2 Basin Setting

2.1 Physical Setting and Characteristics

The Yucaipa Subbasin (DWR Basin Number 8-2.07) comprises an eastern portion of the Upper Santa Ana Valley Groundwater Basin and lies beneath the southeast section of San Bernardino Valley. The Yucaipa Subbasin is bounded to the north and northeast by the San Andreas Fault Zone and the San Bernardino Mountains, to the east by the Yucaipa Hills, to the south by San Timoteo Wash and the San Timoteo Badlands, and to the west by the Crafton Hills and the San Bernardino Basin Area. The Yucaipa Subbasin is overlain by the Yucaipa plain, a gently sloping area of unconsolidated deposits of late Pleistocene and Holocene sediments originating from the surrounding mountains and hills. The Yucaipa Plain is drained by Oak Glen Creek, Wilson Creek, and Yucaipa Creek south and west to San Timoteo Creek, which is tributary to the Santa Ana River (Figure 1-1, Vicinity Map of the Yucaipa Subbasin Plan Area). The Yucaipa Subbasin ranges in elevation from approximately 1,300 feet above the North American Vertical Datum of 1988 (NAVD88) at the downstream end where San Timoteo Canyon Road crosses San Timoteo Creek, to approximately 5,100 feet above NAVD88 at the northeastern end of the Triple Falls Creek subarea.

The bottom of the Yucaipa Subbasin consists of crystalline bedrock divided into two distinct lithologic groups: the Peninsular Range-type bedrock south of the Banning Fault, and the San Gabriel Mountains-type bedrock between the Banning Fault and the San Andreas Fault. The Peninsular Range-type bedrock consists of Mesozoic plutonic rocks and older metasedimentary rocks, which are generally described as very hard, slightly to moderately weathered, and not extensively fractured. The San Gabriel Mountains-type bedrock consists of foliated granodiorite and tonalite that have been deformed by ductile shearing. This bedrock crops out extensively in the hills surrounding the Subbasin. Outcrops of the San Gabriel Mountains-type bedrock are highly weathered and display an abundant number of closely spaced fractures (Mendez et al. 2016).

Overlying the basement rock of the Yucaipa Subbasin are late Pleistocene to Holocene deposits of alluvial sediments originating from the surrounding Crafton Hills, San Bernardino Mountains, and Yucaipa Hills. The deeper sedimentary deposits consist of consolidated and unconsolidated units representing the Pliocene-Pleistocene San Timoteo Formation, the Pleistocene Sedimentary deposits of Live Oak Canyon, and the mid-Pleistocene to Holocene surficial materials (Cromwell et al. 2020a). The primary water-bearing formations in the Yucaipa Subbasin that form the principal aquifer are the Sedimentary deposits of Live Oak Canyon and the San Timoteo Formation.

2.2 Climate

San Bernardino Valley has a semiarid, Mediterranean climate characterized by relatively hot, dry summers and cool winters with intermittent precipitation. Most precipitation occurs from December through March, and rainless periods of several months are common in the summer. Precipitation is mostly in the form of rain in the lower elevations and mostly snow above approximately 6,000 feet above NAVD88 in the San Bernardino Mountains.

Mean annual precipitation by water year (a water year extends from October 1 to September 30 of the following calendar year) in the San Bernardino Valley ranges from approximately 10 inches near Riverside to approximately 30 inches in the upper San Bernardino Mountains (SBVMWD et al. 2017). Mean annual precipitation in the Yucaipa Subbasin is approximately 16 inches. Historical precipitation data indicates that a period of above average or below-average precipitation can last more than 30 years, such as the dry period that extended from 1947 to 1977. The region has been experiencing an ongoing drought since about 1999 (SBVWMD et al. 2017).

The Santa Ana River Basin receives precipitation from three general types of storms: winter storms, local storms, and summer storms. Winter storms originate over the Pacific Ocean and move eastward over the basin usually from December through March. Winter storms often last for several days and are accompanied by widespread precipitation in the form of rain and, at higher elevations, snow. Local storms cover small areas, but can result in high intensity precipitation for durations of approximately 6 hours. These storms can occur any time of the year. Summer storms can occur in the late summer and early fall months in the San Bernardino area, although they are infrequent (SBVWMD et al. 2017).

2.2.1 Precipitation

2.2.1.1 San Bernardino County Flood Control District

The Hydrology Section of the Water Resources Division in San Bernardino County's Department of Public Works collects a variety of climatology data around San Bernardino County. The San Bernardino County Flood Control District (SBCFCD), a division of the Department of Public Works, installed a network of climate stations throughout San Bernardino County to collect precipitation, stream flow and temperature data. The data is used to manage flood control storm warnings, structure and channel design, runoff calculations, and environmental studies (SBCFCD 2021). Daily precipitation data was obtained from San Bernardino's online database for 17 stations within the Plan Area (Figure 2-1, Climate Station Locations in the San Timoteo Wash Watershed). The stations range in elevation from 1,285 feet above NAVD88 at "Redlands - Roth" (Site ID 3023), which is located approximately 850 feet downstream of the farthest downstream end of the Yucaipa Subbasin, to 4,630 feet above NAVD88 at the "Oak Glen" (Site ID 3015) station located near the eastern end of the Triple Falls Creek subarea (Section 2.5.1; Appendix 2-A). Table 2-1 summarizes the locations and periods of record for each of the 17 stations used to characterize precipitation in the Yucaipa Subbasin.

The historical precipitation data collected at the 17 SBCFCD climate stations was used to characterize the water year types from the 1954 WY to the 2018 WY. The Yucaipa GSA defined the following six categories to characterize the water year types based on the amount of precipitation per water year relative to the mean annual precipitation estimated for each subarea in the Yucaipa Subbasin: Wet, Above Normal, Normal, Below Normal, Dry, and Critically Dry. The water year types are intended to define a relationship between changing hydrological conditions and the associated aquifer response to changing water supply, demand, and storage. Further discussion of the use of water year type characterization is included in Section 2.8, Water Budget Analysis.

Table 2-1. San Bernardino County Flood Control District Climatic Stations in the Yucaipa Subbasin

SBCFCD Station ID No.	Site Name	Subarea	Latitude	Longitude	Elevation (ft NAVD88)	Begin Data Record	End Data Record
2890	Yucaipa Regional	Crafton	34.04876	−117.04857	2606	9/5/1989	Ongoing
2915	Wilson Creek	Western Heights	34.03437	−117.07441	2235	2/12/2004	Ongoing
3015	Oak Glen	Triple Falls Creek	34.05185	−116.95272	4680	10/1/1945	Ongoing
3023	Redlands–Roth	Live Oak	34.03402	−117.21035	1285	2/1/1932	Ongoing
3099	Yucaipa County Yard	Western Heights	34.03351	−117.10241	2140	5/1/1957	10/1/1978
3126	Yucaipa	Wilson Creek	34.03340	−117.03511	2815	1/31/1949	10/1/1990
3126A	Calimesa East	Calimesa	34.00444	−117.01733	2813	5/1/1964	Ongoing
3128B	Yucaipa Adams 2e	Wilson Creek	34.02924	−117.04426	2860	10/1/1949	10/1/1980
3129	Yucaipa C.D.F.	Gateway	34.04653	−117.03558	2660	1/1/1951	1/22/1980
3129A	Yucaipa C.D.F.	Gateway	34.04654	−117.03559	2660	1/22/1980	Ongoing
3132	Yucaipa Water Company	Calimesa	34.02157	−117.04470	2710	2/20/1953	Ongoing
3239	Redlands Country Club	Live Oak	34.01898	−117.14947	2080	5/24/1964	1/27/2005
3239A	Redlands Country Club WT	Live Oak	34.01385	−117.13868	2281	1/27/2005	Ongoing
3356	Crafton Hills Fire Station #18	Western Heights	34.03435	−117.09252	2125	9/28/1979	Ongoing
3386	Calimesa–Raisner	Calimesa	34.00435	−117.03375	2620	11/23/1988	Ongoing
3121	Oak Glen–Sample	Oak Glen	34.05525	−116.98675	3695	10/2/1980	Ongoing
2800	Wildwood Canyon	Oak Glen	34.01434	−117.00778	2946	9/14/1999	Ongoing

Note: SBCFCD = San Bernardino County Flood Control District; ft NAVD88 = feet above NAVD88.

Daily precipitation data was collected at various periods between these stations, with the longest running data collection period recorded at the “Oak Glen” station (SBCFCD Station ID No. 3015) from October 1, 1945 to current time (the last data point obtained for purposes in this GSP was September 30, 2018). The daily precipitation data was compiled by water year for each station.

Mean annual precipitation per water year ranged from 11.15 inches at Station 2890 in the Crafton subarea to 24.50 inches at Station 3015 in the Triple Falls Creek subarea (Table 2-2). Precipitation amounts tended to follow the topographical landscape of the Yucaipa Subbasin. Mean annual precipitation declined when transitioning from the highest elevations in the Triple Falls Creek subarea (24.50 inches) and the foothills of the San Bernardino Mountains to the lower elevations in the Yucaipa Plain where mean annual precipitation ranged from 15.09 to 18.15 inches in the Oak Glen, Gateway, Wilson Creek and Calimesa subareas. The mean annual precipitation in the Crafton, Western Heights and Live Oak subareas ranged from 11.15 to 13.65 inches.

The weighted mean annual precipitation across the Plan Area is 15.86 inches based on precipitation data collected at the 17 SBCDPW climate stations from the 1953 WY to the 2018 WY (Table 2-2). The mean annual precipitation estimate was weighted against the number of annual precipitation totals recorded for each station divided by the total number of annual precipitation totals across the Subbasin.

Table 2-2. Mean Annual Precipitation in the Yucaipa Subbasin

Subarea	Mean Annual Precipitation (inches)	Minimum Elevation at SBCFCD Station (ft NAVD88)	Maximum Elevation at SBCFCD Station (ft NAVD88)
Crafton	11.15	2,606	2,606
Live Oak	11.69	1,285	2,281
Western Heights	13.65	2,125	2,235
Gateway	15.09	2,660	2,660
Wilson Creek	15.31	2,815	2,860
Calimesa + Singleton	16.68	2,620	2,813
Oak Glen	18.15	2,946	3,695
Triple Falls Creek	24.50	4,680	4,680
Yucaipa Subbasin	**15.86**	**1,285**	**4,680**

Note: SBCFCD = San Bernardino County Flood Control District; ft NAVD88 = feet above NAVD88.

2.2.1.2 National Oceanic and Atmospheric Administration

Additionally, daily precipitation data were obtained from National Oceanic and Atmospheric Administration (NOAA) weather stations located in Redlands (Station #USC00047306), Yucaipa (Station #US1CASR0044), and Beaumont (Station #US1CARV0018), California. The Redlands station is located approximately 0.5 miles northeast of the farthest downgradient end of the Plan Area (Figure 2-1). The station is at an elevation of 1,417 feet above NAVD88. The Yucaipa station, “Yucaipa 1.5NNE,” is located approximately 0.5 miles northwest of the Wilson Creek spreading basins. The Yucaipa station is at an elevation of 2,776 feet above NAVD88. The Beaumont station is located approximately 2 miles northwest of the intersection of Interstate 10 and State Route 60 in the San Timoteo Wash Watershed, approximately 1.9 miles south of the Singleton Subbasin (Figure 2-1). The elevation of the Beaumont station is 2,532 feet above NAVD88 (Table 2-3).

The mean annual (by water year) precipitation at these three NOAA stations ranged from 12.51 inches to 15.82 inches. The Redlands station, with an annual mean of 12.51 inches, has the longer record of data and is also at the lowest elevation. The highest average was 15.82 inches at the Yucaipa 1.5 NNE station, which is also at the highest elevation at 2,776 feet above NAVD88 (Table 2-3).

Table 2-3. Summary Information for NOAA Climatic Stations in the Vicinity of the Yucaipa Subbasin

NOAA Station ID	NOAA Network ID	Latitude (degrees)	Longitude (degrees)	Elevation (ft NAVD88)	Period of Data Collection	Mean Annual Precipitation (inches)[1]
Redlands	USC00047306	34.037	−117.195	1,417	Oct. 1963–Sep. 2018	12.51
Beaumont 2.5 NW	US1CARV0018	33.954	−117.012	2,532	Oct. 2009–Sep. 2018	12.74
Yucaipa 1.5 NNE	US1CASR0044	34.054	−117.038	2,776	Oct. 2014–Sep. 2018	15.82

Notes: NOAA = National Oceanic and Atmospheric Administration; ft NAVD88 = feet above NAVD88.
1 Per water year (Oct. 1 to Sep. 30).

