 which are perforated in the Pliocene marine deposits and the Santa Margarita Formation (located one mile east of Richgrove, near the center of the District in Section 32 T. 24 S., R. 27E, as can be seen in Figure 1).

Figure 5

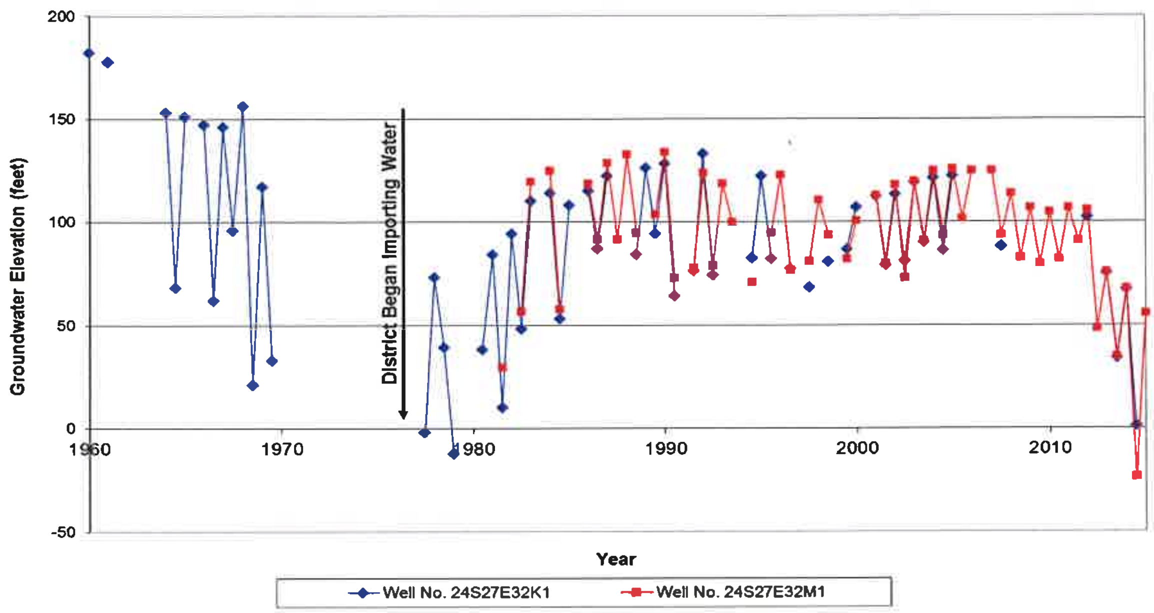


Figure 5: Hydrograph showing historical groundwater elevations two wells within the District (Kern-Tulare Water District, Groundwater Monitoring Plan, 2015).

As shown in Figure 5, spring groundwater levels were at an elevation approximately 180 feet above mean sea level (amsl) in 1960 and declined to an elevation of 60 feet amsl by 1977. In 1977, the District began to import surface water and groundwater pumping was reduced. By 1983, spring groundwater levels recovered to an elevation of approximately 125 feet amsl and remained at that level until 2008. Beginning in 2008, groundwater levels began to fall slightly (likely due to the increasing cost of District water and the resulting increase in groundwater pumping) until 2012. From 2012 to 2015 groundwater levels fell dramatically (likely due to lack of recharge resulting from a sustained drought, reduced District deliveries, and increased development east of the District).

<u>1921 Groundwater Levels</u>

Before intensive development, groundwater levels in the continental deposits rose to about the same level in the semi-confined upper continental deposits and semi-confined aquifer systems and contour maps could be drawn to represent the composite water surface of the continental deposits. Intensive pumping from these deposits since 1930 has developed differences in head between the various strata of the system (Lofgren and Klausing, 1969).

Groundwater elevations in 1921 from Lofgren and Klausing (1969) are shown in Figure 6. The water table elevation drops westward from the recharge area in the east along the flanks of the Sierra.

Figure 6

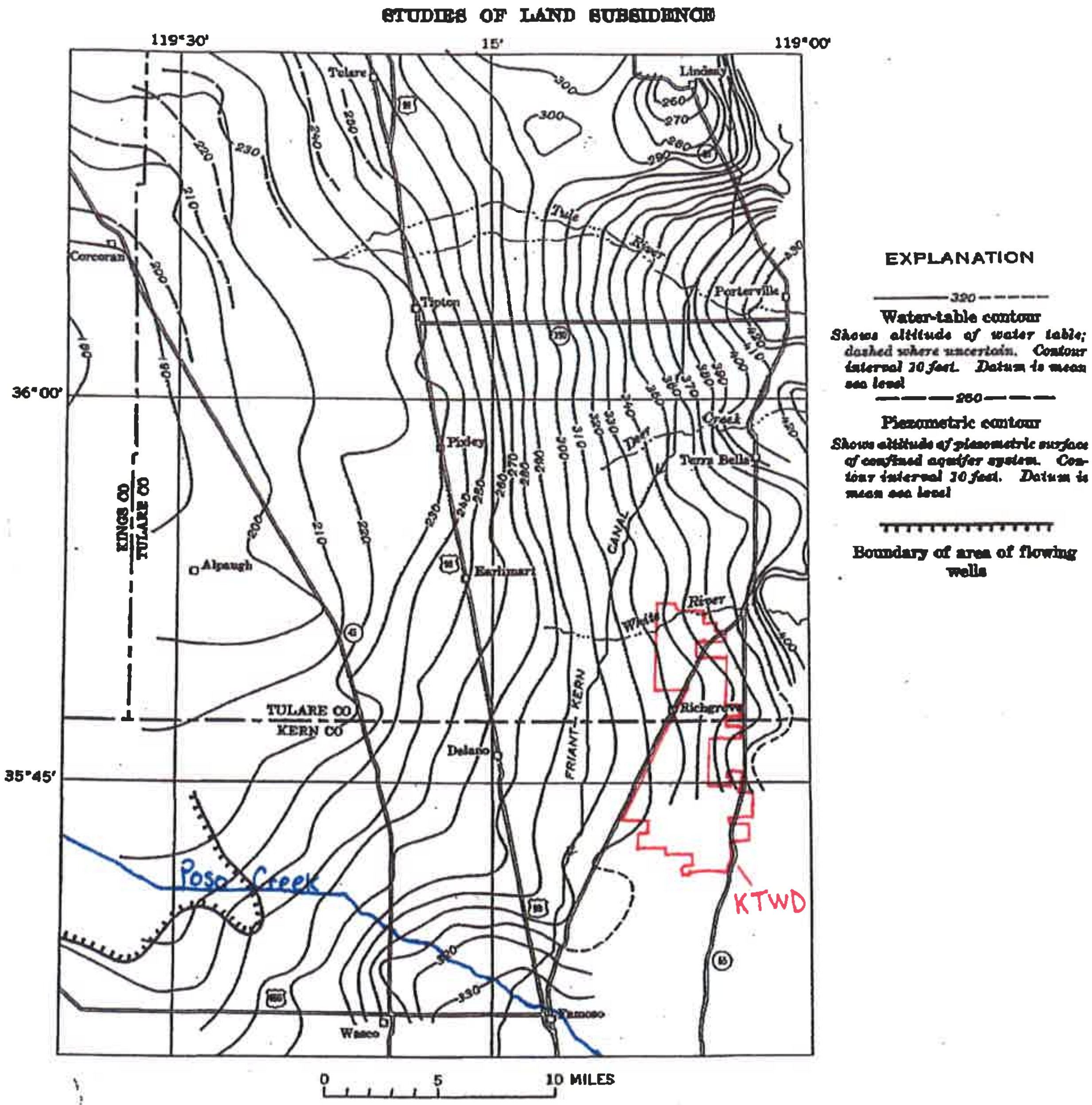


Figure 6: Generalized water level contours for the semi-confined aquifer in the upper continental deposits as of December 1920 (Kern County) and November 1921 (Tulare County). Data from California Department of Engineering (1921, map 2) and Californian Department of Public Works (1922, map 2) (Lofgren and Klausing, 1969). The map has been modified to include an outline of the District (red) and Poso Creek (blue).

Upon review of Figure 6, the following observations can be made.

1. Groundwater is recharged from Tule River, Deer Creek, and White River and moves westerly through the study area.
2. Groundwater recharge from Poso Creek, just north of Wasco and Famoso, moves northwesterly into the study area.

1959 Groundwater Levels

Contours of water surface elevation in February 1959 from Lofgren and Klausing (1969) are presented in Figures 7 through 9. Three contour maps were necessary to describe water levels in the various aquifers. Figure 7 depicts the water level in the semi-confined aquifer in the upper portion (less than 400 feet deep) of the continental deposits (Boyle 1974); Figure 8 depicts the piezometric surface of the semi-confined aquifer in the lower portion (over 500 feet deep) of the continental deposits; and Figure 9 depicts the piezometric surface of the confined aquifer of the Santa Margarita Formation.

Figure 7

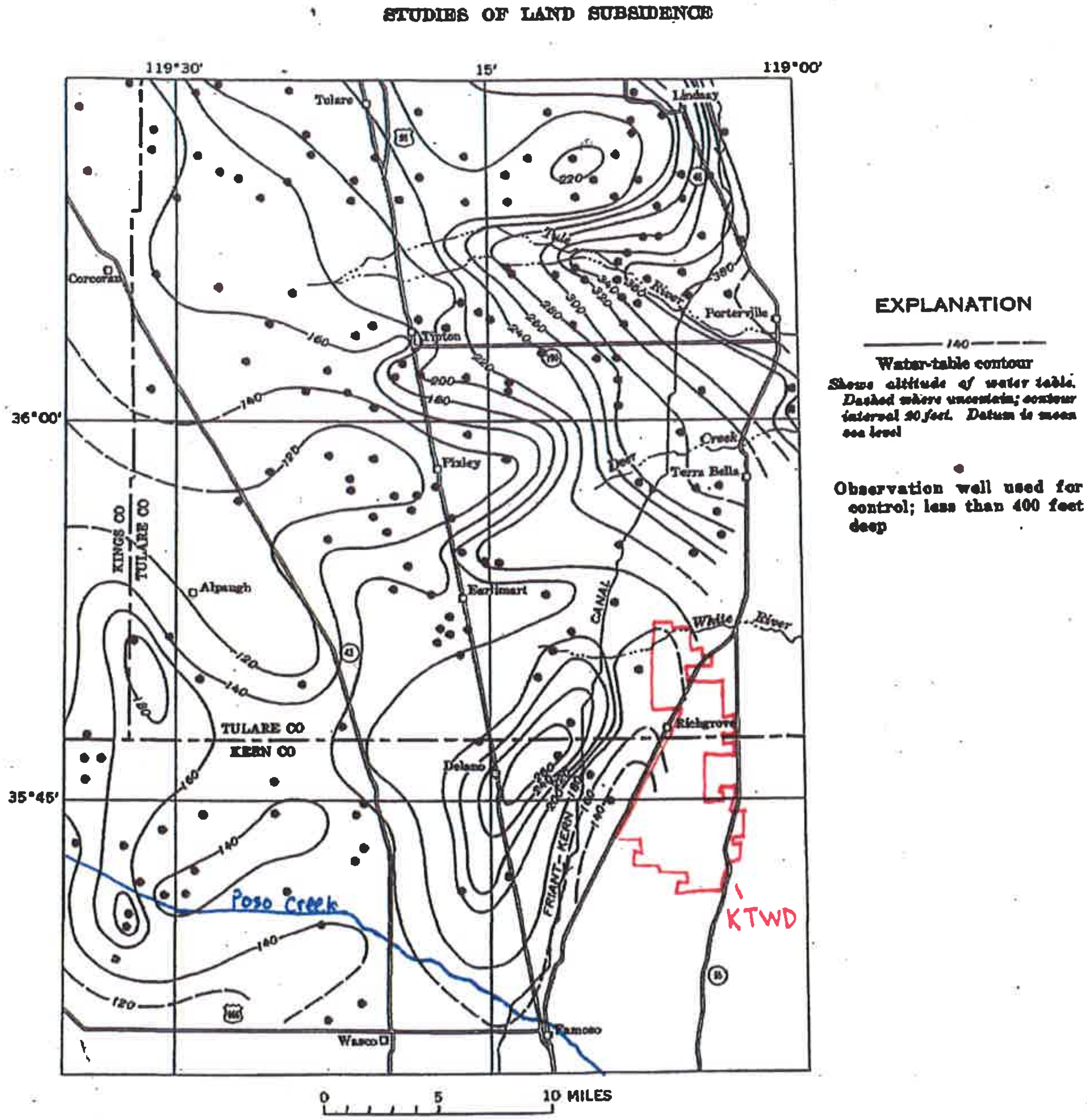


Figure 7: Altitude of the water table in the semi-confined aquifer of the upper continental deposits, February 1959. The map has been modified to include an outline of the District (red) and Poso Creek (blue).