2.2.1.3 Cumulative Departure from Mean Monthly Precipitation

Historical daily precipitation data from the SBCFCD climatic stations 3015 (“Oak Glen”) and 3126A (“Calimesa East”) and from the NOAA Redlands, Yucaipa 1.5 NNE, and Beaumont 2.5NW stations were compiled as total monthly precipitation. Mean monthly precipitation was calculated for each station. Mean monthly precipitation ranged from 0.03 inches in June at the NOAA Beaumont 2.5 NW station to 4.55 inches in February at the SBCFCD “Oak Glen” station (Table 2-4).

The cumulative departure from the mean monthly precipitation was calculated for the SBCFCD “Oak Glen” and “Calimesa East” stations and the NOAA Redlands station because these stations had precipitation data records extending as far back as 1963 (Figure 2-2, Cumulative Departure from Mean Monthly Precipitation at the SBCFCD Oak Glen and Calimesa East Climatic Stations and the NOAA Redlands Climatic Station). The declining cumulative departure of mean monthly precipitation (i.e., less-than-normal rainfall) from the 1945 WY to 1965 WY at the “Oak Glen” station indicates an extended 20-year drought with intermittent wet years in 1951 and 1958. The trend after 1965 reversed direction and generally increased with significant wet periods from 1965-1969, 1978-1983, and 1992-1998. The region experienced another 20-year drought from 1998 to 2018 with intermittent wet years in 2005, 2010 and 2016 (Figure 2-2). This comports with the observation by San Bernardino Valley Municipal Water District et al. that the “region has been experiencing an ongoing drought since about 1999” (SBVMWD et al. 2017). The cumulative departure from the mean monthly for the SBCFCD “Calimesa East” and NOAA Redlands stations show the same trends, but with less variation in the changes in rainfall because these stations are at lower elevations than the “Oak Glen” station.

Table 2-4. Mean Monthly Precipitation in the Yucaipa Subbasin

Climatic Station ID	Elevation (ft NAVD88)	Mean Monthly Precipitation (inches)											
		Oct	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*
SBCFCD 3015 ("Oak Glen")	4,680	0.91	2.28	3.21	4.45	4.55	4.07	1.89	0.94	0.16	0.41	0.46	0.66
SBCFCD 3126A ("Calimesa East")	2,813	0.67	1.72	2.52	3.37	3.55	2.81	1.28	0.62	0.16	0.21	0.20	0.43
NOAA Yucaipa 1.5 NNE	2,776	0.49	1.49	2.74	3.37	2.77	2.25	1.21	1.00	0.04	0.29	0.28	0.33
NOAA Beaumont 2.5 NW	2,532	0.33	1.22	2.79	2.49	2.11	1.93	0.96	0.59	0.03	0.24	0.20	0.13
NOAA Redlands	1,417	0.51	1.20	1.90	2.68	2.56	2.05	0.98	0.37	0.08	0.12	0.19	0.28
Maximum Mean Monthly Precipitation		**0.91**	**2.28**	**3.21**	**4.45**	**4.55**	**4.07**	**1.89**	**1.00**	**0.16**	**0.41**	**0.46**	**0.66**
Minimum Mean Monthly Precipitation		**0.33**	**1.20**	**1.90**	**2.49**	**2.11**	**1.93**	**0.96**	**0.37**	**0.03**	**0.12**	**0.19**	**0.13**

Notes: ft NAVD88 = feet above NAVD88.
1 Per water year (Oct. 1 to Sep. 30)

2.2.1.4 Water Year Type

Periods of above or below average precipitation affect the volume of water that naturally recharges the groundwater aquifer underlying the Plan Area. To characterize the effects of total water year precipitation on local groundwater supplies and demands, and the volume of groundwater in storage, the precipitation measurements were categorized into six water year types. Water year type was characterized by normalizing measured water year precipitation by the long-term water-year precipitation averages measured at each of the 17 SBCFCD climate stations in the Subbasin. The normalized water year precipitation measurements were then categorized into the following water year types:

1. Critically Dry: <50% of the long-term precipitation mean
2. Dry: ≥50%, but <75% of the long-term precipitation mean
3. Below Normal: ≥75%, but <90% of the long-term precipitation mean
4. Normal: ≥90%, but <110% of the long-term precipitation mean
5. Above Normal: ≥110%, but <150% of the long-term precipitation mean
6. Wet: ≥150% of the long-term precipitation mean

Appendix 2-A shows the water year type characterization for the 17 SBCFCD climate stations in the Yucaipa Subbasin. Appendix 2-A is aggregated by hydrogeologic subarea (Section 2.5.1), and both the percentage of annual average water year precipitation and annual water year type characterization are shown for each station. Characterization of basin-wide water year type was computed by taking the average water year type characterization across the 17 SBCFCD stations for each water year. The resulting distribution of water year types from the 1953 WY to the 2018 WY is shown on Figure 2-3, Historical Water Year Types in the Yucaipa Subbasin. Three "above normal" to "wet" water year types were observed from the 1966 WY to the 1969 WY, five from the 1978 WY to the 1983 WY, and six from the 1991 WY to the 1998 WY. However, only four "above normal" to "wet" water year types were observed since the 1999 WY, a span of 20 years from 1999 to 2018. There were four "critically dry" water years in the last 55 years, with three of those "critically dry" water years occurring in the last 17 years.

Precipitation measurements collected at the SBCFCD stations 3015, 3129/3129A, and 3239/3239A were analyzed to characterize historical rainfall variability in the Plan Area. Precipitation measurements are largest in the northern reaches of the Plan Area. Average annual water year precipitation measured at the Oak Glen station is approximately 24.50 inches (Appendix 2-A). Precipitation rates are highest between December and March, with monthly precipitation averaging approximately 4 inches. Large winter storm events can deliver in excess of 20 inches of rain per month. Summer months (June-September) are relatively dry, with monthly precipitation averaging 0.4 inches. Large summer storms can deliver in excess of 5 inches per month at these elevations.

Average annual water year precipitation at intermediate altitudes within the Plan Area is approximately 10 inches less than precipitation measured at the Oak Glen station. Average annual water year precipitation measured at 3129/3129A is approximately 15 inches. Precipitation rates are highest between December and March, with monthly precipitation during these winter months averaging between 2 and 3 inches. Large winter storm events can produce nearly 15 inches of rain. Summer months are relatively dry, with monthly precipitation averaging approximately 0.25 inches. Summer storm events can produce up to 6 inches of rain.

Precipitation gauges 3239 and 3239A are the lowest elevation gauges operated by SBCFCD located within the Plan Area. Average annual water year precipitation measured at these gauges is approximately 12 inches per year. The majority of this precipitation occurs between December and March, where monthly precipitation averages between 1 and 2 inches. Summer months are dry, with monthly precipitation averaging approximately 0.16 inches.

2.2.2 Temperature

The NOAA Redlands climate station also recorded the maximum and minimum daily air temperature from 1900 to 2015. The air temperature data was compiled to characterize the mean daily maximum and minimum temperatures for each month of the year. The highest mean daily temperatures were recorded in July at 34.7°C and August at 34.6°C, or 94.4°F. The lowest mean daily temperatures were recorded in December at 4.3˚C and in January at 4.1°C, or 39.5°F (Figure 2-4, Mean Daily Maximum and Minimum Temperature (Degrees Celsius) at NOAA Redlands Climate Station, and Figure 2-5, Mean Daily Maximum and Minimum Temperature (Degrees Fahrenheit) at NOAA Redlands Climate Station).

NOAA maintains a climate station called, "Mill Creek BDF," which is located at approximately 1 mile northwest of the northwestern end of the Plan Area (34.0836°N and −117.0347°W). The Mill Creek BDF station is at an elevation of 3,400 feet above NAVD88. Daily air temperatures have been measured at this station since February 1998. The highest mean daily temperatures were recorded in July at 34.3°C and August at 34.6°C or 94.3°F. The lowest mean daily temperatures were recorded in December at 6.4°C and in February at 6.2°C or 43.2°F (Figure 2-6, Mean Daily Maximum and Minimum Temperature (Degrees Celsius) at NOAA Mill Creek BDF Climate Station).

2.3 Surface Water and Drainage Features

The Yucaipa Subbasin lies within the San Timoteo Wash watershed. The primary surface water drainage features are Wilson Creek, Oak Glen Creek, Yucaipa Creek and San Timoteo Creek (Figure 2-7, Surface Water Flow in San Timoteo Wash Watershed). The headwaters for Wilson Creek and Oak Glen Creek originate in the San Bernardino Mountains above the Triple Falls Creek subarea (Section 1.4.1.2). Yucaipa Creek begins in the Yucaipa Hills and flows east to west out of Wildwood Canyon. San Timoteo Creek is the major drainage feature in the San Timoteo Wash watershed. It enters the Yucaipa Subbasin at the southern end of the Live Oak subarea and runs approximately 3.5 miles before exiting the Plan Area. San Timoteo Creek is tributary to the Santa Ana River.

The general orientation of surface water flow in the Yucaipa Valley is from northeast to southwest. Oak Glen Creek joins Yucaipa Creek just inside the northern boundary of the Live Oak subarea. Yucaipa Creek converges with San Timoteo Creek at the farthest upstream point of San Timoteo Creek in the Live Oak subarea. Flows in Wilson Creek, Oak Glen Creek and Yucaipa Creek are mostly ephemeral, with some intermittent flows in the upper elevations of the Subbasin where seasonal flows are influenced by groundwater discharges to streams.

Stream flow near the upper reaches of Wilson Creek and Oak Glen Creek may be diverted to the Wilson Creek spreading basins and the Oak Glen spreading basins, respectively (Figure 2-8, Locations of the Wilson Creek and Oak Glen Creek Spreading Basins in the Yucaipa Subbasin). The Wilson Creek spreading basins, which were constructed by the Yucaipa Valley Water Conservation District in 1934–1935, are now owned and maintained by SBCFCD and used for the infiltration of SWP water and stormwater. The Oak Glen Creek spreading basins, which were constructed by the City of Yucaipa and are now owned and maintained by SBCFCD, were designed to reduce flooding downstream of Bryant Street, collect debris and sediment in the basins to improve downstream water quality, enhance groundwater recharge by capturing stormwater runoff, and provide additional open space and habitat.

Approximately 0.25 miles downstream of the confluence of Wilson Creek with Oak Glen Creek the channel becomes an engineered, concrete-line channel developed by SBCFCD for flood control purposes. The concrete-lined channel runs approximately 1.8 miles before becoming unlined in the Western Heights subarea. SBCFCD maintains the unlined channel over the next 1.75 miles by clearing vegetation and employing rock check dams to control flooding.

Yucaipa Creek originates out of the Yucaipa Hills through Wildwood Canyon. An unlined, trapezoidal engineered channel runs from Wildwood Canyon approximately 0.33 miles to spreading basins where stream flow may be diverted for flood control and enhance groundwater recharge. The engineered unlined channel continues to run through the Calimesa subarea before becoming a natural unlined reach just south of Interstate Highway 10. The natural course of Yucaipa Creek and Oak Glen Creek in the Live Oak subarea is a highly incised, slightly meandering channel that flows from an elevation at approximately 1,900 feet above NAVD88 to 1,550 feet above NAVD88 where Yucaipa Creek joins San Timoteo Creek.

2.3.1 Characterization of Flow

2.3.1.1 San Bernardino County Flood Control District

SBCFCD installed five stream gauging stations in the Yucaipa Subbasin (Figure 2-7). Table 2-5 summarizes the details of the five SBCFCD stations, including the latitude/longitude coordinates, station elevations and when the stations were established. These stations were designed to measure peak flow events. SBCFCD stated that for “95% of the year the creeks do not contain significant quantities of water” and, therefore, do not accurately measure flow outside of those peak events (personnel communication with SBCFCD, July 2019). SBCFCD has confidence in measurements collected at stations 3601C and 3608A, the two farthest downstream gauging stations in the Subbasin.

Table 2-5. Summary Details for SBCFCD Stream Gauging Stations in the Yucaipa Subbasin

SBCFCD Station ID	Station Name	Latitude	Longitude	Elevation (ft NAVD88)	Established	Discontinued
2800	Wildwood Canyon	34.0143	−117.0078	2946	9/14/1999	—
2915	Wilson Creek	34.0344	−117.0744	2235	2/12/2004	—
S3601A	Wilson Creek @ Jefferson	34.0184	−117.0963	3025	1/11/1968	—
S3601C	Wilson @ Dunlap	34.0184	−117.0963	2305	9/1/1947	—
S3608A	Wildwood @ Calimesa	34.0118	−117.0691	2280	9/13/1972	—

Note: SBCFCD = San Bernardino County Flood Control District; ft NAVD88 = feet above NAVD88.

2.3.1.1.1 Oak Glen Creek

Stream flow in Oak Glen Creek is measured at SBCFCD gauging stations 2915 (upstream) and S3601C (downstream). Gauging station 2915 is approximately 2 miles downstream of the confluence of Wilson Creek and in an underground, concrete-lined section of the creek. Gauging station S3601C is approximately 1.5 miles downstream of station 2915 in an unlined, trapezoidal channel. The reach between stations 2915 and S3601C is mostly an engineered, unlined trapezoidal channel with rock check dams positioned approximately every 100 feet along the channel.

Figure 2-9, Cumulative Stream Flow at SBCFCD Stations 2915 and S3601C on Oak Glen Creek, shows stream flow data recorded at gauging stations 2915 and S3601C, and the mean monthly precipitation measured at SBCFCD climate stations 2915, 3099 and 3356 since 1995. Beginning in late 2007, stream flow at the upstream gauging station, 2915, is markedly higher than at the downstream gauging station, S3601C. Gauging station 2915 may be registering flows collectively from Wilson Creek and Oak Glen Creek that were conveyed from the confluence of these two creeks in a lined, concrete channel. The marked increase in flow during the later months of 2010 indicates an influence of the more-than-normal rainfall in the 2011 WY wet season, which was a "Wet" water year type that ranged from 138% to 188% of mean annual rainfall measured in the Yucaipa Subbasin (Appendix 2-A).

In contrast, the lower flows measured at the downstream gauging station indicated that the reach between 2915 and S3601C was a losing stream where surface water discharged to groundwater. SBCFCD, however, does not have high confidence in stream flow measured at gauging station 2915. In correspondence with SBCFCD in July 2019, the high and consistent rate of flow registered at this station between 2007 and 2009, and again from 2011 to 2013, could not be explained. SBCFCD suggested the "elevated baseflow [was] likely due to silt/debris build up on the pressure transducer" that was installed in the wall of the channel to gauge flow. A site inspection of the gauging station to clear silt/debris build-up and calibrate the pressure transducer may improve results. The alternative is modifying the gauging station so that it collects representative data during lower flow events.

2.3.1.1.2 Yucaipa Creek

Stream flow in Yucaipa Creek is measured at SBCFCD gauging stations 2800 (upstream) and S3608A (downstream). Gauging station 2800 is approximately 1,400 feet downstream from the narrow gap between the Yucaipa Hills in Wildwood Canyon. Gauging station S3608A is approximately 3.5 miles downstream of gauging station 2800. The entire reach of Yucaipa Creek between these two stations is an unlined, engineered trapezoidal channel. Just downstream of gauging station S3608A the creek enters its natural, deeply incised and slightly meandering course. Higher flows were measured at the downstream gauging station compared to the upstream gauging station, indicating that this reach of the Yucaipa Creek was potentially a gaining stream (i.e., groundwater discharging to surface water), or runoff entered the creek between the two stations that increased surface water flows (Figure 2-10, Cumulative Stream Flow at SBCFCD Stations 2800 and S3608A on Yucaipa Creek).

Gauging station 2800 measured a constant discharge of approximately 1 cubic foot per second after 2010. As with gauging station 2915 in Oak Glen Creek, SBCFCD does not have high confidence in the stream flow measured at gauging station 2800. Per personal correspondence with SBCFCD (July 31, 2019, email), stream flow is measured using a dedicated pressure transducer where the pressure head (i.e., water level) is converted to stream flow based on a rating curve established at this station. SBCFCD noted that the "constant baseflow is likely due to silting of pipe with transducer (debris settles on pressure transducer causing a non-zero low flow)." As with gauging station 2915, a site inspection to clear silt/debris build-up and calibrate the pressure transducer may improve results. The alternative is modifying the gauging station so that it collects representative data during lower flow events.

2.3.1.2 United States Geological Survey

The U.S. Geological Survey (USGS) installed stream flow gauging station 11057000 (34.0159° N, −117.1229° W) where San Timoteo Canyon Road crosses over San Timoteo Creek (Figure 2-7). This location represents the farthest downstream extent of the Yucaipa Subbasin. This gauging station operated from October 1926 to April 1979. It is no longer in service. Cumulative annual (by water year) stream flow measured at station 11057000 was compared to annual precipitation (by water year) from 1926 to 1979 to characterize the relationship between rainfall and stream flow at this location of the Yucaipa subbasin (Figure 2-11, Stream Flow Measured at USGS Station 11057000 and Precipitation at NOAA Redlands). The mean annual precipitation observed at the NOAA Redlands station from the 1927 WY to the 1978 WY was 13.23 inches.

Marked increases in streamflow out of the Yucaipa Subbasin occurred after wet water years (e.g., 1936–1937, 1943–1944, 1952–1953) when the annual precipitation was 159% to 201% of the mean annual precipitation. No stream flow data was recorded from the 1969 WY to the 1973 WY, and so no relationship could be characterized between stream flow and the wet 1969 WY when the annual precipitation was 190% of the mean annual. In contrast to the marked increases in annual stream flow following major wet years, increases in stream flow were minimal during dry years when the annual precipitation was less than the mean annual precipitation (e.g., 1946–1952, 1959–1966, and 1970–1977).

The USGS installed a replacement station, 11057500 (34.0341° N, −117.1600° W), located approximately 4.2 miles farther downstream from former station 11057000 (Figure 2-7). This station records stream flow in San Timoteo Creek approximately 1 mile upstream of its confluence with the Santa Ana River. In addition to measuring stream flow originating from the San Timoteo Wash watershed, this station captures runoff from a 125-square-mile watershed that is more urbanized than Yucaipa Valley. Stream flow measured at this station does not accurately represent runoff from the Plan Area and will not be used to characterize flows leaving the Yucaipa Subbasin.

2.4 Geology

2.4.1 Geology and Geologic Structures

The Yucaipa Subbasin (DWR Basin Number 8-2.07) is located at the southeastern corner of the Upper Santa Ana Valley Groundwater Basin, which exists in a “right-step-over” zone between the active San Andreas and San Jacinto Fault Zones (Matti et al. 2003). Several branches, or strands, of the San Andreas Fault Zone run in a southeast-northwest direction across the Upper Santa Ana Valley Groundwater Basin (Figure 2-12, Geologic Map of the Yucaipa Subbasin). The San Bernardino strand, the modern trace of the San Andreas Fault, marks the northern boundary of the Yucaipa Subbasin. The Banning Fault, “a major right-lateral strike-slip fault that was part of the San Andreas system in late Miocene time (Matti et al. 2003),” marks the boundary between the Yucaipa Plain and the San Timoteo Badlands to the south. The Yucaipa Plain lies between these two fault systems and comprises an extensive deposition of Quaternary sediments originating from the San Bernardino Mountains to the north and Yucaipa Hills to the east.

The “right-step-over” zone created by the lateral displacement along the San Andreas and San Jacinto Fault Zones created a series of northeast–southwest-trending normal-slip faults. Displacement along these faults, in turn, created drop-down structures that filled in with Quaternary alluvial sediments originating from the surrounding Crafton Hills, San Bernardino Mountains and Yucaipa Hills. Some of the northeast–southwest-trending normal-slip faults mark the boundaries of hydrogeologic subareas delineated in the Yucaipa Subbasin and act as partial barriers to groundwater flow (Figure 2-12).

2.4.1.1 Geologic History

The geologic structures defining the Yucaipa Subbasin evolved from tectonic activity in the Mesozoic and Cenozoic eras. Activity of the right-lateral strike-slip San Andreas and San Jacinto fault zones created a drop-down block of the San Gabriel Mountain-type crystalline bedrock (Mendez et al. 2001). This drop-down block, or graben, was then filled by the deposition of Quaternary sediments originating from the surrounding San Bernardino Mountains and Yucaipa Hills. The earliest deposited sediments comprised the early Quaternary San Timoteo beds of Frick, or San Timoteo Formation. This formation was overlain by middle to late-Quaternary sediments deposited by several generations of axial-valley stream flows and alluvial-fan sediments. The Quaternary deposits most likely originated from, "west-flowing stream flows of the ancestral San Gorgonio River and its tributaries and…middle and late Quaternary fault movements…" (Matti et al. 2003).

The present alignment of the San Andreas Fault zone has been tectonically active for approximately 5 million years, or 5 mega-annums (Ma). The San Jacinto Fault zone has been active for approximately 1.2 Ma to 1.5 Ma (Cromwell and Matti 2020). These two fault zones converge approximately 31 miles northwest of the Yucaipa Subbasin. Movement between these two northwest-southeast trending fault zones created the drop-down geologic structure of the Yucaipa Subbasin. The Banning Fault is a right-lateral strike-slip fault that bisects the Yucaipa Subbasin between the San Andreas and San Jacinto Fault zones (Figure 2-12). This fault, however, has been inactive since approximately 5 Ma (Cromwell and Matti 2020). The eastern extent of the Banning Fault (east of Calimesa) marks the contact between the southern extent of the crystalline bedrock of the Yucaipa Hills and the Sedimentary Deposits of Live Oak Canyon. The Banning Fault is concealed west of this contact in the Yucaipa Subbasin beneath Pleistocene deposits of the Live Oak Formation and older alluvium.

Tectonic activity and motion between the right-lateral strike-slip San Andreas and San Jacinto Fault zones created a series of northeast-southwest trending dip-slip faults that mark the western and southwestern boundaries of the Yucaipa Subbasin. These faults have been active for approximately 1.2 Ma. Cromwell and Matti (2020) note that the "dip-slip motion across these faults is responsible for much of the present-day topographic relief in the area, notably between the sedimentary plain of the Yucaipa Subbasin and the surrounding Crafton and Yucaipa Hills." These faults include the Live Oak Canyon fault, the Crafton Hills fault zone, the Yucaipa Graben fault, Chicken Hill Fault and the Casa Blanca Fault (Figure 2-12).

2.4.1.2 Geologic Units

There are four major geologic units defined within the Yucaipa Subbasin: Mesozoic and older crystalline bedrock, the Plio-Pleistocene San Timoteo Formation, the Quaternary Sedimentary Deposits of Live Oak Canyon and surficial alluvial deposits. The crystalline bedrock provides the base for the sedimentary deposits in the Yucaipa Subbasin (Mendez et al. 2016). The San Timoteo Formation and the Sedimentary Deposits of Live Oak Canyon define the principal aquifer in the Yucaipa Subbasin, with the Sedimentary Deposits of Live Oak Canyon being the more permeable and higher-yielding unit of the aquifer. The surficial alluvial deposits are unsaturated and presently hold no groundwater.

2.4.1.2.1 Mojave Desert-Type Crystalline Bedrock

The Mojave Desert-type crystalline bedrock forms the San Bernardino Mountains north of the San Andreas Fault zone. The Mojave Desert-type crystalline bedrock consists "primarily of foliated and gneissic Mesozoic granitoid rocks (e.g., granodiorite) that intrude older plutonic rocks (e.g., Triassic quartz monzonite) and older metamorphic rocks" (Cromwell and Matti 2020). These rocks comprise the west-facing San Bernardino Mountains from the trace of the San Andreas Fault zone to the ridge marking the eastern boundary of the Yucaipa Valley watershed. The Mojave Desert-type crystalline bedrock is north and outside the Yucaipa Subbasin.