Figure 8

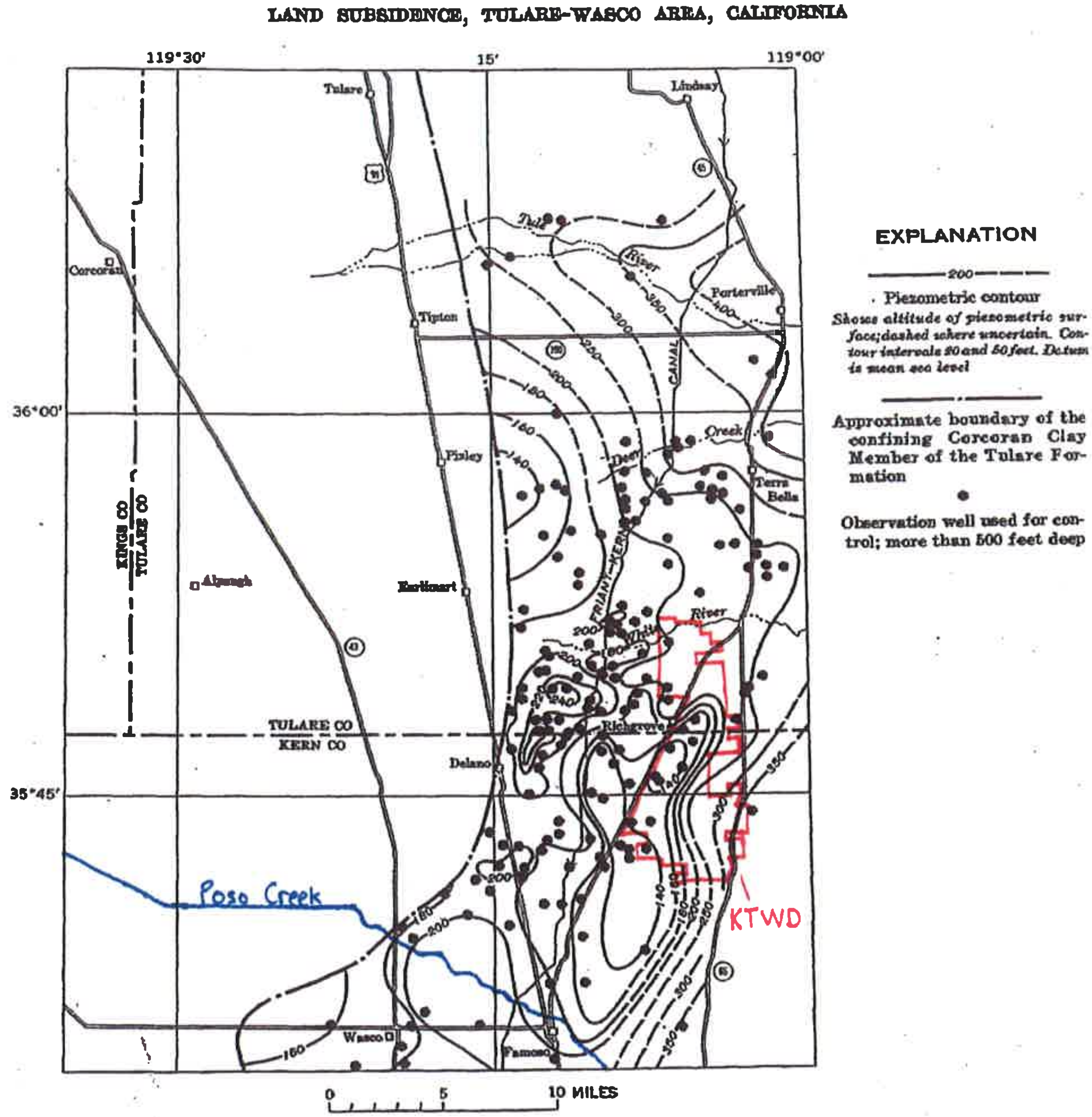


Figure 8: Piezometric surface of the lower semi-confined aquifer system, February 1959. The map has been modified to include an outline of the District (red) and Poso Creek (blue).

Figure 9

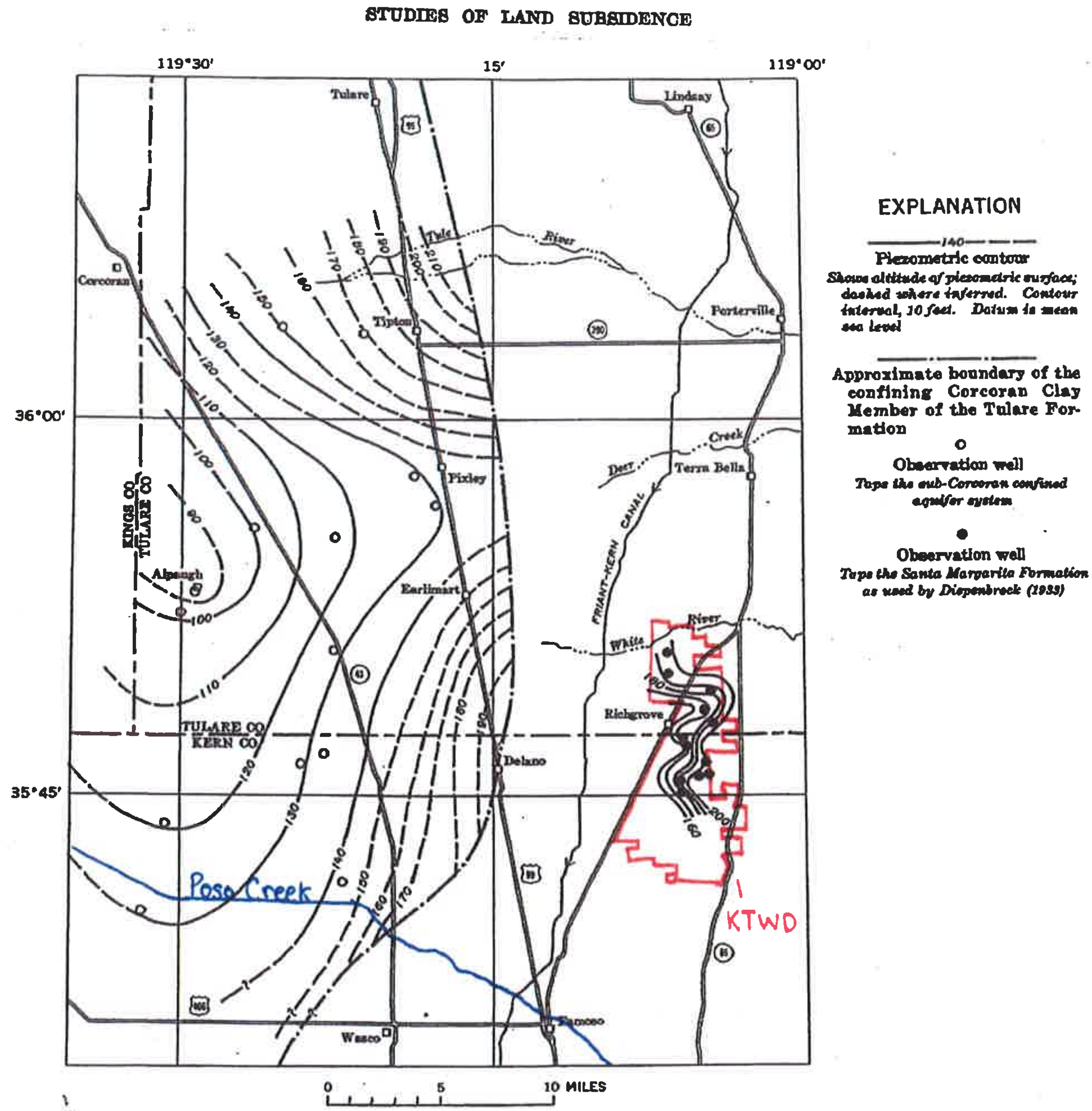


Figure 9: Piezometric surfaces of the confined aquifer systems, February 1959. Dashed contours near boundary of the Corcoran Clay Member are extensions of the piezometric surface in the semi-confined aquifer system. Note that the western contours represent the elevation of the piezometric surface in the continental deposits below the Corcoran Clay (where the Corcoran Clay is present). The eastern contours represent the piezometric surface within the confined aquifer of the Santa Margarita Formation. The map has been modified to include an outline of the District (red) and Poso Creek (blue).

Semi-Confined Aquifer—upper continental deposits (Figure 7)

Contours of elevation of the water surface in February 1959 from wells having a depth of less than 400 feet are presented in Figure 7. This contour map is representative of the water surface of the aquifer system in the upper 400 feet of the continental deposits within the District (Lofgren and Klausing, 1969).

Upon review of Figure 7, several observations can be made:

1. The source of groundwater recharge is primarily from Deer Creek and Tule River.
2. A mound in the Delano area is created from importation of water from the Friant-Kern Canal
3. A depression west of Pixley is caused by groundwater pumping in excess of recharge.
4. A depression south of Richgrove along the Richgrove-Famoso Highway is created from pumping in excess of recharge.

Semi-confined Aquifer—lower continental deposits (Figure 8)

Contours of elevation of the piezometric surface in February 1959 from wells having a depth of greater than 500 feet, but not tapping the confined aquifers, are presented in Figure 8. Only the area east of the Corcoran Clay is shown in these contours. The water table contours of 1959 are highly irregular, in contrast to the relatively smooth and gently westward-sloping water table in 1921 in Figure 6. In most areas the groundwater level rose as a result of increased deliveries from the Friant-Kern Canal. South of Richgrove, pumping from an area of minimal recharge created a depression in the piezometric surface along the Richgrove-Famoso highway (Lofgren and Klausing, 1969).

Confined Aquifer (Figure 9)

Contours of the piezometric surfaces of the confined aquifer systems in February 1959 (Lofgren and Klausing, 1969) are presented in Figure 9. Separate piezometric surfaces are shown for the confined aquifer beneath the Corcoran Clay which is only present to the west of the District and for the confined aquifer of the Santa Margarita Formation (which was only perforated in wells east of Richgrove).

DEID 2005 Contours of Groundwater Levels

Groundwater levels in 2005 from DEID's groundwater management plan are presented in Figure 10 (Provost & Pritchard 2007). Groundwater levels shown in Figure 10 are not distinguished by aquifer. Therefore, groundwater measurements are contoured as if they were all from the same aquifer, which is misleading along the eastern boundary of DEID where the contours show an abnormally steep gradient as a result of contouring water levels from wells completed in separate aquifers. Contour lines of the semi-confined aquifer beneath DEID should not extend to the eastern border of DEID and do not drop off dramatically as pictured. Independent contours should be drawn for the semi-confined aquifer and the confined aquifer as noted in Lofgren and Klausing (1969) and shown in their maps in figures 8 and 9.