2.4.1.2.2 San Gabriel Mountains-Type Crystalline Bedrock

The bedrock underlying the alluvial deposits of Quaternary age sediments in the Yucaipa Subbasin derives from the San Gabriel Mountains-type rock, which consists of "two suites [or plates] separated by a low-angle thrust fault – the region-wide Vincent Thrust" (Matti et al. 2003). The lower plate is northwest of the Yucaipa Subbasin and outside the Plan Area. The upper plate comprises the Crafton Hills on the west side of the Subbasin, and the Yucaipa Hills on the east side of the Subbasin (Figure 2-12). The Crafton Hills and Yucaipa Hills consist "of strongly foliated Mesozoic granitoid rocks that mainly are granodiorite and tonalite in composition" (Matti et al. 2003).

2.4.1.2.3 Peninsular Ranges-Type Crystalline Bedrock

The Peninsular Ranges-type bedrock includes mainly granitoid rocks of various tonalite, granodiorite and quartz diorite composition and various Mesozoic rock that intruded "much older metasedimentary rock (quartzite, marble, biotite-quartz gneiss)" (Cromwell and Matti 2020). The Peninsular Ranges-type bedrock is found in the subsurface in the Yucaipa Subbasin south of the Banning Fault (Figure 2-12).

2.4.1.2.4 San Timoteo Formation

Overlying the San Gabriel Mountains-type bedrock in the Yucaipa Subbasin is a grouping of consolidated and unconsolidated sedimentary materials originally characterized as the upper member of the San Timoteo beds of Frick. Matti et al. (2003) provided the following description:

> The San Timoteo beds are named from exposures in the San Timoteo Badlands, which parallel the San Jacinto Fault and extend more than 40 km from the Loma Linda area southeastward to the San Jacinto Mountains. Canyons and arroyos eroded into the Badlands during the last million years or so reveal a gently- to moderately-dipping sequence of nonmarine sediment and sedimentary rock that have been deformed into a major anticlinal fold that for much of its length plunges gently to the northwest. Due to this gentle tilting, older strata in the sequence crop out in the southeast San Timoteo Badlands while younger strata crop out in the northwestern Badlands, mainly in the Redlands, San Bernardino South, and Yucaipa quadrangles.

Mendez et al. (2016) notes that the Pliocene to mid-Pleistocene members of the San Timoteo Formation (QTst), despite being exposed only south of the Banning Fault, are "likely to underlie the Yucaipa groundwater subbasins" because the Banning Fault likely terminated slip prior to the deposition of these beds (Figure 2-12). The middle member of the San Timoteo formation "generally consists of light-gray, sheetlike layers of pebble-cobble conglomerate, with medium to thick intervals of gray-brown fine to coarse sandstone and minor amount of siltstone and mudstone intervals" (Cromwell and Matti 2020). The upper San Timoteo formation has been characterized as predominantly "sand, gravelly sand, and gravel and their consolidated equivalents (sandstone, conglomeratic sandstone, conglomerate)" with minor occurrences of "muddy materials and their consolidated equivalents (mudstone, claystone, siltstone)" (Matti et al. 2003). The upper San Timoteo formation was deposited along streambeds and drainages down an ancestral valley to the south and southwest between the Crafton Hills and Yucaipa Hills. The deposited alluvial sediments originated from rocks of both the San Gabriel Mountains and San Bernardino Mountains.

Matti et al. (2003) note that the contact between the upper San Timoteo beds and the overlying alluvium is not well documented because, "sedimentary materials in this part of the stratigraphic section have generally similar lithologic characterizations." The distinction between the San Timoteo beds and the overlying older alluvium has been difficult in the vicinity of Live Oak Canyon (Matti et al. 2003).

Cromwell and Matti (2020) note that "sediments of the San Timoteo formation are more compacted, consolidated, cemented, and have a greater abundance of clay and silt relative to the overlying Sedimentary deposits of Live Oak Canyon and Quaternary surficial material. The San Timoteo formation is likely the least transmissive sedimentary unit in the study area." Dutcher et al. (1972) estimated a transmissivity for the middle San Timoteo formation at 3,000 gallons per day per foot (gpdf) based on a 24-hour aquifer test conducted "at the city of Redlands deep test hole (2S/3W-10B2), which was located approximately 1.25 miles downstream of the intersection of San Timoteo Canyon Road and Live Oak Canyon Road along the San Timoteo Creek corridor just north of Alessandro Road." The estimated hydraulic conductivity of the middle unit of the San Timoteo formation, based on a saturated thickness of 600 feet when the test was conducted, was 5 gallons per day per square foot (gpdf^2), or 1 foot per day.

2.4.1.2.5 Sedimentary Deposits of Live Oak Canyon

The upper member of the San Timoteo beds of Frick, or San Timoteo Formation, was "reassigned by Matti and others to 'Sedimentary deposits of Live Oak Canyon' because it developed in a synclinal trough north of the San Timoteo Badlands about 1.2 million years ago" (Mendez et al. 2016). The Pleistocene Sedimentary deposits of Live Oak Canyon (Qsdloc) outcrop primarily south of the Banning Fault in the western part of the Yucaipa Subbasin (Figure 2-12). As previously described for the upper San Timoteo Formation, Matti et al (2015) described the Sedimentary deposits of Live Oak Canyon as having an abundance of coarser grained materials (gravel and sand-bearing) than finer grained materials (mud-bearing). Mendez (2016) describes the Sedimentary deposits of Live Oak Canyon as "medium- to thick-bedded, moderately to well sorted, moderately indurated, very fine- to coarse-grained sandstone interlayered with subordinate pebbly sandstone and pebble to small-cobble gravel."

Matti et al (2015) noted that the Sedimentary deposits of Live Oak Canyon coincide "with sedimentary materials that are more permeable and hydrologically more transmissive than tighter rocks of the underlying [middle and lower units of the] San Timoteo formation." Cromwell and Matti (2020) note that "Sedimentary deposits of Live Oak Canyon are generally found to the north and east of San Timoteo Canyon, with outcrops throughout much of the southern half of the Yucaipa Subbasin." The Sedimentary deposits of Live Oak Canyon are characterized as both consolidated and unconsolidated coarse-grain sand and gravel that derived from the San Gabriel Mountains and Mojave Desert-type rocks, which resulted as a function of tectonic movement along the San Andreas Fault zone that brought the Yucaipa Subbasin in contact with this rock type.

Cromwell and Matti (2020) note that the "Sedimentary deposits of Live Oak Canyon are the primary aquifer unit in the Yucaipa Subbasin" and that it is the "most extensive and voluminous sedimentary unit in the Subbasin." The water table exists almost exclusively within the Sedimentary deposits of Live Oak Canyon. Dutcher et al. (1972) estimated a transmissivity for this unit at 25,000 gpdf based on an aquifer test conducted at well 2S/3W-11M1 located approximately 0.65 mile downstream of the intersection of San Timoteo Canyon Road and Live Oak Canyon Road. The aquifer test included pumping the well at 80 GPM for 15.5 hours. The hydraulic conductivity was estimated at 220 gpdf^2, or 30 feet per day, using a saturated thickness of 116 feet at the time of the aquifer test.

2.4.1.2.6 Quaternary Surficial Deposits

Overlying the Sedimentary deposits of Live Oak Canyon is a sequence of Quaternary (early Pleistocene to Holocene age) deposits of alluvium (Qa) characterized as unconsolidated, coarse-grained sediments of approximately 30 to 50 feet thick (Figure 2-12). The alluvial deposits sit above the regional water table and are unsaturated. The Quaternary sedimentary deposits are "mostly alluvial-fan or alluvial axial-valley deposits, with local outcrops of landslide, wash, and colluvial materials" (Cromwell and Matti 2020). Alluvial-fan sediments are coarser-grained, gravel-rich, and more poorly sorted than the axial-valley sediments, which include lenses of clay and silt interbedded in layers of sand and gravel. The Quaternary surficial deposits are exposed along the deeply incised channels of Yucaipa Creek and Oak Glen Creek.

2.4.1.2.7 Surficial Soils

The United States Department of Agriculture (USDA) has classified twelve major soil types, or classes, based on the percentages of sand (between 0.02 and 2 millimeters (mm) in size), silt (between 0.002 and 0.02 mm in size) and clay (less than 0.002 mm) in soil. The soil type data was obtained from the USDA Natural Resources Conservation Service (NRCS) Web Soil Survey website (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) in November 2020. The four soil types identified in Yucaipa Valley were silt loam, loam, sandy loam, and loamy sand (Figure 2-13, Soils within the San Timoteo Wash Watershed). Additionally, two other soil classifications were identified in the Plan Area within the San Timoteo Wash watershed: bedrock outcrop and terrace deposits, which have low percentages of sand relative to the loams identified in the Yucaipa Valley. The USDA characterizes each soil type with a series of physical and chemical properties. Some of these properties include the soil's capacity to hold water, its permeability under saturated conditions, rooting depths, and slope. These properties help characterize the infiltration of water through the soil and the potential runoff of rainfall from the soil surface.

The soil types with the lowest infiltration rates in the Plan Area were the rock outcrop and terrace deposits. Rock outcrops occur at the highest elevations in the Plan Area and are composed of granitic bedrock. Terrace deposits are also found at higher elevations where bedrock has been subjected to weathering (Figure 2-13). Terrace deposits are comprised of boulders and alluvium from various sources. The low infiltration rates for these soil types indicates a low recharge rate from precipitation relative to the amount of runoff that contributes to streamflow in the lower elevations in the Plan Area.

Infiltration rates increase with higher percentages of sand. The following order of soil types identified in the Yucaipa Valley begins with the highest in sand content to the lowest (and therefore from the highest infiltration rate to the lowest infiltration rate): loamy sand, sandy loam, loam, and silt loam. The following includes a brief summary of each soil type identified in the Yucaipa Valley:

- The soil type with the highest infiltration rate in the San Timoteo Wash watershed is loamy sand. Loamy sands consist of 70% to 90% sand with smaller fractions of silt and clay. Sandy loam soils are found along drainages and in the higher elevations in the northern part of the San Timoteo Wash watershed. Loamy sand soils cover approximately 8,200 acres, or 10% of the area in the San Timoteo Wash Watershed (Figure 2-13).
- Sandy loam soils consist of 50% to 70% sand with lower percentages of silt and clay. Sandy loam soils are the most widespread in the San Timoteo Wash watershed, generally being found in areas with lower topographic relief between drainages. Sandy loam soils cover approximately 41,200 acres, or 53% of the area in the San Timoteo Wash Watershed (Figure 2-13).

- Loam soils consist nearly equal parts sand and silt (approximately 40% each) with a smaller fraction of clay at approximately 20%. Loam soils in the San Timoteo Wash watershed are generally found on the tops of hills in the southern part of the watershed. Loam soils cover approximately 10,400 acres, or 13% of the San Timoteo Wash Watershed (Figure 2-13).
- Silt loam consists of 20% to 50% sand and 50% to 80% silt. The larger percentage of silt means that silt loam has low infiltration rates. As a result, less recharge occurs through silt loam soils than in soils with higher sand content. In the San Timoteo Wash watershed, silt loam soils are found in a relatively small area along San Timoteo Creek and its tributaries east of its confluence with Yucaipa Creek. Silt loam soil type covers approximately 520 acres, or 1% of the San Timoteo Wash Watershed (Figure 2-13).

2.4.1.3 Geologic Structures

The Yucaipa Subbasin is situated between the right-lateral strike-slip San Andreas and San Jacinto fault zones (Figure 2-12). Extensional stress caused by their lateral displacements created northeast-southwest trending normal dip-slip faults that compartmentalized the Yucaipa Subbasin. Displacements along these normal faults caused the down-dropped graben complex in the Yucaipa Valley, which created the current topography defined by the Crafton Hills in the west and the Yucaipa Hills in the east, with the valley filled in between with alluvial deposits originating from these hills. The northeast-southwest trending normal faults, to some extent, act as partial groundwater flow barriers and affect the movement of groundwater through the Yucaipa Subbasin. Consequently, the Yucaipa Subbasin was further divided into nine hydrogeologic subareas based on ancestral northwest-southeast trending fault splays originating from tectonic activity along the San Andreas and San Jacinto fault zones, and northeast-southwest trending normal faults resulting from the right-lateral displacements of the San Andreas and San Jacinto fault zones (Figure 2-14, Hydrogeologic Subareas in the Yucaipa Subbasin).

2.4.1.3.1 Mission Creek and San Bernardino Strands of the San Andreas Fault Zone

The Mission Creek strand represents a major strand of the San Andreas Fault zone where crystalline rocks of the San Bernardino-type rocks are juxtaposed against San Gabriel Mountain-rock types. This strand underlies Quaternary deposits of alluvium along the base of the San Bernardino Mountains. Matti et al. (2003) inferred that the Mission Creek strand is concealed and lies underneath the younger San Bernardino strand, which represents the modern trace of the San Andreas Fault (Figure 2-12). The San Bernardino strand “evolved through re-activation of the older fault (Mission Creek strand), and the two structures occupy the same trace” (Matti et al. 2003).

The San Bernardino strand of the San Andreas Fault Zone defines the southwest margin of the San Bernardino Mountains. It also marks the northern boundary of the Plan Area (Figure 2-12). The Triple Falls Creek subarea lies between the northern and southern branches of the San Bernardino strand. The extension of the San Bernardino strand of the San Andreas Fault southeast of Mill Creek has an average orientation of N 55° W. Evidence of recent movement characterized in the latest Pleistocene and Holocene indicates a slip rate of approximately 25 millimeters per year (Matti et al. 2003).

2.4.1.3.2 Banning Fault

The Banning Fault is an ancestral major right-lateral strike-slip fault that was part of the San Andreas system in late Miocene time. Matti et al. (2003) mapped the Banning Fault as a concealed trace through the Yucaipa Valley and observed “no evidence that the Banning fault breaks Quaternary alluvial deposits or the upper member of the San Timoteo beds of Frick” (i.e., Sedimentary deposits of Live Oak Canyon) and, therefore, concluded that the Banning fault had no influence on the Quaternary structural history in the Yucaipa Subbasin (Figure 2-12). Whereas the Banning Fault was previously identified as the southern boundary of the Yucaipa Subbasin by Burnham and Dutcher (1960), Cromwell and Matti (2020) noted that the Banning Fault does not influence the hydrogeology of the Subbasin and, therefore, has no role in defining the Subbasin boundaries. Cromwell and Matti (2020) noted that the Banning Fault does not offset the Sedimentary deposits of Live Oak Canyon, the main aquifer unit in the Yucaipa Subbasin, and there is no evidence of a significant influence on hydraulic heads across the inferred concealed boundary of the Banning.

2.4.1.3.3 San Jacinto Fault Zone

The San Jacinto Fault zone lies approximately 1.5 miles southwest of the Yucaipa Subbasin (Figure 2-12). It bounds the western extent of the San Timoteo Badlands and briefly intersects the western boundary of the San Timoteo Wash watershed. This fault zone does not define any hydrogeologic boundary of the Subbasin.

2.4.1.3.4 Crafton Hills Fault Zone

The Crafton Hills Fault Zone defines a series of sub-parallel, northeast-trending normal dip-slip faults that run along the east side of the Crafton Hills (Figure 2-12). The fault zone demarks the boundary between the uplifted crystalline bedrock of San Gabriel Mountains-type of the Crafton Hills and the alluvial deposits in the down-dropped Yucaipa valley. The zone extends from west of Live Oak Canyon near its confluence with San Timoteo Creek northeast to where it encounters the normal faults associated with the Yucaipa Graben Complex. Cromwell and Matti (2020) note that the Crafton Hills Fault zone "defines the northwestern boundary of the Yucaipa Subbasin."

2.4.1.3.5 Yucaipa Graben Complex

The Yucaipa Graben Complex is a series of northeast- to northwest-trending normal dip-slip faults that form the northeastern terminus of the Crafton Hills Fault zone (Figure 2-12). Associated with the Yucaipa Graben Complex are the Oak Glen Fault, a south-facing scarp mostly parallel with the San Andreas Fault zone, and the Chicken Hill Fault. The Oak Glen Fault lies within the Yucaipa Subbasin and curves southward to become part of the east-facing, north-south trending fault scarps that characterize the Yucaipa Graben Complex. Cromwell and Matti (2020) note that the Oak Glen Fault "does not appear to inhibit groundwater flow within the Yucaipa groundwater basin."

2.4.1.3.6 Chicken Hill Fault Zone

The Chicken Hill Fault is a northeast-trending normal fault that is associated with the Yucaipa graben complex and extends southwest down Live Oak Canyon (Matti et al, 2003). The Chicken Hill Fault zone is east of the Crafton Hills Fault zone, in which tectonic activity between these two fault zones led to the down-dropped graben that formed Live Oak Canyon (Figure 2-12). Burnham and Dutcher (1960) and Cromwell and Matti (2020) recognize the Chicken Hill Fault as a barrier to groundwater flow. This is evidenced by the marked difference in hydraulic heads measured at YVWD and City of Redlands wells on the east side of the fault in the Calimesa subarea compared to hydraulic heads measured at WHWC wells on the west side of the fault. The difference in hydraulic head across the fault is approximately 200 to 300 feet (see Section 2.5.1.6).

2.4.1.3.7 Live Oak Canyon Fault Zone

Cromwell and Matti (2020) characterized the Live Oak Canyon Fault Zone, which is located along the north flank of San Timoteo Canyon and runs parallel with San Timoteo Creek before turning west at the downstream terminus of the Yucaipa Subbasin (Figure 2-12), as north-dipping contractional structures (e.g., reverse and thrust faults). Cromwell and Matti (2020) note that the Live Oak Canyon Fault zone does not act as a barrier to groundwater flow as “a few groundwater measurements indicate that there is little offset in hydraulic heads.”

2.4.1.3.8 Oak Glen Fault

Moreland (1970) identified a fault trace parallel to and approximately 1 mile south of the San Andreas Fault Zone as the Oak Glen Fault (Figure 2-12). A south-facing scarp near its western end is the only surficial evidence of the Oak Glen Fault. Cromwell and Matti (2020) note that the Oak Glen Fault does not extend west beyond the Crafton Hills, but “instead curves southward to form one of several east-facing north-south trending fault scarps that [are associated with the] Yucaipa graben complex.” Moreland (1970) noted that the Oak Glen Fault does impede groundwater flow to where a hydraulic head difference “of as much as 400 feet exist across part of the fault.” However, Cromwell and Matti (2020) noted that this structure “does not appear to inhibit groundwater flow within the Yucaipa groundwater basin.”

2.4.1.3.9 Hydrogeologic Barriers

SBVMWD entered into a contract with DWR to receive SWP water beginning in 1972. The Yucaipa area was tentatively scheduled to receive 5,000 AFY of SWP water by 1972. One possible use of the SWP water was to temporarily store the water in the alluvial aquifer as part of an aquifer storage and recovery project. Moreland (1970), in cooperation with SBVMWD, conducted an investigation to evaluate the feasibility of artificially recharging the Yucaipa Subbasin with imported SWP water. The investigation included estimates of storage capacity, aquifer transmissivity, infiltration rates, and a reassessment of the subareas within the Yucaipa Subbasin that were previously defined by others based on the influence of fault zones on groundwater flow.

Moreland (1970) noted that “faults that transect permeable unconsolidated materials may produce barriers to ground-water flow.” Moreland (1970) noted that geologic structures mapped as “faults,” such as the San Andreas Fault and the Chicken Hill Fault, are based on exposures and surficial evidence of displacement; whereas “barriers to ground-water flow” have no surface expressions, but are postulated from geophysical and water level data. Moreland (1970) identified the South Mesa Barrier and the Casa Blanca Barrier as probable faults based on the marked hydraulic head differences observed in wells on either side of these barriers (Figure 2-12). The hydraulic head difference across the Casa Blanca Barrier was approximately 600 feet in 1968, while the hydraulic head difference across the South Mesa Barrier was approximately 160 to 200 feet (Moreland, 1970).

Moreland (1970) identified seven hydrogeologic subareas within the Yucaipa Subbasin: Triple Falls Creek, Crafton, Oak Glen, Gateway, Wilson, Calimesa, and Western Heights. These seven subareas were defined within the Yucaipa Subbasin and north of the Banning Fault. Subsequent investigations by Geoscience (2014) and Cromwell et al. (2020a) led to further refinements of the boundaries of these subareas, plus the additions of the Live Oak and Singleton subareas that were defined south of the Banning Fault and extend to the southern boundary of the Yucaipa Subbasin.

2.4.2 Basin Bottom

In 2009, the USGS, in collaboration with SBVMWD, conducted a gravity anomaly survey to estimate the depths to bedrock in the Yucaipa Subbasin and thickness of alluvial fill in the Yucaipa Valley (Mendez et al. 2016). The survey was part of an investigation to enhance an understanding of the basin geometry and structure, which would lead to better management of groundwater resources by the water purveyors extracting groundwater from the Subbasin. Mendez et al. (2016) noted that the Yucaipa Subbasin is underlain by San Gabriel-Mountain type bedrock between the San Andreas Fault and the Banning Fault, and by Peninsular Ranges-type bedrock south of the Banning Fault (which includes the Live Oak and Singleton subareas). The San Gabriel Mountains-type bedrock is characterized as, "strongly foliated granitoid rocks, mainly of granodiorite to tonalite, that have been deformed by brittle-ductile and ductile shearing" (Mendez et al. 2016). The Peninsular Ranges-type bedrock is characterized as, "very hard; slightly to moderately weathered, where exposed; and not extensively fractured" (Mendez et al. 2016).

The 2009 survey included 256 gravity measurements along 20 profiles in the Yucaipa Subbasin. These measurements supplemented a previous survey conducted in 1982 that included 384 gravity measurements. The combined gravity datasets were used to estimate the depth to contact with the bedrock. There was a marked contrast between the gravity values for the bedrock, which corresponded with the high gravity values measured at exposed bedrock in the Crafton Hills and Yucaipa Hills, and the overlying alluvial fill in the Yucaipa Valley. The USGS calibrated the subsurface gravity measurements to gravity measurements of bedrock outcrops and to the depths-to-bedrock recorded in drilling logs for wells drilled in the study area. The USGS reviewed the drilling logs for 51 wells, where the drillers noted that they penetrated bedrock at 15 of these wells (Mendez et al. 2016).

The USGS estimated the thickness of alluvial deposits in the basin at 0 feet at the fringes of Yucaipa Valley to approximately 3,000 feet in the Western Heights subarea, to approximately 7,000 feet south of the Banning Fault (Mendez et al. 2016). The estimated alluvial thickness in the Live Oak subarea ranges from approximately 2,000 feet to 5,000 feet. The USGS presented a series of cross-sections detailing the depth-to-bedrock profiles across the Subbasin. These profiles were incorporated into the development of the hydrogeologic conceptual model for this GSP (Section 2.6).

2.5 Hydrogeology

2.5.1 Hydrogeologic Subareas

The Yucaipa Subbasin is divided into nine hydrogeologic subareas, or subareas, based on the apparent influences of faults (both mapped and inferred) on groundwater flow. The configuration of these subareas in the Yucaipa Subbasin is shown in Figure 2-14. The following presents a brief description of each subarea, from northeast to southwest across the Yucaipa Valley, and the apparent influence of the faults that mark their boundaries on groundwater flow.

2.5.1.1 Triple Falls Creek Subarea

The Triple Falls Creek subarea is the northernmost subarea in the Plan Area and lies between the east–west-trending San Andreas Fault Zone and the Oak Glen Fault (Figure 2-14). The subarea is approximately 1,000 acres in area with land surface elevations ranging from approximately 2,900 feet above NAVD88 in the southwestern corner to approximately 5,100 feet above NAVD88 in the northeastern corner of the subarea. Wilson Creek and Oak Glen Creek begin in this subarea with runoff from the adjacent San Bernardino Mountains. Birch Creek is a minor drainage that flows out of the San Bernardino Mountains and is tributary to Oak Glen Creek. Sources of water to this subarea include infiltrating stream flow, subsurface flows from the adjacent San Bernardino Mountains (i.e., mountain front recharge), and deep percolation from direct precipitation.

Six private wells and two municipal water supply wells owned by YVWD (YVWD-31 and YVWD-36) were drilled in this subarea. The estimated thickness of alluvium in this subarea ranges from land surface at the contact with the San Bernardino Mountains to 430 feet, the depth at which bedrock was encountered when drilling YVWD-36. The static depths-to-water (DTW) measured at YVWD-31 and YVWD-36 ranged from 200 to 260 feet below ground surface (bgs) in the 1990s, or at elevations of 2,880 to 2,950 feet above NAVD88. No groundwater levels were measured at these wells after 1999. Moreland (1970) noted that, "the water table ranges from a few feet below land surface near the mountain front to 300 feet below land surface at well 1S/2W-24H1 in the central part of the subbasin."