Figure 10

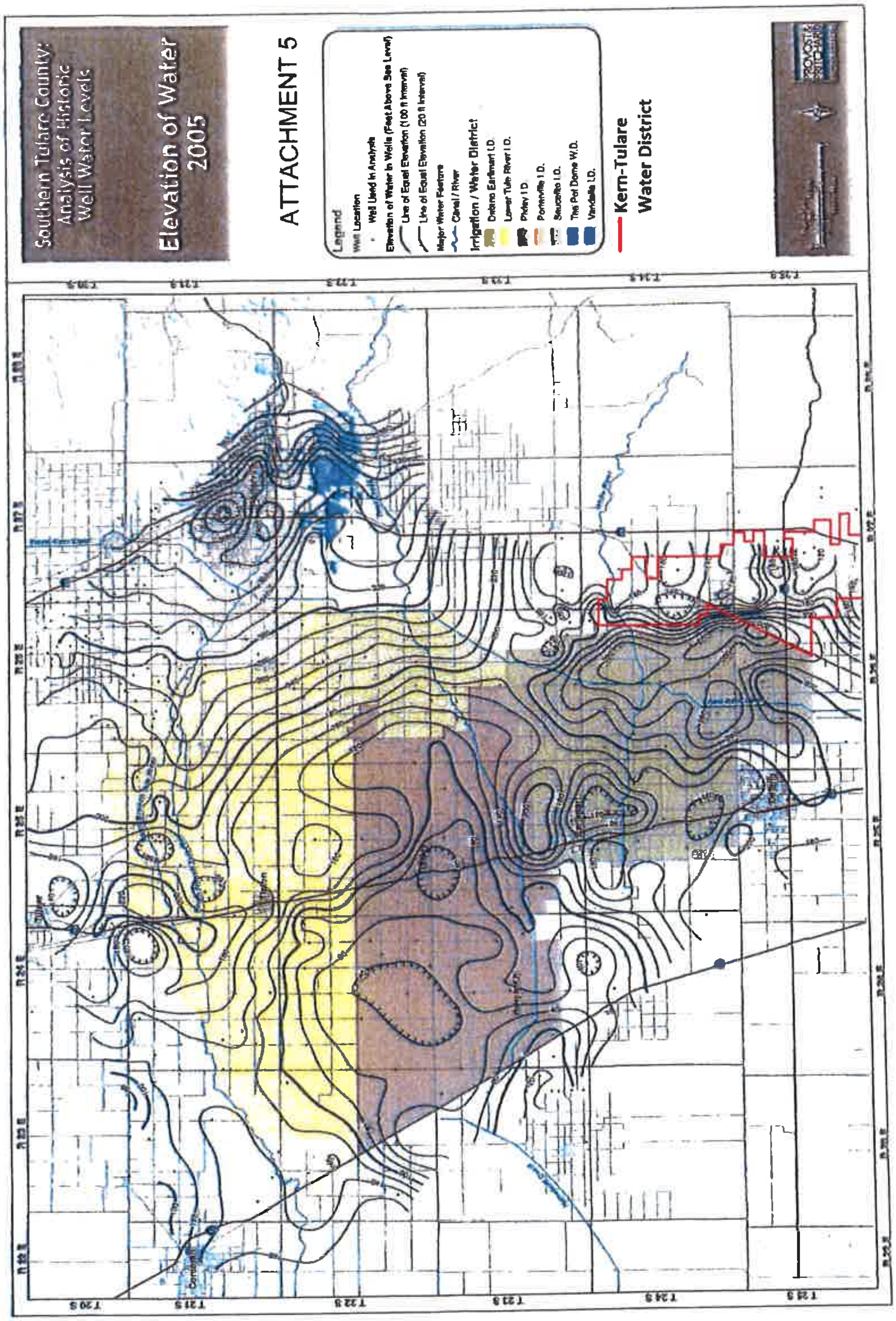


Figure 10: Groundwater level contours in the Southern Tulare County. The measurements are contoured as if one aquifer is present. Independent contours should be drawn for the semi-confined aquifer and confined aquifers. The map has been modified to include the Kern-Tulare Water District's boundaries (red).

2010 Contours of Groundwater Levels

Elevations (above mean sea level) of groundwater levels for all wells in DWR's Well Data Library within the District for spring 2010 are presented in Figure 11.

As shown in Figure 11, groundwater elevations within the study area are highly variable and difficult to contour. In some cases, water levels in adjacent wells vary by over 100 feet. A contributing factor to the difficulty in evaluating groundwater levels within the study area is that wells are perforated in multiple aquifers and data are not available to determine in which aquifer each well is perforated, only the depths at which they were perforated. In Figure 4, wells in the study area that are perforated deep enough to tap the Santa Margarita Formation lie just east of the District's western border. In Figure 11 those wells east of the District's western border show a lower groundwater elevation than those that are completed in the semi-confined aquifer above. Therefore, it can reasonably be assumed that the relatively higher groundwater levels are from wells that tap the semi-confined aquifer and the relatively lower groundwater levels are from wells which tap the Santa Margarita Formation.

A cross section looking north along County Line Road is presented in Figure 12. Water levels from wells within 1 mile of county line road shown in Figure 11 are plotted in this cross section. From observation of the water levels, the aquifer which is tapped becomes obvious. This cross section shows water levels for 2010 and illustrates a water level elevation discontinuity of over 100 feet between the semi-confined aquifer west of the District and the confined aquifer of the Santa Margarita Formation within the District.

Figure 11

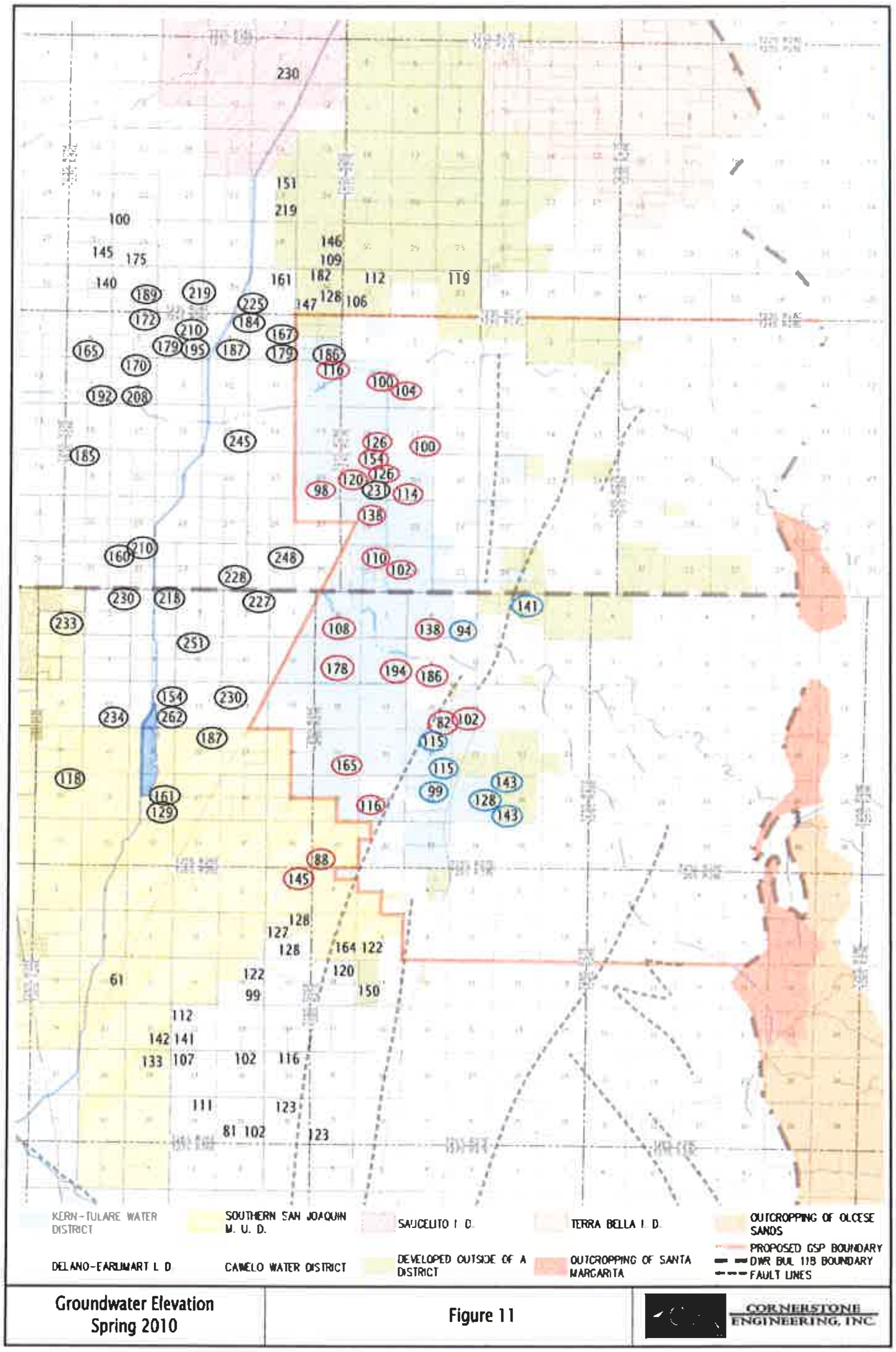


Figure 11: Elevations (above mean sea level) of groundwater levels for all wells in DWR's Well Data Library within and around the District for spring 2010. Elevations within the District are lower than those to west leading to the assumption that wells within the District are completed to the Santa Margarita Formation, and those to the west are not. Wells exclusively completed in the continental deposits are circled in black. Wells completed in the Santa Margarita Formation are circled in red. Wells completed in the Olcese Formation are circled in blue. All of the wells identified as completed in the Santa Margarita and Olcese Formations are also completed in the continental deposits.