Annual groundwater production in the Triple Falls Creek subarea from the 1966 WY to 2014 WY has ranged between approximately 85 AF (2014 WY) to 750 AF (1983 WY) (Alzraiee et al. 2020). The volume of groundwater produced in the 2014 WY was approximately 85 AF (Alzraiee et al. 2020). Production since the 1995 WY has been attributed to private well users, which has steadily decreased from a peak of approximately 290 AFY in the 1999 WY to 85 AFY in the 2014 WY. One municipal water supply well, YVWD-36, was active from 1965 to 1993. Municipal water supply well YVWD-31 never produced groundwater.

2.5.1.2 Oak Glen Subarea

The Oak Glen subarea is bounded to the north by the Oak Glen Fault (adjacent to the Triple Falls Creek subarea), to the east by the Yucaipa Hills, to the west by the Casa Blanca Barrier, and the south by the South Mesa Barrier (Figure 2-14). The area of the subarea is approximately 3,660 acres with land surface elevations ranging from approximately 2,500 feet above NAVD88 in the southwest corner of the subarea to 4,900 feet above NAVD88 in the northeast corner. The upper reaches of Wilson Creek and Oak Glen Creek run northeast to southwest through the subarea (Figure 2-1). Sources of water to this subarea include infiltrating stream flow from Wilson Creek, Oak Glen Creek, and Wildwood Creek, subsurface flows from the adjacent Yucaipa Hills (i.e., mountain front recharge) and the adjacent Triple Falls Creek subarea to the north, and deep percolation from direct precipitation.

The Oak Glen subarea includes the Wildwood Creek detention basins, which were built by the City of Yucaipa to control flooding and mitigate damage to downstream, adjacent residential properties of Wildwood Creek. The detention basins include a desilting basin, two retention basins, and a bioretention swale that bypasses the desilting and detention basins and conveys low flows and first flush flows (URS 2007). Stormwater runoff contained by the retention basins is a source of local recharge to the underlying aquifer.

YVWD operates eight (8) municipal water supply wells in the subarea, with a few other wells used for monitoring groundwater elevations. There are also 8 private wells in the subarea (Alzraiee et al. 2020). The aquifer thickness in the subarea ranges from land surface at the contact with the Yucaipa Hills to 420 feet, the depth at which bedrock was encountered when drilling YVWD-50, which is located near the southwestern corner of the subarea and the farthest from the Yucaipa Hills (Figure 2-14). Static groundwater elevations have ranged from 2,275 feet above NAVD88 at YVWD-50 to 3,837 feet above NAVD88 at well YVWD-25, which is located in the higher elevations of the subarea at approximately 3,880 feet above NAVD88.

Annual groundwater production in the Oak Glen subarea from the 1966 WY to 2014 WY has ranged from approximately 150 AFY (2011 WY) to 600 AFY (1995 WY) (Alzraiee et al. 2020). The volume of groundwater produced in the 2014 WY was approximately 160 AF (Alzraiee et al. 2020). Production has steadily declined since the peak of approximately 600 AF in the 1995 WY to 160 AFY in the 2018 WY. Approximately 60 AFY has been produced by private well users since the 1998 WY (Alzraiee et al. 2020).

Infrastructure is in place to divert surface water from Birch Creek and Oak Glen Creek to the Oak Glen Surface Water Filtration Facility (OGSWFF), but no surface water has been diverted from Birch Creek since 2009 and from Oak Glen Creek since 2017 because of "numerous clay pipe transmission line failures" (personal communication with YVWD, 9/4/2020). Water produced from well YVWD-25 is under the direct influence of surface water from nearby Oak Glen Creek. Water produced from YVWD-25 is treated at the OGSWFF located approximately 0.25 mile west of YVWD-25. Since the 2001 WY, YVWD-25 has delivered 192 AFY to 342 AFY of water to the OGSWFF.

2.5.1.3 Gateway Subarea

The Gateway subarea is bounded to the north by the San Andreas Fault (adjacent to the Triple Falls Creek subarea), to the east by the Casa Blanca Barrier, to the south by the Chicken Hill Fault, and to the west by the Yucaipa Graben Complex (Figure 2-14). The area of the subarea is approximately 1,500 acres. Land surface elevation ranges from approximately 2,460 feet above NAVD88 in the southwest corner to 3,400 feet above NAVD88 in the northeast corner. The subarea includes the Wilson Creek spreading basins, where a branch of the SWP pipeline along Bryant Street connects to these spreading basins and surplus SWP water is diverted for artificial recharge purposes. Sources of water to this subarea include infiltrating stream flow from Wilson Creek and Oak Glen Creek, subsurface flows from the adjacent Triple Falls Creek and Oak Glen subareas, imported SWP water discharged to the Wilson Creek and Oak Glen spreading basins, irrigation return flows and deep percolation from direct precipitation.

YVWD owns nine municipal water supply wells in the subarea. The aquifer thickness in the subarea ranges from 380 feet to 1,210 feet, the depths at which bedrock were encountered when drilling YVWD-44 and YVWD-53, respectively. Static groundwater elevations have ranged from 2,178 feet above NAVD88 at YVWD-56 to 2,661 feet above NAVD88 at well YVWD-43, which is the farthest north well in the subarea near the Oak Glen Fault.

Annual groundwater production in the Gateway subarea from the 1966 WY to 2014 WY has ranged from approximately 570 AFY (1983 WY) to 3,100 AFY (2005 WY) (Alzraiee et al. 2020). The volume of groundwater produced in the 2014 WY was approximately 2,260 AF (Alzraiee et al. 2020). Private well users produced approximately 1,000 AFY from the mid-1960s to early 1970s, and then steadily decreased production to approximately 90 AFY in the 2001 WY. No production by private well users occurred after the 2001 WY (Alzraiee et al. 2020).

2.5.1.4 Wilson Creek Subarea

The Wilson Creek subarea is bounded to the north and west by the Chicken Hill Fault (adjacent to the Gateway subarea), to the east by the Casa Blanca Barrier, and to the south by the South Mesa Barrier (Figure 2-14). The area of the subarea is approximately 1,250 acres. Land surface elevation ranges from approximately 2,330 feet above NAVD88 in the southwest corner to 2,960 feet above NAVD88 in the northeast corner. Sources of water to this subarea include infiltrating stream flow from Wilson Creek and Oak Glen Creek, subsurface flows from the adjacent Gateway and Oak Glen subareas, irrigation return flows and deep percolation from direct precipitation.

YVWD owns four (4) municipal water supply wells in the subarea. The aquifer thickness in the subarea ranges from approximately 600 feet at YVWD-6 to 1,150 feet at YVWD-46. Static groundwater elevations have ranged from 2,185 feet above NAVD88 to 2,452 feet above NAVD88.

Annual groundwater production in the Wilson Creek subarea from the 1966 WY to 2014 WY has ranged from 0 AF (1988 WY) to 2,100 AFY (2001 WY) (Alzraiee et al. 2020). Well YVWD-46 came online in 1990 and has been the only municipal water supply well operating in this subarea since 2011. The annual average production by YVWD-46 from the 2011 WY to 2018 WY is 1,500 AFY. No private well users produced groundwater in this subarea from the 1966 WY to the 2018 WY (Alzraiee et al. 2020).

2.5.1.5 Crafton Subarea

The Crafton subarea is bounded to the north by the Oak Glen Fault, to the east by the Yucaipa Graben Complex, to the south by the South Mesa Barrier and to the west by the Crafton Hills Fault (Figure 2-14). The area of the subarea is approximately 1,360 acres. Land surface elevation ranges from approximately 2,330 feet above NAVD88 in the southeast corner to 3,040 feet above NAVD88 in the northeast corner. Sources of water to this subarea include subsurface flows from the adjacent Crafton Hills (i.e., mountain front recharge), subsurface flows from the adjacent Triple Falls Creek, Gateway and Wilson Creek subareas, irrigation return flows and deep percolation from direct precipitation.

The Crafton subarea also includes the Yucaipa Regional Park, which consists of three surface water reservoirs, called the Yucaipa Lakes, that receive leakage from the nearby Crafton Hills Reservoir. The three Yucaipa Lakes were constructed with clay and asphaltic liners, each with a drain blanket underneath to capture leakage. SBVMWD owns and manages the Yucaipa Lakes and reported that no “significant amount of water [i.e., leakage] was ever recorded” from the Yucaipa Lakes (SBVMWD personal communication 2020). SBVMWD estimates that any leakage from the Yucaipa Lakes is negligible. The Crafton Hills Reservoir is part of the East Branch Aqueduct that brings SWP water to the Yucaipa area. The reservoir is managed by DWR, which reported that, on average, seepage from the two reservoir dams is approximately 50 gpm. The seepage flows in the natural drainages leading from the reservoir to Yucaipa Lakes Reservoir 2 (the middle lake) (DWR, pers. comm., 2020).

YVWD owns four municipal water supply wells in the subarea. The aquifer thickness in the subarea ranges from land surface at the contact with the Crafton Hills to 860 feet at YVWD-57. Static groundwater elevations have ranged from 2,187 feet above NAVD88 at YVWD-57 to 2,642 feet above NAVD88 at well YVWD-37.

Annual groundwater production in the Crafton subarea from the 1966 WY to 2014 WY has ranged from approximately 20 AF (2010 WY) to 310 AF (1994 WY) (Alzraiee et al. 2020). The volume of groundwater produced in the 2014 WY was approximately 30 AF (Alzraiee et al. 2020). Groundwater production has averaged 160 AFY since 1970. No private well users produced groundwater in this subarea from the 1966 WY to the 2018 WY (Alzraiee et al. 2020).

San Bernardino County maintains the former Yucaipa Landfill, which is located on the slopes of the Crafton Hills south and adjacent to the Yucaipa Regional Park. A network of shallow groundwater monitoring wells is sampled periodically to monitor contaminants originating from wastes buried at the landfill. Further discussion of the contaminants detected in the shallow groundwater at this former landfill site is discussed in Section 1.5.4 Water Quality. In summary, no contaminants have migrated from the former landfill site to adversely impact water quality at nearby municipal water supply wells YVWD-55 and YVWD-57.

2.5.1.6 Calimesa Subarea

The Calimesa subarea is bounded to the north by the South Mesa Barrier, to the east by the Yucaipa Hills, to the south by the Banning Fault, and to the west by the Chicken Hill Fault (Figure 2-14). The subarea is approximately 5,290 acres in area. Land surface elevation ranges from 1,900 feet above NAVD88 in the southwest corner of the subarea to 3,000 feet above NAVD88 at the farthest eastern extent rising up into the Yucaipa Hills. Sources of water to this subarea include infiltrating stream flow from Yucaipa Creek, subsurface flows from the Yucaipa Hills and the adjacent Oak Glen, Wilson Creek and Singleton subareas, irrigation return flows, and deep percolation from direct precipitation. Moreland (1970) stated, “underflow across the South Mesa barrier and runoff from the Yucaipa Hills are the primary sources of recharge to the subbasin.”

There are 16 municipal water supply wells that are owned and operated by YVWD and South Mesa in the Calimesa subarea. Eight of the 16 municipal water supply wells have been actively producing water in the last 5 years. South Mountain owns two irrigation supply wells, Chicken Hill and Hog Canyon 2, that pump groundwater to the Crafton Hills College located partly in the Western Heights subarea.

Annual groundwater production in the Calimesa subarea from the 1966 WY to 2014 WY has ranged from approximately 3,400 AF (1969 WY) to 6,500 AF (2002 WY) (Alzraiee et al. 2020). The volume of groundwater produced in the 2014 WY was approximately 4,600 AF (Alzraiee et al. 2020). Groundwater production has averaged approximately 3,300 AFY from the 2015 WY to 2018 WY.

The depth to bedrock ranges from 375 feet bgs (well South Mesa-02) to >1,400 feet bgs (well South Mesa-09). There are 8 private wells in the subarea, one of which is the only well that has produced groundwater since the 2007 WY. This well, located just east of the Chicken Hill Fault, produced approximately 190 AFY from the 2007 WY to the 2018 WY (Alzraiee et al. 2020).