Figure 12

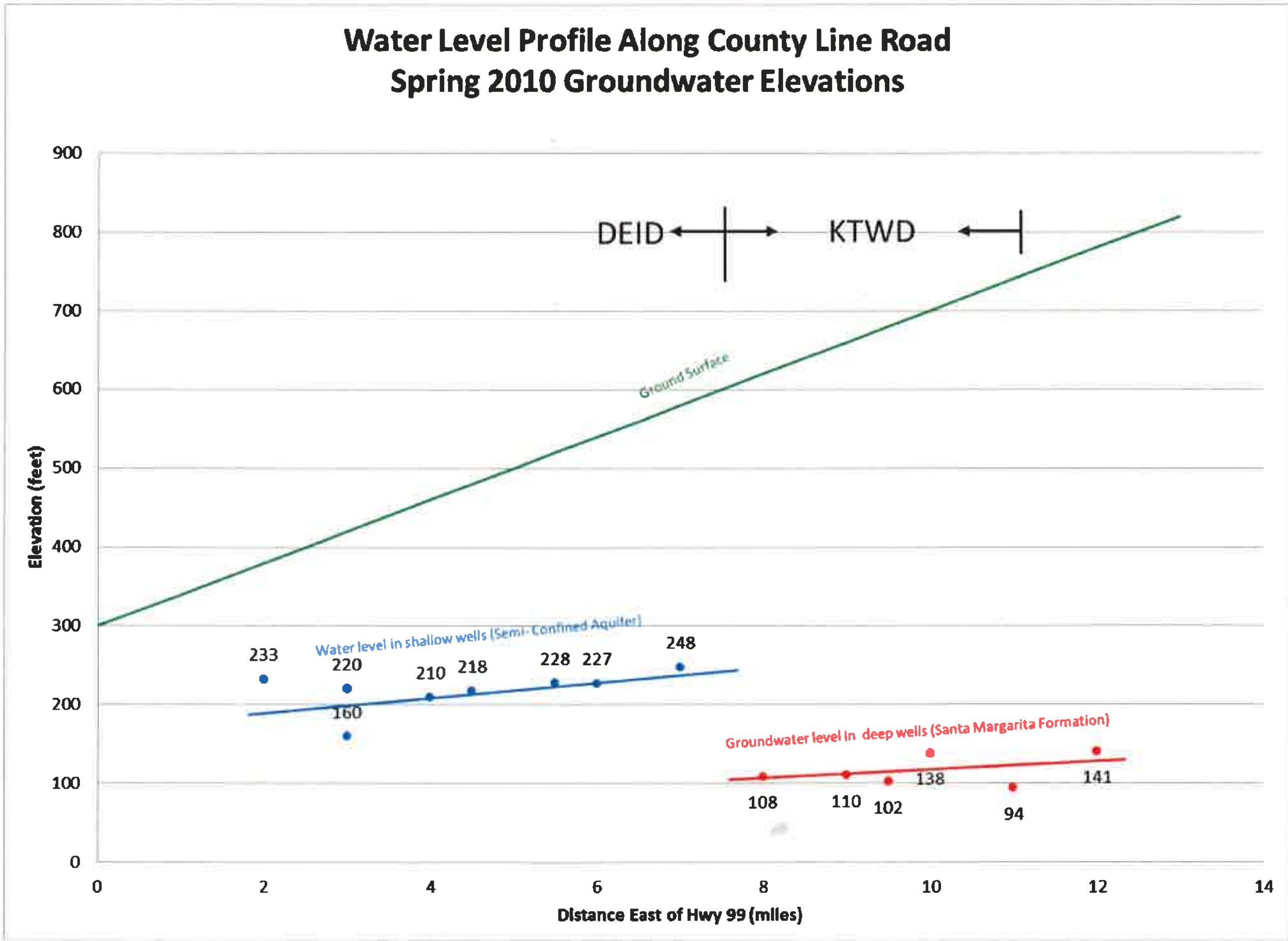


Figure 12: Water level profile along county line road. Wells west of the District are within the semi-confined aquifer in the continental deposits. Wells within the District are completed to the Santa Margarita Formation. This can be seen by the difference in water surface elevations (above mean sea level) between each aquifer.

EVALUATION OF SUSTAINABILITY

Due to the low yield of the mostly dewatered continental sediments beneath the District and the poor permeability of the Pliocene marine sediments, nearly all of the groundwater within the District is from the Santa Margarita Formation and Olcese Sands, which are separate from the main groundwater aquifer of the continental deposits in the Tulare Lake Basin (Lofgren and Klausing, 1969; Boyle 1974).

The Santa Margarita and Olcese groundwater basins are confined beneath the District and do not directly receive recharge from precipitation or return flows from above. The only significant source of recharge is from influent streams draining the Sierra mountain front east of the District and the only significant source of discharge is from groundwater pumping. Therefore, the sustainable yield of the groundwater basin can be evaluated by comparing groundwater pumping with changes in groundwater elevation over a period of average precipitation.

Selection of Plan Area

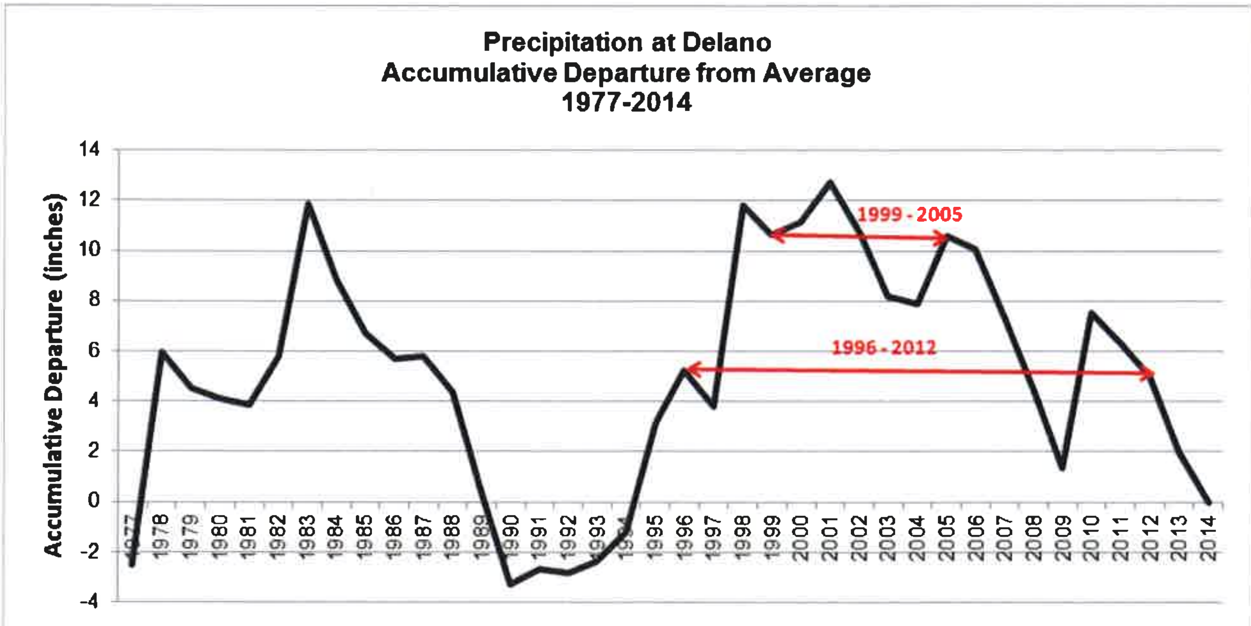
The proposed GSP boundary is shown in Figure 1. This boundary was drawn to include lands east of the District where landowners create a contiguous boundary with no land left out.

Selection of Evaluation Period

Precipitation records are available at Delano (NOAA Cooperative Station no. 042346) from 1906 to date. The average annual precipitation for the period of record is 7.25 inches. Figure 13 is a graph of the accumulative departure from average for precipitation at Delano from 1977 to 2015. As shown in Figure 13, the periods from 1996 to 2012 and from 1999 to 2005 represent average periods of precipitation because the accumulative departure from average is the same in the first and last years of each period.

Refer to Appendix B for an explanation and example on how to determine an average period of precipitation based on the accumulative departure from average method.

Figure 13



Evaluation of Groundwater Level Changes

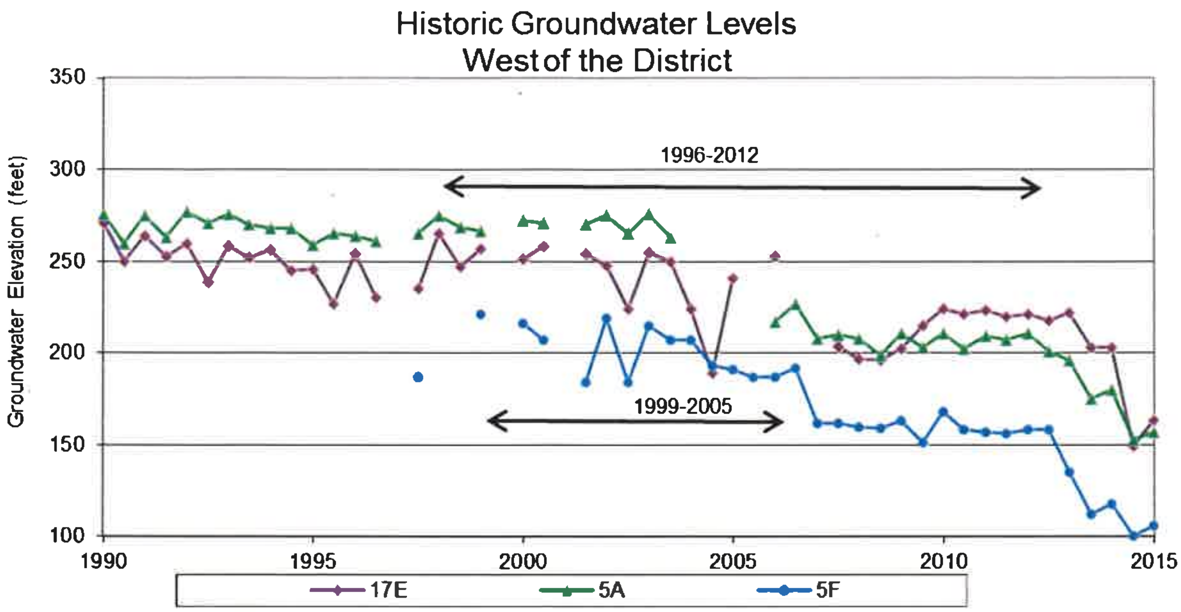
Hydrographs of water levels in three wells west of the District, three wells within the District, and two wells east of the District were prepared for the period from 1990 through 2015. These wells were selected so that they were spread geographically throughout the study area based upon wells available in DWR's Water Data Library with records from 1990 to 2015. The locations of these wells are presented in Figure 1.

The hydrographs for each of these groups of wells is presented in Figures 14 through 16 and are discussed below.

<u>West of the District</u>

A hydrograph of groundwater levels west of the District for years 1990 to 2015 is presented in Figure 14. The source of groundwater for these wells is the semi-confined aquifer in the continental deposits of the Tulare Formation.

Figure 14

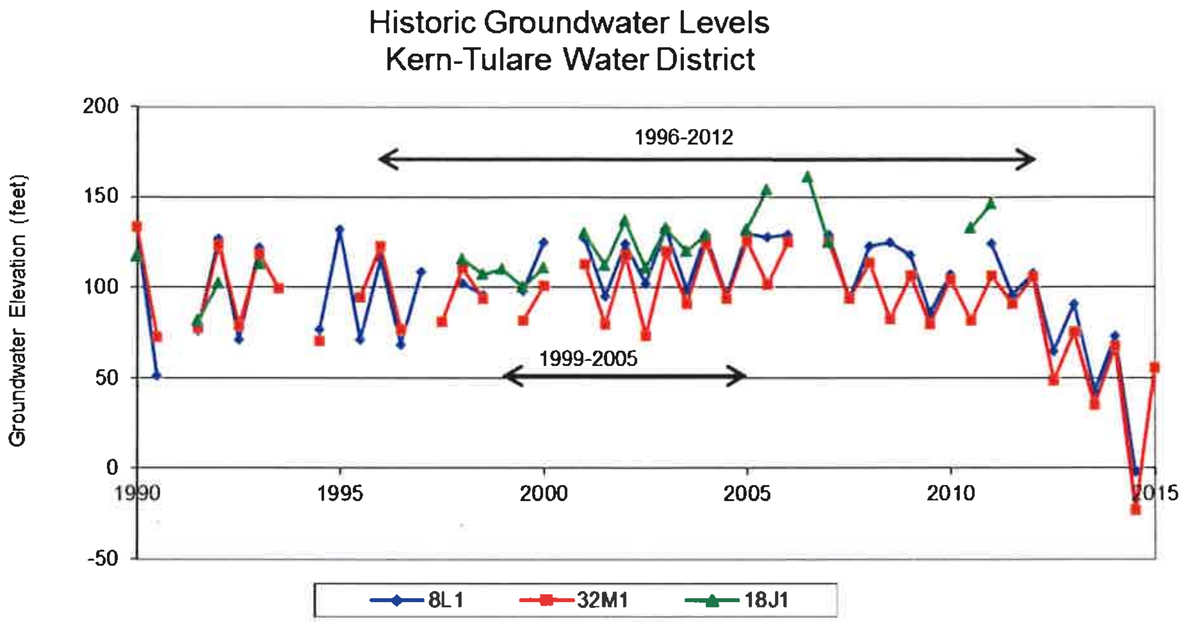


Based upon the average of the three wells west of the District, groundwater levels fell by 54 feet from 1996 to 2012 (-3.4 feet per year) and groundwater levels fell by 26 feet from 1999 to 2005 (-4.3 feet per year). This decrease in water levels is caused from pumping more from the basin than is replaced by recharge. Contributing to this problem is the 20,000 acres or more of permanent crops located north of the District shown in Figure 1 that have no imported source of water. The greater drawdown in the northernmost well (Well 5F) provides evidence for this. Management of groundwater west and north of the District is the responsibility of others.