Historically, static groundwater elevations measured in the Calimesa subarea have ranged from 1,942 feet above NAVD88 at the Hog Canyon 2 well to 2,276 feet above NAVD88 at well YVWD-02. Groundwater elevations measured across the South Mesa Barrier and the Chicken Hill Fault indicate that they influence groundwater flow. Groundwater elevations measured at wells on either side of the Chicken Hill Fault indicate a hydraulic head difference of approximately 300 feet (see Section 2.5.1.7). The hydraulic head difference across the South Mesa Barrier is approximately 100 to 200 feet (see Section 2.9.2). The Banning Fault, as mentioned in Section 2.4.1.3.2, does not influence groundwater flow, although it does mark the southern boundary of the Calimesa subarea.

2.5.1.7 Western Heights Subarea

The Western Heights subarea is bounded to the north by the South Mesa Barrier, to the east by the Chicken Hill Fault, to the south by the Banning Fault, and to the west by Crafton Hills (Figure 2-14). The area of the Western Heights subarea is approximately 2,500 acres. Land surface elevations range from 1,900 to 2,500 feet above NAVD88. WHWC is the sole water purveyor in the subarea. Sources of water to this subarea include infiltrating stream flow from unlined sections of Oak Glen Creek, subsurface flows from the Crafton Hills and the adjacent Crafton, Calimesa and Live Oak subareas, irrigation return flows, septic system discharges, and deep percolation from direct precipitation. WHWC began purchasing SWP water from YVWD in 2008 to supplement its water supply, which led to a reduction in groundwater pumping from an average of 2,500 AFY in the 5 years prior to 2008 to 1,900 AFY after 2008.

The Chicken Hill Fault, which marks the boundary between the Western Heights and Calimesa subareas, has a marked influence on groundwater flow. Hydraulic heads measured at wells WHWC-11 and WHWC-12, located west of the Chicken Hill Fault in the Western Heights subarea, were approximately 300 feet lower than hydraulic heads measured at wells YVWD-49 and City of Redlands wells Chicken Hill and Hog Canyon 2, located east of the fault in the Calimesa subarea (Figure 2-15, Hydraulic Heads across the Chicken Hill Fault).

WHWC owns and operates eight municipal water supply wells in the Western Heights subarea. Private well users stopped producing groundwater in 2000. Annual groundwater production from the 1966 WY to 2014 WY has ranged from approximately 1,900 AF (2010 WY) to 3,200 AF (1998 WY) (Alzraiee et al. 2020). The volume of groundwater produced in the 2014 WY was approximately 2,100 AF (Alzraiee et al. 2020). Wells WHWC-10, WHWC-11, WHWC-12 and WHWC-14 have collectively produced groundwater in the last 10 years at an average annual rate of 1,900 AFY. The estimated alluvial thickness in the Western Heights subarea ranges from 0 feet at the contact with the Crafton Hills to approximately 1,100 feet, which was the depth to bedrock reported in the driller's log for well WHWC-14.

2.5.1.8 Singleton Subarea

The Singleton Subarea is bounded to the east and south by the southern flank of the Yucaipa Hills, and to the north and west by the Banning Fault and a splay of the San Gorgonio Pass Fault Zone (Figure 2-14). The area of the Singleton subarea is approximately 700 acres. Land surface elevations range from 2,400 to 3,040 feet above NAVD88. Sources of water to this subarea include infiltrating stream flow from an unnamed tributary that terminates at small spreading basins located near the southwestern boundary between the Yucaipa Subbasin and the adjudicated Beaumont Basin, subsurface flows from the adjacent Calimesa subarea, irrigation return flows and deep percolation from direct precipitation.

YVWD operated municipal water supply well YVWD-47 from 1987 to 1994 at an average rate of 17 AFY. YVWD-47 has not produced water since 1994. Three private wells located in this subarea have not produced groundwater since the 1966 WY (Alzraiee et al. 2020). The estimated alluvial thickness ranges from 0 feet at the contact with the Yucaipa Hills to >300 feet, the total depth of well YVWD-47. No bedrock was encountered when drilling YVWD-47.

2.5.1.9 Live Oak Subarea

The Live Oak subarea is the farthest downgradient subarea in the Yucaipa Subbasin and includes the lowest reach of Yucaipa Creek to where it joins San Timoteo Creek (Figure 2-14). Surface water flow out of the Yucaipa Subbasin is in San Timoteo Creek. The Live Oak subarea is bounded to the north by the Banning Fault and the City of Redlands, to the east and south by a ridgeline marking the boundary of the minor Yucaipa Creek watershed and terminates where San Timoteo Creek leaves the Yucaipa Subbasin and continues to the Santa Ana River. The subarea is approximately 5,000 acres. Land surface elevation ranges from 2,500 feet above NAVD88 at the eastern corner of the subarea to 1,280 feet above NAVD88 where San Timoteo Creek leaves the Yucaipa Subbasin. Sources of water to this subarea include infiltrating stream flow from Yucaipa Creek, San Timoteo Creek and other minor tributaries, subsurface flows from the adjacent Western Heights and Calimesa subareas, and deep percolation from direct precipitation.

South Mesa owns and operates three municipal water supply wells, South Mesa-01, South Mesa-05 and South Mesa-07, in the upper eastern portion of the subarea. Wells South Mesa-05 and South Mesa-07 are active and have produced an average 550 AFY from 2014 WY to 2018 WY. South Mesa-01 historically produced water, but is currently used to measure static groundwater levels. Static groundwater elevations in the upper eastern portion of the subarea have ranged from 1,978 feet above NAVD88 to 2,268 feet above NAVD88 since 1966 (Figure 2-16, Hydraulic Heads at South Mesa Wells 1, 5, and 7). There are no other municipal water supply wells in the subarea.

YVWD installed a network of shallow groundwater observation wells to monitor groundwater levels as part of the Habitat Monitoring Program implemented along San Timoteo Creek (Section 1.5.1.2). The shallow observation wells indicate that the depth-to-groundwater is approximately 2 to 20 feet along the reach of San Timoteo Creek in the Yucaipa Subbasin. This reach of San Timoteo Creek includes groundwater dependent ecosystems (GDEs). There are approximately 140 acres of citrus groves along the west bank of San Timoteo Creek beginning approximately 0.7 miles downstream of the confluence of Yucaipa Creek and San Timoteo Creek. There is one known irrigation supply well within the citrus groves, but other wells operating outside the Subbasin and located in the hills west of San Timoteo Canyon supply irrigation water to the groves. SBCFCD created a series of flood control basins in the last 0.7 miles of San Timoteo Creek before it leaves the Yucaipa Subbasin.

2.5.2 Principal Aquifer

The principal aquifer in the Yucaipa Subbasin comprises the Sedimentary deposits of Live Oak Canyon and the underlying San Timoteo Formation. The majority of public water supply wells are screened in these two formations. Cromwell and Matti (2020) note that the "Sedimentary deposits of Live Oak Canyon are the primary aquifer unit in the Yucaipa Subbasin." The water table exists almost exclusively within this unit. The estimated transmissivity is 25,000 gallons per day per foot (gpdf), or 3,340 square feet per day (Dutcher and Fenzel 1972). The hydraulic conductivity was estimated at 220 gallons per day per square foot ($gpdf^2$), or 30 feet per day, using a saturated thickness of 116 feet at the time of the aquifer test.

Cromwell and Matti (2020) note that "sediments of the San Timoteo formation are more compacted, consolidated, cemented and have a greater abundance of clay and silt relative to the overlying Sedimentary deposits of Live Oak Canyon and Quaternary surficial material. The estimated transmissivity for the San Timoteo formation is 3,000 gpdf, or 400 square feet per day (Dutcher and Fenzel 1972). The estimated hydraulic conductivity of the San Timoteo formation, based on a saturated thickness of 600 feet when the test was conducted, was approximately 5 $gpdf^2$, or 1 foot per day.

2.5.2.1 Safe Yield

Geoscience Support Services, Inc. (GSSI) conducted a study to estimate the useable storage capacity and safe yield in the Yucaipa Subbasin and for its subareas (GSSI 2014a). GSSI (2014a) defined safe yield as a "sustainable yield," which takes into account natural and anthropogenic sources of recharge to the Subbasin. Natural recharge occurs from infiltration of rainfall, streambed recharge and mountain-front recharge. Anthropogenic sources derive from return flows from applied irrigation, septic systems and imported water to artificially recharge the Subbasin. GSSI (2014a) applied three different methods to estimate the safe yield: zero-net draft method, the Hill method, and applied a hydrologic water balance to the Yucaipa Subbasin using a watershed model.

The zero-net draft method "involves plotting average groundwater elevation for a selected period of time, and comparing it to groundwater production for the same period. If the mean groundwater elevation at the beginning and end of the period is the same, the production during the period is taken as a measure of the sustainable yield" (GSSI 2014a). The Hill method includes comparing annual changes in groundwater elevations to annual production, with the safe yield equivalent to the annual production that resulted in a net zero change in groundwater elevation.

At the time of the GSSI study, the southern boundary of the Yucaipa Subbasin was defined by the Banning Fault. Therefore, it did not include the Singleton and Live Oak subareas, which were later included in the Yucaipa Subbasin when it was expanded during the basin boundary modification adopted by DWR in 2016. Table 2-6 summarizes the estimates of safe yield for the Triple Falls Creek, Oak Glen, Gateway, Wilson Creek, Crafton, Calimesa, and Western Heights subareas, and provides an estimate of safe yield for the Yucaipa Subbasin north of the Banning Fault. An estimate of the sustainable yield, as defined under the Sustainable Groundwater Management Act (SGMA), for the entire Yucaipa Subbasin (including the Singleton and Live Oak subareas) is presented in Section 2.8.6.

Table 2-6. Estimated Safe Yields in the Yucaipa Subbasin

Subarea	Estimates of Safe Yield (AFY)		
	Zero-Net Draft	*Hill Method*	*Hydrologic Water Balance*
Triple Falls Creek	215	310	—
Oak Glen	415	600	—
Gateway	1,775	1,440	—
Wilson Creek	1,520	1,245	—
Crafton	200	370	—
Calimesa	3,195	3,580	—
Western Heights	2,270	2,100	—
Total for Yucaipa Subbasin[1]	**9,590**	**9,645**	**9,683**

Notes: AFY = acre-feet per year.
1 Excludes the Singleton and Live Oak subareas south of the Banning Fault.

2.5.3 Groundwater Production Wells

The California Department of Water Resources designated the Yucaipa Subbasin as a high priority basin. This designation resulted from a dependence on groundwater as a local source of water, the density of water production wells per square mile in the Subbasin, and the population being reliant on the local water supply. There are 90 water supply wells in the Subbasin, with approximately one-third of those wells being privately owned and used to produce domestic and/or irrigation water supply (Figure 2-17, Well Locations and Well Owners Within the Yucaipa Subbasin; Tables 2-7a, 2-7b). YVWD maintains 34 municipal water supply wells within the Subbasin, with 12 currently active. YVWD reported approximately 4,600 AF of groundwater production from within the Subbasin in WY 2018.

YVWD also maintains 24 wells outside the Subbasin, 20 of which produce groundwater from the fractured San Gabriel-type rock in the Yucaipa Hills. These wells supply water to the local communities outside the Subbasin, but within YVWD's service area. YVWD also maintains three wells, YVWD-34, YVWD-35, and YVWD-48, in the adjudicated Beaumont basin. Wells YVWD-34 and YVWD-35 are inactive and used for monitoring purposes only, but YVWD-48 is active and supplies water to a portion of YVWD's service area within the Singleton, Calimesa and Live Oak subareas. Well YVWD-51 is northwest of the Subbasin in the Mill Creek subbasin and produces water for the local community within YVWD's service area. No groundwater produced from YVWD-51 enters the Subbasin.

WHWC maintains 10 municipal water supply wells (4 are currently active), all within the Western Heights subarea, and South Mesa maintains 12 municipal water supply wells in the Calimesa and Live Oak subareas (seven are currently active). South Mesa also has two municipal water supply wells outside the Subbasin in the adjudicated Beaumont basin. One of these wells, South Mesa-04, is active and conveys water to South Mesa's drinking water distribution system in its service area. The other well, South Mesa-03, is inactive and used to measure groundwater elevations only. Both mutual water companies produced approximately 2,000 AF from the Yucaipa Subbasin in the 2018 WY.