Within the District

A hydrograph of groundwater levels within the District for years 1990 to 2015 is presented in Figure 15. The source of groundwater for these wells is the confined aquifer of the Santa Margarita Formation.

Figure 15

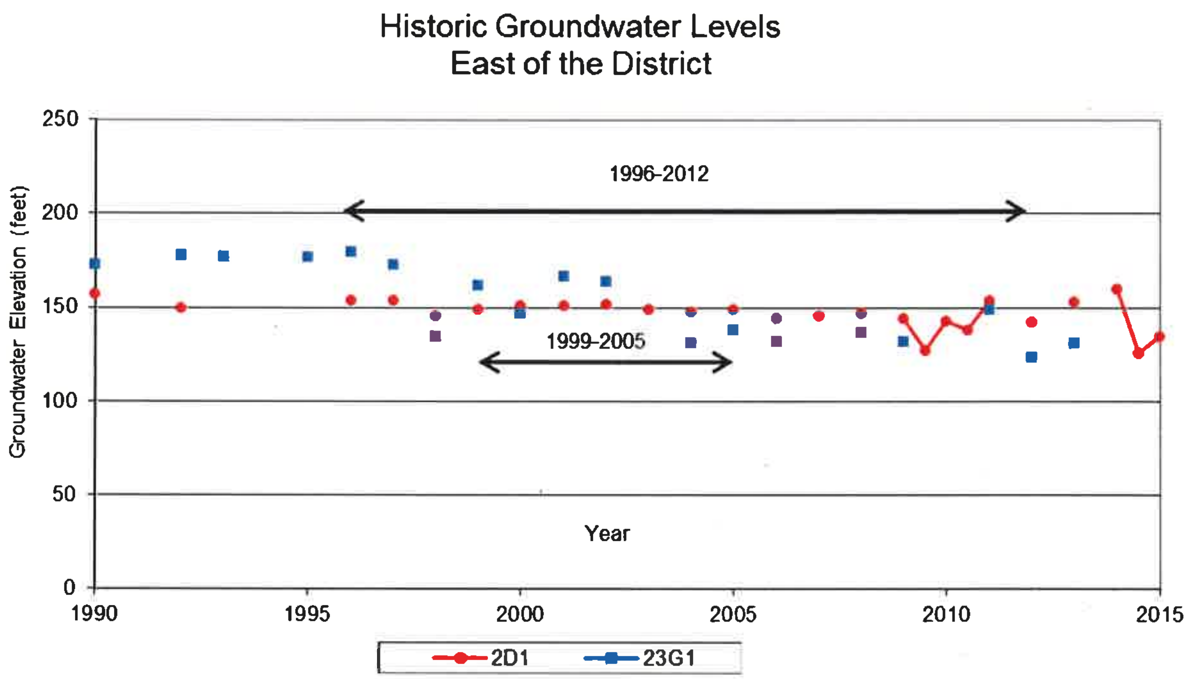


Based upon the average of the three wells selected within the District, groundwater levels remained stable from 1996 to 2012 (0 feet per year) and groundwater levels rose by 17 feet from 1999 to 2005 (+2.8 feet per year). This is evidence that the amount of pumping from the Santa Margarita aquifers within the District was sustainable over the period evaluated. Stable or rising groundwater levels in the confined aquifer while water levels are lowering in the semi-confined aquifer is further evidence that the confined aquifers beneath the District are hydraulically independent from the semi-confined aquifer tapped to the west. The drop in water levels post 2012 is a result of reduced recharge due to the ongoing drought and increased pumping caused by reduced imported waters supplies.

East of the District

A hydrograph of groundwater levels east of the District for years 1990 to 2015 is presented in Figure 16. The source of groundwater for these wells is the Santa Margarita Formation and Olcese Sands.

Figure 16



Based upon the average of the two wells selected east of the District, groundwater levels fell by 34 feet from 1996 to 2012 (-2.1 feet per year) and groundwater levels fell by 12 feet from 1999 to 2005 (-2.0 feet per year). This is evidence that lands overlying the Santa Margarita and Olcese aquifers east of the District are pumping more from the basin than is replaced by recharge.

Estimated Groundwater Pumping

Estimates of groundwater pumping were made for lands within the District and for lands east of the District within the proposed GSP boundaries. These periods are 1996-2012 and 1999-2005 and represent accumulative departures from average. The year 2014 represents recent plantings. Estimates of groundwater pumping were made by calculating the applied water demand for crops and subtracting water provided from the District. The applied water demand for crops was calculated based upon annual land use surveys, published reports of evapotranspiration by crop type, monthly estimates of effective precipitation, and assumed irrigation efficiencies.

This analysis is presented in Appendix A and summarized by historical period in Tables 4 through 6.

Table 4

Historical Period 1996-2012				
		Average Annual Water Use (ac-ft)		
	Acres	From Ground Water	From District Deliveries	Total Irrigation Demand
Within District				
Irrigated	18,133	16,337	38,549	54,886
Non-Irrigated	5,574	0	0	0
Total	23,707	16,337	38,549	54,886
East of District				
Irrigated	5,088	16,118	0	16,118
Non-Irrigated	62,887	0	0	0
Total	67,975	16,118	0	16,118
Total	91,682	32,455	38,549	71,004

Table 5

Historical Period 1999-2005				
		Average Annual Water Use (ac-ft)		
	Acres	From Ground Water	From District Deliveries	Total Irrigation Demand
Within District				
Irrigated	17,870	13,531	40,201	53,732
Non-Irrigated	6,267	0	0	0
Total	24,136	13,531	40,201	53,732
East of District				
Irrigated	4,923	15,608	0	15,608
Non-Irrigated	63,052	0	0	0
Total	67,975	15,608	0	15,608
Total	92,111	29,139	40,201	69,340

Table 6

Recent Plantings (2014)				
		Average Annual Water Use (ac-ft)		
	Acres	From Ground Water	From District Deliveries	Total Irrigation Demand
Within District				
Irrigated	17,427	34,031	20,660	54,691
Non-Irrigated	2,850	0	0	0
Total	20,277	34,031	20,660	54,691
East of District				
Irrigated	6,732	22,727	0	22,727
Non-Irrigated	61,243	0	0	0
Total	67,975	22,727	0	22,727
Total	88,252	56,758	20,660	77,418

Evaluation of Sustainability

Table 7 compares groundwater pumping estimates with the change in groundwater elevation for the two periods of average precipitation evaluated and includes groundwater pumping estimates for 2014.

Table 7

	1996-2012		1999-2005		2014
	Groundwater Pumping (ac-ft/year)	Change in Groundwater Elevation (feet/year)	Groundwater Pumping (ac-ft/year)	Change in Groundwater Elevation (feet/year)	Groundwater Pumping (ac-ft/year)
Within District	16,337	0	13,531	+2.8	34,031
East of District	16,118	-2.1	15,608	-2.0	22,727
Total	32,455		29,139		56,758

The following observations are made from Table 7:

1. Based upon the 1996-2012 change in groundwater levels and groundwater pumping estimates, groundwater pumping of 16,337 ac-ft per year within the District appears to be sustainable.
2. East of the District, the historic pumping of 15,608 ac-ft per year is not sustainable and must be reduced. With the recent planting of an additional 1,600 acres east of the District, this situation has been made even worse.

<u>Note:</u>

In discussions with water users in the District, crops in the District have a higher ET than the published ET values in Appendix A and used in the above analysis. This is due to later maturing varieties of fruit and closer plant spacing than used in the published data. Thus, the groundwater pumping estimates and sustainable groundwater pumping amounts are likely higher than determined above.

FINDINGS AND CONCLUSIONS

1. The District overlies the Santa Margarita Formation and Olcese Sands. Both aquifers are confined and are hydrologically separate from the remainder of the Tulare Lake groundwater basin.
2. Wells within the District are drilled to a depth of 1,800 to 2,400 feet and typically yield 2,000 to 2,500 gpm. Wells extend into the continental deposits, the Pliocene marine deposits, the Santa Margarita Formation, and the Olcese Sands. Wells drilled in the 1950's and 1960's are perforated from the top of first encountered water to the bottom of the well. More recent wells tend to be perforated only in the deeper zones—the confined Santa Margarita Formation and Olcese Sands.
3. The continental deposits within the District are substantially dewatered and the Pliocene marine deposits contain mainly thin, lenticular, low permeability sands, therefore the only significant source of groundwater within the District is the Santa Margarita Formation and Olcese Sands.
4. Fresh water confined in the Santa Margarita Formation and Olcese Sands have dissolved solids concentrations ranging from 200 to 400 ppm.
5. The confined aquifers of the Santa Margarita Formation and Olcese Sands rise eastward and grade into sandy formations that crop out near the mountain front where the aquifers are recharged by streams flowing from the Sierras.
6. The sands in the Santa Margarita Formation and Olcese Sands were originally deposited in a marine environment and at one time contained salt water. The fact that they are now filled with fresh water is evidence that groundwater movement has occurred. Rainfall and stream seepage have fed fresh water into these sands to maintain a westward hydraulic gradient in the sands. The fresh water has moved down-structure and flushed the saline waters westward.
7. A saline-fresh water contact exists along the western border of the District within the Santa Margarita Formation and Olcese Sands. Extreme caution should be exercised in pumping from the Santa Margarita Formation and Olcese Sands east of the District to avoid the eastward migration of the fresh-saltwater interface and producing water with a harmful salt content.
8. West of the District, groundwater wells tap the continental deposits. These wells are drilled to a depth of 800 to 1,200 feet and typically yield 1,000 to 1,500 gpm. The Santa Margarita Formation is at least 2,500 feet deep at the District's western boundary and gets deeper and more saline to the west.

9. Reliance on the Santa Margarita Formation and Olcese Sands is limited by the amount of recharge from the mountain front.
10. Based upon the 1996-2012 change in groundwater levels and groundwater pumping estimates, groundwater pumping of approximately 16,400 ac-ft per year within the District is sustainable if pumping east of the District is kept within historical quantities.
11. East of the District, wells are drilled to a depth of 1,500 to 1,800 feet and predominately tap the Santa Margarita Formation and the Olcese Sands. Wells located further east also tap the Pyramid Hills, Vedder, and Walker Formations. Groundwater production is reduced closer to the mountain front due to a reduction in saturated thickness of the aquifers.
12. East of the District, the historic pumping of approximately 15,600 ac-ft per year is not sustainable and must be reduced. With recent plantings of an additional 1,600 acres east of the District, this situation has worsened.
13. Care must be taken in determining which aquifer is being measured when contouring groundwater levels. Groundwater levels in DEID's groundwater management plan do not distinguish between the semi-confined and the confined aquifers. As a result, groundwater measurements are contoured as if they were all from the same aquifer, which is misleading along the eastern boundary of DEID.

RECOMMENDATIONS

1. Develop a Groundwater Sustainability Plan for the Santa Margarita and Olcese Sands within the District and east of the District. This plan should be developed in consultation with and coordinated with plans of surrounding water districts, affected property owners, the County of Kern, and the County of Tulare. The Groundwater Sustainability Plan should include the following:
    a. Manage pumping from wells within and east of the District to a quantity that will stabilize groundwater levels in the plan area. This may require the metering of all wells in the plan area, limiting groundwater pumping, and establishing a method to enforce pumping limits.

2. Future data collection and monitoring:
    a. Perform groundwater level measurements for selected wells within the District, east of the District, and within 2 miles west of the District. Collect driller's logs for all wells measured. Prepare separate groundwater level contours for the semi-confined aquifer and the confined aquifer. Based upon the results of the water level measurement and information from driller's logs, revise the District's groundwater monitoring plan.
    b. Perform a water quality analysis for selected wells within the District, east of the District, and within 2 miles west of the District. Based upon the results of the water quality testing, develop a groundwater quality management program for the District.

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APPENDIX A

Estimates of Groundwater Pumping

Kern-Tulare Water District

Historic Land Use

Year	Irrigated Acres [1] Vines	Nuts	Citrus	Other	Total	Non-Irrigated Acres [1]	Total Acres
			Within District				
1996	7,848	1,739	8,512	952	19,051	7,154	26,205
1997	7,926	1,851	8,587	936	19,300	6,935	26,235
1998	7,464	1,963	9,232	1,124	19,783	6,271	26,054
1999	7,771	2,200	8,635	533	19,139	6,834	25,973
2000	8,116	2,045	8,243	391	18,795	5,342	24,137
2001	7,622	2,166	8,208	255	18,251	5,884	24,135
2002	7,151	2,082	7,975	150	17,358	6,513	23,871
2003	6,723	2,013	7,396	1,007	17,139	6,753	23,892
2004	7,146	2,238	7,750	70	17,205	6,672	23,877
2005	6,897	3,081	7,134	89	17,201	5,869	23,069
2006	6,368	4,493	7,376	129	18,367	5,000	23,367
2007	5,622	4,906	7,427	189	18,144	5,298	23,441
2008	5,798	4,809	7,501	600	18,708	4,104	22,812
2009	5,722	4,956	6,717	159	17,554	4,606	22,160
2010	5,466	5,526	6,901	399	18,293	4,103	22,396
2011	5,474	4,977	6,238	139	16,828	3,890	20,718
2012	5,525	5,155	6,232	239	17,152	3,523	20,674
2013	5,678	5,062	6,032	240	17,012	3,301	20,313
2014	6,307	5,164	5,712	244	17,427	2,850	20,277
1999-2005	7,347	2,261	7,906	356	17,870	6,267	24,136
1996-2012	6,743	3,306	7,651	433	18,133	5,574	23,707
			East of District [2, 3]				
1996	0	0	5,000	0	5,000	62,975	67,975
1997	0	0	5,000	0	5,000	62,975	67,975
1998	0	0	5,000	0	5,000	62,975	67,975
1999	0	0	5,000	0	5,000	62,975	67,975
2000	0	0	5,000	0	5,000	62,975	67,975
2001	0	0	5,000	0	5,000	62,975	67,975
2002	0	0	5,000	0	5,000	62,975	67,975
2003	0	0	4,850	0	4,850	63,125	67,975
2004	0	0	4,824	0	4,824	63,151	67,975
2005	0	0	4,788	0	4,788	63,187	67,975
2006	0	0	4,547	0	4,547	63,428	67,975
2007	0	0	4,730	0	4,730	63,245	67,975
2008	0	0	4,906	0	4,906	63,069	67,975
2009	0	0	5,510	0	5,510	62,465	67,975
2010	0	0	5,910	0	5,910	62,065	67,975
2011	0	0	5,840	0	5,840	62,135	67,975
2012	0	0	5,600	0	5,600	62,375	67,975
2013	0	0	5,600	0	5,600	62,375	67,975
2014	0	1,258	5,474	0	6,732	61,243	67,975
1999-2005	0	0	4,923	0	4,923	63,052	67,975
1996-2012	0	0	5,088	0	5,088	62,887	67,975

Notes:

[1] From KTWD annual crop survey.

[2] Aerial photography used from Google Earth to determine irrigated acreage.

[3] Red values = estimated because of lack of aerial photography available.

Kern-Tulare Water District

Monthly Precipitation (inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Within and East of District [1]													
1996	0.62	1.57	0.91	0.24	0.02	0.00	0.01	0.00	0.00	0.88	2.12	3.02	9.39
1997	2.15	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.15	1.80	1.39	5.83
1998	1.58	5.54	2.73	0.58	2.34	0.80	0.00	0.00	0.02	0.44	0.93	0.27	15.23
1999	3.82	0.52	0.53	0.66	0.00	0.00	0.00	0.00	0.13	0.00	0.38	0.07	6.11
2000	1.02	3.11	1.40	0.64	0.00	0.17	0.02	0.00	0.00	1.39	0.00	0.00	7.75
2001	1.97	2.12	0.30	1.19	0.00	0.00	0.00	0.00	0.00	0.08	1.86	1.32	8.84
2002	0.74	0.26	0.56	0.67	0.09	0.00	0.00	0.00	0.00	0.00	1.30	1.62	5.24
2003	0.00	0.97	0.50	0.96	0.52	0.00	0.04	0.00	0.00	0.00	0.63	1.09	4.71
2004	0.86	1.85	0.60	0.03	0.00	0.00	0.00	0.00	0.00	2.01	0.31	1.30	6.96
2005	2.92	1.58	2.31	0.66	1.41	0.00	0.00	0.00	0.03	0.15	0.10	0.79	9.95
2006	0.00	0.26	2.29	2.73	0.34	0.00	0.00	0.00	0.00	0.55	0.04	0.55	6.76
2007	0.56	1.46	0.92	0.28	0.02	0.00	0.01	0.00	0.26	0.05	0.05	0.87	4.48
2008	1.57	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	1.01	0.49	4.38
2009	0.41	0.88	0.14	0.31	0.35	0.11	0.00	0.00	0.03	0.21	0.38	1.35	4.17
2010	2.57	1.87	0.35	1.39	0.12	0.00	0.00	0.00	0.00	0.52	0.53	6.10	13.45
2011	1.13	0.20	1.77	0.47	0.45	0.54	0.00	0.00	0.02	0.56	0.89	0.00	6.03
2012	0.56	0.13	1.56	1.76	0.00	0.00	0.00	0.00	0.00	0.00	0.40	1.59	6.00
2013	0.72	0.80	0.99	0.00	0.70	0.00	0.08	0.00	0.00	0.08	0.73	0.08	4.18
2014	0.08	0.44	1.39	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.66	2.18	5.28

Notes:

[1] Source: Western Region Climate Center (WRCC) Delano Station No. 042346 - http://www.wrcc.dri.edu/WRCCWrappers.py?sodxtrmts+042346+por+por+pcpn+none+msum+5+01+F

Kern-Tulare Water District

Effective Precipitation (acre-feet) [1]

Vines

Year	Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ET (inches) [2]:		0.98	0.87	0.48	1.77	3.97	5.95	5.82	4.62	2.42	0.34	0.76	1.02	29.00
Within District														
1996	7,848	0	0	314	118	13	0	7	0	0	222	497	0	1,171
1997	7,926	0	0	0	0	0	0	0	0	26	99	502	0	627
1998	7,464	0	0	299	271	1,455	498	0	0	12	211	434	0	3,180
1999	7,771	0	0	257	321	0	0	0	0	84	0	185	0	847
2000	8,116	0	0	325	325	0	115	14	0	0	230	0	0	1,008
2001	7,622	0	0	143	567	0	0	0	0	0	51	483	0	1,243
2002	7,151	0	0	250	299	54	0	0	0	0	0	453	0	1,056
2003	6,723	0	0	210	403	291	0	22	0	0	0	265	0	1,192
2004	7,146	0	0	268	13	0	0	0	0	0	202	138	0	622
2005	6,897	0	0	276	284	810	0	0	0	17	86	43	0	1,517
2006	6,368	0	0	255	939	180	0	0	0	0	180	16	0	1,571
2007	5,622	0	0	225	98	9	0	5	0	122	23	18	0	500
2008	5,798	0	0	0	0	0	0	0	0	0	53	366	0	419
2009	5,722	0	0	50	111	167	52	0	0	14	100	136	0	631
2010	5,466	0	0	120	475	55	0	0	0	0	155	181	0	985
2011	5,474	0	0	219	161	205	246	0	0	9	155	304	0	1,300
2012	5,525	0	0	221	608	0	0	0	0	0	0	138	0	967
2013	5,678	0	0	227	0	331	0	38	0	0	38	259	0	893
2014	6,307	0	0	252	209	0	0	0	0	0	0	260	0	721
East of District														
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

[1] Effective precipitation computed based upon precipitation that satisfies monthly evapotranspiration during the growing season.

[2] Source: Irrigation Training & Research (ITRC) at Cal Poly, San Luis Obispo - Zone 15 Drip/Micro Irrigation Typical Year for Grape Vines with 80% canopy - http://www.itrc.org/etdata/wbdata/dmtypwb15.pdf

Kern-Tulare Water District

Effective Precipitation (acre-feet) [1]
Nuts

Year	Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ET (inches) [2]:		0.96	1.06	1.19	4.15	6.62	6.97	6.79	5.98	4.24	2.07	0.75	1.01	41.79
Within District														
1996	1,739	0	154	99	26	3	0	1	0	0	128	109	0	519
1997	1,851	0	35	0	0	0	0	0	0	6	23	116	0	180
1998	1,963	0	173	195	71	383	131	0	0	3	72	114	0	1,142
1999	2,200	0	72	73	91	0	0	0	0	24	0	52	0	311
2000	2,045	0	181	179	82	0	29	3	0	0	237	0	0	711
2001	2,166	0	191	41	161	0	0	0	0	0	14	135	0	543
2002	2,082	0	34	73	87	16	0	0	0	0	0	130	0	340
2003	2,013	0	122	63	121	87	0	7	0	0	0	79	0	479
2004	2,238	0	198	84	4	0	0	0	0	0	375	43	0	704
2005	3,081	0	272	306	127	362	0	0	0	8	39	19	0	1,132
2006	4,493	0	73	446	767	127	0	0	0	0	206	11	0	1,630
2007	4,906	0	433	282	86	8	0	4	0	106	20	15	0	956
2008	4,809	0	361	0	0	0	0	0	0	0	44	301	0	705
2009	4,956	0	273	43	96	145	45	0	0	12	87	118	0	819
2010	5,526	0	488	121	480	55	0	0	0	0	239	183	0	1,567
2011	4,977	0	62	494	146	187	224	0	0	8	232	277	0	1,630
2012	5,155	0	42	503	567	0	0	0	0	0	0	129	0	1,240
2013	5,062	0	253	313	0	295	0	34	0	0	34	231	0	1,160
2014	5,164	0	142	449	171	0	0	0	0	0	0	213	0	975
East of District														
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	1,258	0	35	109	42	0	0	0	0	0	0	52	0	237

Notes:

[1] Effective precipitation computed based upon precipitation that satisfies monthly evapotranspiration during the growing season.

[2] Source: Irrigation Training & Research (ITRC) at Cal Poly, San Luis Obispo - Zone 15 Drip/Micro Irrigation Typical Year for Almonds - http://www.itrc.org/etdata/wbdata/dmtypwb15.pdf

Kern-Tulare Water District

Effective Precipitation (acre-feet) [1]

Citrus

Year	Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ET (inches) [2]:		0.97	2.22	2.86	4.33	5.10	5.29	5.16	4.54	3.56	2.67	1.38	1.13	39.21
Within District														
1996	8,512	330	835	484	128	14	0	7	0	0	624	979	802	4,203
1997	8,587	694	161	0	0	0	0	0	0	29	107	966	746	2,703
1998	9,232	746	1,708	1,575	335	1,800	615	0	0	15	339	537	156	7,826
1999	8,635	698	281	286	356	0	0	0	0	94	0	205	38	1,957
2000	8,243	525	1,525	721	330	0	117	14	0	0	955	0	0	4,187
2001	8,208	663	1,088	154	610	0	0	0	0	0	55	944	677	4,191
2002	7,975	369	130	279	334	60	0	0	0	0	0	648	751	2,570
2003	7,396	0	448	231	444	320	0	25	0	0	0	291	504	2,263
2004	7,750	417	896	291	15	0	0	0	0	0	1,298	150	630	3,696
2005	7,134	577	704	1,030	294	838	0	0	0	18	89	45	352	3,947
2006	7,376	0	120	1,056	1,259	209	0	0	0	0	338	18	254	3,253
2007	7,427	260	678	427	130	12	0	6	0	161	31	23	404	2,132
2008	7,501	606	563	0	0	0	0	0	0	0	69	473	230	1,941
2009	6,717	172	369	59	130	196	62	0	0	17	118	160	567	1,849
2010	6,901	558	807	151	600	69	0	0	0	0	299	229	650	3,361
2011	6,238	441	78	690	183	234	281	0	0	10	291	347	0	2,555
2012	6,232	218	51	608	686	0	0	0	0	0	0	156	587	2,305
2013	6,032	271	302	373	0	352	0	40	0	0	40	275	30	1,684
2014	5,712	29	157	496	189	0	0	0	0	0	0	236	538	1,645
East of District														
1996	5,000	194	491	284	75	8	0	4	0	0	367	575	471	2,469
1997	5,000	404	94	0	0	0	0	0	0	17	63	563	434	1,574
1998	5,000	404	925	853	181	975	333	0	0	8	183	291	84	4,239
1999	5,000	404	163	166	206	0	0	0	0	54	0	119	22	1,133
2000	5,000	319	925	438	200	0	71	8	0	0	579	0	0	2,540
2001	5,000	404	663	94	372	0	0	0	0	0	33	575	413	2,553
2002	5,000	231	81	175	209	38	0	0	0	0	0	406	471	1,611
2003	4,850	0	294	152	291	210	0	16	0	0	0	191	330	1,484
2004	4,824	259	558	181	9	0	0	0	0	0	808	93	392	2,301
2005	4,788	387	473	691	197	563	0	0	0	12	60	30	236	2,649
2006	4,547	0	74	651	776	129	0	0	0	0	208	11	156	2,005
2007	4,730	166	432	272	83	8	0	4	0	102	20	15	257	1,358
2008	4,906	397	368	0	0	0	0	0	0	0	45	310	150	1,269
2009	5,510	141	303	48	107	161	51	0	0	14	96	131	465	1,516
2010	5,910	478	691	129	513	59	0	0	0	0	256	196	557	2,879
2011	5,840	412	73	646	172	219	263	0	0	10	273	325	0	2,392
2012	5,600	196	46	546	616	0	0	0	0	0	0	140	527	2,071
2013	5,600	252	280	347	0	327	0	37	0	0	37	256	28	1,563
2014	5,474	27	151	476	181	0	0	0	0	0	0	226	515	1,576

Notes:

[1] Effective precipitation computed based upon precipitation that satisfies monthly evapotranspiration during the growing season.

[2] Source: Irrigation Training & Research (ITRC) at Cal Poly, San Luis Obispo - Zone 15 Drip/Micro Irrigation Typical Year for Citrus (no ground cover) - http://www.itrc.org/etdata/wbdata/dmtypwb15.pdf

Kern-Tulare Water Districts

Effective Precipitation (acre-feet) [1]
Other Crops

Year	Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ET (inches) [2]:		1.02	0.85	1.10	1.70	2.54	7.42	7.53	2.72	0.02	0.31	0.79	1.05	27.05
Within District														
1996	952	37	67	54	14	2	0	1	0	0	25	63	83	346
1997	936	80	18	0	0	0	0	0	0	2	12	62	81	253
1998	1,124	96	80	103	41	219	75	0	0	2	29	65	19	728
1999	533	45	17	18	22	0	0	0	0	1	0	13	2	118
2000	391	25	28	34	16	0	6	1	0	0	10	0	0	119
2001	255	22	18	5	19	0	0	0	0	0	2	17	21	103
2002	150	7	2	5	6	1	0	0	0	0	0	10	13	45
2003	1,007	0	61	31	60	44	0	3	0	0	0	40	69	308
2004	70	4	5	3	0	0	0	0	0	0	2	1	6	20
2005	89	8	6	8	4	11	0	0	0	0	1	1	4	43
2006	129	0	2	12	18	4	0	0	0	0	3	0	4	44
2007	189	7	13	11	3	0	0	0	0	0	1	1	10	47
2008	600	51	43	0	0	0	0	0	0	0	6	38	18	155
2009	159	4	9	1	3	5	1	0	0	0	3	4	13	44
2010	399	34	28	9	35	4	0	0	0	0	10	13	35	168
2011	139	10	2	13	4	5	6	0	0	0	4	8	0	52
2012	239	8	2	22	26	0	0	0	0	0	0	6	21	86
2013	240	11	12	15	0	14	0	2	0	0	2	11	1	67
2014	244	1	7	21	8	0	0	0	0	0	0	10	21	69
East of District														
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

[1] Effective precipitation computed based upon precipitation that satisfies monthly evapotranspiration during the growing season.

[2] Source: Irrigation Training & Research (ITRC) at Cal Poly, San Luis Obispo - Zone 15 Drip/Micro Irrigation Typical Year for Miscellaneous field crops - http://www.itrc.org/etdata/wbdata/dmtypwb15.pdf

Kern-Tulare Water District

Irrigation Efficiency

Year	Irrigation Method as Percentage of Service Area: Drip/Micro	Furrow	Sprinkler	Total	Average Irrigation Efficiency
			Within District		
1996	84%	9%	7%	100%	86%
1997	84%	9%	7%	100%	86%
1998	84%	9%	7%	100%	86%
1999	87%	9%	4%	100%	86%
2000	91%	8%	1%	100%	87%
2001	95%	4%	1%	100%	88%
2002	95%	4%	1%	100%	88%
2003	95%	4%	1%	100%	88%
2004	95%	4%	1%	100%	88%
2005	97%	3%	0%	100%	89%
2006	99%	1%	0%	100%	90%
2007	99%	1%	0%	100%	90%
2008	99%	1%	0%	100%	90%
2009	99%	1%	0%	100%	90%
2010	99%	1%	0%	100%	90%
2011	99%	1%	0%	100%	90%
2012	99%	1%	0%	100%	90%
2013	99%	1%	0%	100%	90%
2014	99%	1%	0%	100%	90%
			East of District		
1996	100%	0%	0%	100%	90%
1997	100%	0%	0%	100%	90%
1998	100%	0%	0%	100%	90%
1999	100%	0%	0%	100%	90%
2000	100%	0%	0%	100%	90%
2001	100%	0%	0%	100%	90%
2002	100%	0%	0%	100%	90%
2003	100%	0%	0%	100%	90%
2004	100%	0%	0%	100%	90%
2005	100%	0%	0%	100%	90%
2006	100%	0%	0%	100%	90%
2007	100%	0%	0%	100%	90%
2008	100%	0%	0%	100%	90%
2009	100%	0%	0%	100%	90%
2010	100%	0%	0%	100%	90%
2011	100%	0%	0%	100%	90%
2012	100%	0%	0%	100%	90%
2013	100%	0%	0%	100%	90%
2014	100%	0%	0%	100%	90%

Notes:
1996 through 1999 irrigation method based upon straight line interpolation between 1977 and 2000
2000 irrigation method based upon field survey conducted on 8/23/01
2001 through 2004 irrigation method based upon field survey conducted on 4/26/04
2005 through 2015 from the District's Annual Crop Survey

Kern-Tulare Water District

Effective Precipitation (acre-feet) [1]

Year	Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Within District														
1996	19,051	367	1,056	951	286	32	0	16	0	0	999	1,647	885	6,238
1997	19,300	774	213	0	0	0	0	0	0	63	241	1,645	827	3,764
1998	19,783	842	1,961	2,171	717	3,858	1,319	0	0	33	651	1,150	175	12,876
1999	19,139	743	369	634	789	0	0	0	0	202	0	455	40	3,233
2000	18,795	550	1,733	1,259	752	0	266	31	0	0	1,432	0	0	6,024
2001	18,251	685	1,297	342	1,357	0	0	0	0	0	122	1,579	698	6,080
2002	17,358	376	166	608	727	130	0	0	0	0	0	1,241	764	4,011
2003	17,139	0	631	536	1,028	743	0	57	0	0	0	675	572	4,243
2004	17,205	420	1,099	645	32	0	0	0	0	0	1,877	333	635	5,043
2005	17,201	584	983	1,620	710	2,021	0	0	0	43	215	108	357	6,639
2006	18,367	0	195	1,768	2,983	520	0	0	0	0	728	46	258	6,498
2007	18,144	267	1,124	945	318	30	0	15	0	389	76	57	414	3,635
2008	18,708	657	966	0	0	0	0	0	0	0	171	1,178	248	3,221
2009	17,554	176	651	154	340	512	161	0	0	44	307	417	580	3,342
2010	18,293	592	1,323	400	1,589	183	0	0	0	0	704	606	685	6,081
2011	16,828	450	142	1,415	494	631	757	0	0	28	682	936	0	5,536
2012	17,152	227	94	1,353	1,887	0	0	0	0	0	0	429	608	4,597
2013	17,012	282	567	928	0	992	0	113	0	0	113	776	31	3,804
2014	17,427	30	306	1,218	577	0	0	0	0	0	0	719	559	3,409
East of District														
1996	5,000	194	491	284	75	8	0	4	0	0	367	575	471	2,469
1997	5,000	404	94	0	0	0	0	0	0	17	63	563	434	1,574
1998	5,000	404	925	853	181	975	333	0	0	8	183	291	84	4,239
1999	5,000	404	163	166	206	0	0	0	0	54	0	119	22	1,133
2000	5,000	319	925	438	200	0	71	8	0	0	579	0	0	2,540
2001	5,000	404	663	94	372	0	0	0	0	0	33	575	413	2,553
2002	5,000	231	81	175	209	38	0	0	0	0	0	406	471	1,611
2003	4,850	0	294	152	291	210	0	16	0	0	0	191	330	1,484
2004	4,824	259	558	181	9	0	0	0	0	0	808	93	392	2,301
2005	4,788	387	473	691	197	563	0	0	0	12	60	30	236	2,649
2006	4,547	0	74	651	776	129	0	0	0	0	208	11	156	2,005
2007	4,730	166	432	272	83	8	0	4	0	102	20	15	257	1,358
2008	4,906	397	368	0	0	0	0	0	0	0	45	310	150	1,269
2009	5,510	141	303	48	107	161	51	0	0	14	96	131	465	1,516
2010	5,910	478	691	129	513	59	0	0	0	0	256	196	557	2,879
2011	5,840	412	73	646	172	219	263	0	0	10	273	325	0	2,392
2012	5,600	196	46	546	616	0	0	0	0	0	0	140	527	2,071
2013	5,600	252	280	347	0	327	0	37	0	0	37	256	28	1,563
2014	6,732	27	185	585	223	0	0	0	0	0	0	278	515	1,814

Notes:

[1] Effective precipitation computed as all precipitation that satisfies monthly evapotranspiration during the growing season.

Kern-Tulare Water District

Annual Irrigation Demand [1]

Year	Irrigation Efficiency	Evapotranspiration During Growing Season (acre-feet) Vines	Nuts	Citrus	Other	Total	Effective Precip. (acre-feet)	Irrigation Demand (acre-feet)
	ET (inches):	29.00	41.79	39.21	27.05			
Within District								
1996	86%	18,966	6,056	27,813	2,146	54,981	6,238	56,834
1997	86%	19,155	6,446	28,058	2,110	55,769	3,764	60,637
1998	86%	18,038	6,836	30,166	2,534	57,573	12,876	52,116
1999	86%	18,780	7,662	28,215	1,201	55,858	3,233	60,907
2000	87%	19,614	7,122	26,934	881	54,551	6,024	55,752
2001	88%	18,420	7,543	26,820	575	53,357	6,080	53,545
2002	88%	17,282	7,251	26,058	338	50,929	4,011	53,138
2003	88%	16,247	7,010	24,166	2,270	49,694	4,243	51,477
2004	88%	17,269	7,795	25,325	158	50,547	5,043	51,537
2005	89%	16,667	10,728	23,310	201	50,907	6,639	49,767
2006	90%	15,390	15,647	24,102	292	55,430	6,498	54,581
2007	90%	13,586	17,084	24,267	427	55,364	3,635	57,702
2008	90%	14,011	16,748	24,509	1,353	56,621	3,221	59,565
2009	90%	13,827	17,258	21,949	359	53,393	3,342	55,830
2010	90%	13,210	19,245	22,548	900	55,904	6,081	55,574
2011	90%	13,228	17,331	20,383	314	51,256	5,536	50,998
2012	90%	13,352	17,952	20,364	540	52,208	4,597	53,107
2013	90%	13,722	17,628	19,710	541	51,601	3,804	53,315
2014	90%	15,242	17,984	18,664	550	52,440	3,409	54,691
East of District								
1996	90%	0	0	16,338	0	16,338	2,469	15,410
1997	90%	0	0	16,338	0	16,338	1,574	16,404
1998	90%	0	0	16,338	0	16,338	4,239	13,443
1999	90%	0	0	16,338	0	16,338	1,133	16,894
2000	90%	0	0	16,338	0	16,338	2,540	15,331
2001	90%	0	0	16,338	0	16,338	2,553	15,316
2002	90%	0	0	16,338	0	16,338	1,611	16,362
2003	90%	0	0	15,846	0	15,846	1,484	15,958
2004	90%	0	0	15,764	0	15,764	2,301	14,959
2005	90%	0	0	15,643	0	15,643	2,649	14,438
2006	90%	0	0	14,856	0	14,856	2,005	14,279
2007	90%	0	0	15,455	0	15,455	1,358	15,664
2008	90%	0	0	16,029	0	16,029	1,269	16,399
2009	90%	0	0	18,004	0	18,004	1,516	18,319
2010	90%	0	0	19,312	0	19,312	2,879	18,259
2011	90%	0	0	19,083	0	19,083	2,392	18,545
2012	90%	0	0	18,298	0	18,298	2,071	18,030
2013	90%	0	0	18,298	0	18,298	1,563	18,594
2014	90%	0	4,381	17,887	0	22,268	1,814	22,727

Notes:

[1] Irrigation Demand computed as (Evapotranspiration less Effective Precip.) / Irrigation Efficiency

Kern-Tulare Water District

Annual Irrigation Deliveries

		Irrigation Deliveries (acre-feet)					Irrigation Deliveries (ac-ft per acre)			
Year	Effect. Precip.	From Surface Water	From Ground Water	From Oil Fields	Total	Irrigated Acres	From Surface Water	From Ground Water	From Oil Fields	Total
Within District										
1996	6,238	41,342	15,116	376	56,834	19,051	2.17	0.79	0.02	2.96
1997	3,764	44,264	16,027	346	60,637	19,300	2.29	0.83	0.02	3.12
1998	12,876	34,833	17,006	277	52,116	19,783	1.76	0.86	0.01	2.62
1999	3,233	41,445	19,215	247	60,907	19,139	2.17	1.00	0.01	3.17
2000	6,024	44,252	11,244	256	55,752	18,795	2.35	0.60	0.01	2.95
2001	6,080	44,888	8,417	240	53,545	18,251	2.46	0.46	0.01	2.92
2002	4,011	38,099	14,801	238	53,138	17,358	2.19	0.85	0.01	3.05
2003	4,243	36,614	14,656	207	51,477	17,139	2.14	0.86	0.01	2.99
2004	5,043	38,370	12,903	264	51,537	17,205	2.23	0.75	0.02	2.98
2005	6,639	36,072	13,479	216	49,767	17,201	2.10	0.78	0.01	2.88
2006	6,498	35,167	19,210	204	54,581	18,367	1.91	1.05	0.01	2.96
2007	3,635	38,071	19,275	356	57,702	18,144	2.10	1.06	0.02	3.16
2008	3,221	39,599	19,332	634	59,565	18,708	2.12	1.03	0.03	3.15
2009	3,342	35,474	19,727	629	55,830	17,554	2.02	1.12	0.04	3.14
2010	6,081	32,178	22,704	692	55,574	18,293	1.76	1.24	0.04	3.00
2011	5,536	32,752	17,368	878	50,998	16,828	1.95	1.03	0.05	2.98
2012	4,597	34,683	17,254	1,170	53,107	17,152	2.02	1.01	0.07	3.03
2013	3,804	36,365	15,626	1,324	53,315	17,012	2.14	0.92	0.08	3.06
2014	3,409	19,092	34,031	1,568	54,691	17,427	1.10	1.95	0.09	3.05
1999-2005	5,039	39,963	13,531	238	53,732	17,870	2.23	0.76	0.01	2.99
1996-2012	5,357	38,124	16,337	425	54,886	18,133	2.10	0.90	0.02	3.00
East of District										
1996	2,469	0	15,410	0	15,410	5,000	0.00	3.08	0.00	3.08
1997	1,574	0	16,404	0	16,404	5,000	0.00	3.28	0.00	3.28
1998	4,239	0	13,443	0	13,443	5,000	0.00	2.69	0.00	2.69
1999	1,133	0	16,894	0	16,894	5,000	0.00	3.38	0.00	3.38
2000	2,540	0	15,331	0	15,331	5,000	0.00	3.07	0.00	3.07
2001	2,553	0	15,316	0	15,316	5,000	0.00	3.06	0.00	3.06
2002	1,611	0	16,362	0	16,362	5,000	0.00	3.27	0.00	3.27
2003	1,484	0	15,958	0	15,958	4,850	0.00	3.29	0.00	3.29
2004	2,301	0	14,959	0	14,959	4,824	0.00	3.10	0.00	3.10
2005	2,649	0	14,438	0	14,438	4,788	0.00	3.02	0.00	3.02
2006	2,005	0	14,279	0	14,279	4,547	0.00	3.14	0.00	3.14
2007	1,358	0	15,664	0	15,664	4,730	0.00	3.31	0.00	3.31
2008	1,269	0	16,399	0	16,399	4,906	0.00	3.34	0.00	3.34
2009	1,516	0	18,319	0	18,319	5,510	0.00	3.32	0.00	3.32
2010	2,879	0	18,259	0	18,259	5,910	0.00	3.09	0.00	3.09
2011	2,392	0	18,545	0	18,545	5,840	0.00	3.18	0.00	3.18
2012	2,071	0	18,030	0	18,030	5,600	0.00	3.22	0.00	3.22
2013	1,563	0	18,594	0	18,594	5,600	0.00	3.32	0.00	3.32
2014	1,814	0	22,727	0	22,727	6,732	0.00	3.38	0.00	3.38
1999-2005	2,039	0	15,608	0	15,608	4,923	0.00	3.17	0.00	3.17
1996-2012	2,120	0	16,118	0	16,118	5,088	0.00	3.17	0.00	3.17
Total										
1996	8,707	41,342	30,525	376	72,243	24,051	1.72	1.27	0.02	2.99
1997	5,338	44,264	32,431	346	77,041	24,300	1.82	1.33	0.01	3.16
1998	17,115	34,833	30,450	277	65,560	24,783	1.41	1.23	0.01	2.63
1999	4,367	41,445	36,108	247	77,800	24,139	1.72	1.50	0.01	3.21
2000	8,563	44,252	26,576	256	71,084	23,795	1.86	1.12	0.01	2.98
2001	8,634	44,888	23,733	240	68,861	23,251	1.93	1.02	0.01	2.95
2002	5,623	38,099	31,163	238	69,500	22,358	1.70	1.39	0.01	3.10
2003	5,727	36,614	30,614	207	67,435	21,989	1.67	1.39	0.01	3.06
2004	7,343	38,370	27,862	264	66,496	22,029	1.74	1.26	0.01	3.01
2005	9,289	36,072	27,917	216	64,205	21,988	1.64	1.27	0.01	2.91
2006	8,503	35,167	33,489	204	68,860	22,913	1.53	1.46	0.01	3.00
2007	4,992	38,071	34,938	356	73,365	22,874	1.66	1.53	0.02	3.19
2008	4,490	39,599	35,731	634	75,964	23,613	1.68	1.51	0.03	3.19
2009	4,858	35,474	38,046	629	74,149	23,064	1.54	1.65	0.03	3.19
2010	8,960	32,178	40,963	692	73,833	24,203	1.33	1.69	0.03	3.02
2011	7,928	32,752	35,914	878	69,544	22,668	1.44	1.58	0.04	3.03
2012	6,668	34,683	35,284	1,170	71,137	22,752	1.52	1.55	0.05	3.08
2013	5,367	36,365	34,220	1,324	71,909	22,612	1.61	1.51	0.06	3.12
2014	5,223	19,092	56,759	1,568	77,418	24,159	0.79	2.35	0.06	3.14
1999-2005	7,078	39,963	29,139	238	69,340	22,793	1.75	1.28	0.01	3.03
1996-2012	7,477	38,124	32,456	425	71,005	23,222	1.64	1.40	0.02	3.04

APPENDIX B

Accumulative Departure from Average

The following is an explanation of the Accumulative Departure from Average method on selection of the two average periods of precipitation (1996-2012 and 1999-2005) in this document. An example is provided for ease of understanding.

Example:

Between years 2000 and 2005 the average precipitation was 5 inches:
Year 2000 average rainfall = 2 inches
Year 2001 average rainfall = 5 inches
Year 2002 average rainfall = 10 inches
Year 2003 average rainfall = 7 inches
Year 2004 average rainfall = 3 inches
Year 2005 average rainfall = 3 inches

Departure from average (how far away the current year average is away from the overall average) is determined for each year: (Current Year Average – Average of All Years)
Year 2000: (2 in) – (5 in) = -3 inches
Year 2001: (5 in) – (5 in) = 0 inches
Year 2002: (10 in) – (5 in) = 5 inches
Year 2003: (7 in) – (5 in) = 2 inches
Year 2004: (3 in) – (5 in) = -2 inches
Year 2005: (3 in) – (5 in) = -2 inches

Accumulative Departure from Average: (Previous Year Departure + Current Year Departure)
Year 2000: -3 inches
Year 2001: (-3 in) + (0 in) = -3 inches
Year 2002: (-3 in) + (5 in) = 2 inches
Year 2003: (2 in) + (2 in) = 4 inches
Year 2004: (4 in) + (-2 in) = 2 inches
Year 2005: (2 in) + (-2 in) = 0 inches

In year 2002 the amount of rainfall accumulated was 2 inches above the overall average.
In year 2003 the amount of rainfall accumulated was 4 inches above the overall average.
In year 2004 the amount of rainfall accumulated was 2 inches above the overall average.

This means that the amount of rainfall between 2002 – 2004 increased and decreased by the same amount of rainfall. This is why the years 2002 – 2004 represent an average period of precipitation.

The 0 on the y-axis of the following graph represents the average, a positive slope indicates an above average precipitation, and a negative slope indicates a below average precipitation. Because it's an accumulation, whenever the line starts and then ends at the same value at any time in the future, it represents an average period of precipitation.