There are 1.5 municipal water supply wells per square mile in the Subbasin (Tables 2-7a, 2-7b). Figure 2-17 includes the status for each of the municipal water supply wells: "production wells" are connected to their respective water agency's drinking water distribution system and are active or inactive, "abandoned" wells are abandoned and/or destroyed wells that are no longer accessible, and "monitoring" wells are existing wells used only for monitoring purposes (e.g., measuring groundwater elevations and/or collecting water quality samples).

Table 2-7a. Wells in the Yucaipa Subbasin

Public Agency or Private Well Owners	Number of Water Supply Wells in Subbasin	Number of Active Wells in Subbasin
YVWD	34	12
WHWC	10	4
South Mesa	12	7
South Mountain	2	2
Private	32	5
Total number of wells	**90**	**30**

Table 2-7b. Plan Area and Wells per Square Mile

Plan Area/Wells per Square Mile	Area/Number
Area of Plan Area (square miles)	39.5
Public supply wells per square mile (number)	1.5
Total wells per square mile (number)	**2.3**

Prior to 1900, water supply in Yucaipa Valley was sourced from naturally flowing streams originating from the adjacent mountains, and from spring flow along the Chicken Hill Fault Zone (YVWD 2008). A number of wells completed in the western portion of the valley were artesian. From 1900 to 1930, the valley experienced an increase in agricultural development along with an increase in groundwater production. After 1945, groundwater production from the principal aquifer increased due to further expansion and development of residential communities in the Plan Area. Total groundwater production averaged approximately 10,000 AFY from the late 1960s into the mid-1980s (Figure 2-18, Annual Groundwater Production by Water Agency in the Yucaipa Subbasin). Pumping data included in Figure 2-18 was obtained from the USGS Yucaipa Integrated Hydrologic Model (YIHM) numerical model and represents pumping during the historical period from 1947 to 2014 (Alzraiee et al. 2020).

Further expansion and development in the Plan Area after 1985 increased the water demand to where groundwater production approached 15,000 AFY and markedly exceeded the estimated safe yield of 9,640 AFY (average of the three methods used to estimate the safe yield in Table 2-6) for the Yucaipa Subbasin (GSSI 2014a). The maximum amount of groundwater produced was approximately 15,400 AF in the 2002 WY (Figure 2-18).

Annual production by private well owners in the late 1960s averaged approximately 3,200 AFY, which was comparable to the average annual production of 3,300 AFY by YVWD (Figure 2-18). The peak production by private well owners was approximately 3,900 AF in the 1966 WY, which constituted 33% of the total production from the Subbasin. Since the 1966 WY, production by private wells steadily declined to an average 375 AFY after 2005, or less than 4% of the total production from the Subbasin.

Production by YVWD steadily increased from 1984 to 2002 to a peak of approximately 9,100 AFY in the 2002 WY (Figure 2-18). YVWD production averaged 60% of the total production from the Subbasin. Groundwater production by YVWD markedly declined after the 2007 WY when YVWD began importing SWP water as a supplement to its water supply. In that water year, YVWD purchased 3,539 AF SWP water from SBVMWD, to which all of it was delivered to the YVWRFF for treatment. Consequently, groundwater production by YVWD declined from 7,800 AF in the 2007 WY to 6,300 AF in the 2008 WY. YVWD pumped an average 6,000 AFY between the 2008 WY and 2015 WY until a further decline in groundwater production occurred during the 2016 WY when production fell to 3,900 AF. YVWD averaged 3,900 AFY between the 2016 WY and 2018 WY. The decrease in groundwater production was attributed to the use of recycled water beginning in the 2015 WY and an increase in the amount of SWP water imported via SBVMWD that, together, reduced the demand for groundwater. YVWD's share of the total groundwater produced from the Subbasin was approximately 50% between the 2016 WY and 2018 WY, with the remaining production coming from WHWC and South Mesa.

WHWC and South Mesa showed steady increases in groundwater production since the early 1980s. The peak annual production by WHWC was 3,000 AF in the 1998 WY, which was approximately 25% of the total production from the Subbasin in that water year. WHWC began purchasing water from YVWD in the 2008 WY. Consequently, the average annual groundwater production by WHWC declined from approximately 2,500 AF (1998 WY–2008 WY) to 1,800 AF (2009 WY–2018 WY) (Figure 2-18). Recent groundwater production by WHWC has declined to a level comparable to production in the early 1980s.

The recent peak annual production by South Mesa was 2,300 AF in the 2003 WY, which was approximately 16% of the total production from the Subbasin (Figure 2-18). Groundwater production by South Mesa has declined since then to an average annual rate of approximately 1,900 AFY in the last five years. South Mountain operates two water supply wells within the Calimesa subarea, which deliver water to locations outside the Calimesa subarea for irrigation purposes only. Production by these wells has averaged an annual rate of approximately 700 AF between the 1966 WY and 2005 WY. After which, the wells were idle until the 2014 WY. These wells averaged approximately 220 AFY after they resumed production in 2014 (Figure 2-18).

The majority of groundwater production has consistently been from the Calimesa and Western Heights subareas (Figure 2-19, Annual Groundwater Production by Hydrogeologic Subarea in the Yucaipa Subbasin). Production increased in the Gateway and Wilson Creek subareas after the 2000 WY to annual rates comparable to production in the Western Heights subarea. Production in the Oak Glen, Triple Falls Creek, Crafton, and Singleton subareas has each been below 250 AFY since the 2009 WY. The primary use of groundwater produced from the principal aquifer is for municipal water supply.

2.5.4 Supplemental Water

2.5.4.1 Groundwater Under the Influence of Surface Water

YVWD uses well YVWD-25 as a source of supply for the OGSWFF. Groundwater produced by this well is under the direct influence of surface water from nearby Oak Glen Creek and requires additional treatment for the production of drinking water. YVWD-25 previously pumped approximately 300 AFY until production was reduced to approximately 200 AFY after the 2012 WY (Figure 2-20, Groundwater under the Influence of Surface Water).

2.5.4.2 Surface Water Diversions

YVWD constructed diversion structures to divert surface water from Oak Glen Creek and Birch Creek, which is tributary to Oak Glen Creek. YVWD historically diverted an average 40 AFY from the 2001 WY to 2018 WY at the Oak Glen Creek diversion, and an average of 70 AFY from the 2001 WY to 2009 WY at the Birch Creek diversion point. No surface water has been diverted from Birch Creek since the 2009 WY. Surface water diversions from Oak Glen Creek have declined to approximately 1 AFY or less since the 2018 WY. Both surface water diversion structures have experienced clogging and other technical issues that prevent further diversions of surface water.

The Oak Glen Creek basins, located 0.25 miles south of the Wilson Creek basins, were constructed to control flooding, enhance the infiltration of stormwater to the underlying groundwater, and create a wildlife habitat and ecological landscape for the public. The Wilson Creek basins are primarily used to artificially recharge the Yucaipa Subbasin using surplus SWP water delivered via the SWP East Branch Extension. Both basins have received surplus SWP water. The Wilson Creek spreading basins have received the majority of surplus SWP water with a peak discharge of 6,579 AF in the 2017 WY (Figure 2-21, Annual Distribution of State Water Project Water in the Yucaipa Subbasin).

The Wildwood Creek detention basins include a desilting basin, two retention basins, and a bioretention swale that bypasses the desilting and detention basins and conveys low flows and first flush flows (URS 2007). Stormwater runoff contained by the retention basins is a source of local recharge to the underlying aquifer. Other stormwater retention basins have been constructed in the Subbasin and are summarized in Section 4.3, Projects, of Chapter 4, Projects and Management Actions.

2.5.4.3 State Water Project

YVWD began purchasing SWP water from SBVMWD in the 2003 WY. YVWD purchased 855 AF of SWP water from SBVMWD in that water year (Figure 2-21). YVWD may also purchase and import SWP water from SGPWA, but only purchased 226 AF of SWP water in the 2019 WY (not included in Figure 2-21). The SWP water purchased from SBVMWD from the 2003 WY to 2006 WY was treated at the YVWRFF for distribution in YVWD's drinking water distribution system. Some surplus SWP water (48 AF) was diverted to the Oak Glen Creek spreading basins in the dry 2009 WY, but it wasn't until the 2011 WY, which was characterized as a "wet" water year type with 22.24 inches of rainfall, when approximately 1,500 AF of surplus SWP water was diverted to the Wilson Creek spreading basins (the Oak Glen Creek spreading basins received 141 AF).

Over the subsequent two water years, which were characterized as "below normal" and "critically dry" water year types, YVWD imported approximately 9,000 AFY, with approximately 3,000 AFY of surplus SWP water being discharged to the Wilson Creek and Oak Glen Creek spreading basins. Despite the drier climatic conditions, there was a surplus of water banked by DWR that was made available up to two years after the "wet" 2011 WY. The extended drought through the next three water years (2013-2014 to 2015-2016) resulted in no surplus water and a general decline of SWP water available (Figure 2-21). The subsequent 2017 WY, which was characterized as an "above normal" water year type with 17.75 inches of rainfall, resulted in the peak purchase of 15,343 AF, to which 6,579 AF of surplus water was discharged to the Wilson Creek spreading basins. In the subsequent 2018 WY, which was characterized as "critically dry" with 6.50 inches of rainfall, the same volume of SWP water was purchased and transferred to the YVWRFF for treatment, but only 1,700 AF of surplus water was available to discharge to the spreading basins (Figure 2-21).

2.6 Hydrogeologic Conceptual Model

The Emergency Groundwater Sustainability Plan regulations (Section 354.14) state that each Plan "shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterize the physical components and interaction of the surface water and groundwater systems in the basin." The previous sections in this chapter characterized the physical components that influence the groundwater resources in the Subbasin.

In summary, the Yucaipa Subbasin exists in a "right-step-over" zone between the active San Andreas and San Jacinto Fault Zones. The Yucaipa Plain lies between these two fault systems and comprises an extensive deposition of Quaternary sediments originating from the San Bernardino Mountains and Yucaipa Hills. The "right-step-over" zone created by the lateral displacement along the San Andreas and San Jacinto Fault Zones created a series of northeast-southwest trending normal-slip faults. Displacement along these faults, in turn, created drop-down structures that filled in with Quaternary alluvial sediments (Figure 2-12).

The geologic units defined within the Yucaipa Subbasin are Mesozoic and older crystalline bedrock, the Plio-Pleistocene San Timoteo Formation, and the Quaternary Sedimentary Deposits of Live Oak Canyon and surficial alluvial deposits. The crystalline bedrock provides the base for the sedimentary deposits in the Yucaipa Subbasin. The San Timoteo Formation and the Sedimentary Deposits of Live Oak Canyon define the principal aquifer in the Yucaipa Subbasin. The primary use of groundwater produced from the principal aquifer is for municipal water supply. The Yucaipa Subbasin is divided into nine hydrogeologic subareas based on the apparent influences of faults (both mapped and inferred) on groundwater flow (Figure 2-14).

In 2009, the USGS conducted a gravity anomaly survey to estimate the depths to bedrock in the Yucaipa Subbasin and thickness of alluvial fill in the Yucaipa Valley (Mendez et al. 2016). The Yucaipa Subbasin is underlain by San Gabriel-Mountain type bedrock between the San Andreas Fault and the Banning Fault, and by Peninsular Ranges-type bedrock south of the Banning Fault. The USGS estimated the thickness of alluvial deposits in the basin to approximately 3,000 feet in the Western Heights subbasin, to approximately 7,000 feet south of the Banning Fault (Mendez et al. 2016). The estimated alluvial thickness in the Live Oak subbasin ranges from approximately 2,000 feet to 5,000 feet.

The major surface water drainages in the Yucaipa Subbasin include Wilson Creek, Oak Glen Creek, Yucaipa Creek and San Timoteo Creek. San Timoteo Creek conveys surface water out of the Plan Area and is tributary to the Santa Ana River. Surficial soils mapped in the Plan Area indicate that the surface water drainages are underlain by highly permeable loamy sand with relatively high infiltration rates; thereby, indicating that leakage from stream flow is a major contributor to groundwater recharge.

The following geologic cross-sections provide scaled details of the physical features that influence groundwater flow and provide a visual approximation of the storage capacity of the Subbasin. The construction details of some public water supply wells are provided to give context to where groundwater is produced from the Subbasin.

2.6.1 Geologic Cross-Sections

Geologic cross-sections prepared by Mendez (2016) and GSSI (2014a) were the foundational pieces used to develop geologic cross-sections characterizing the geometry of the Yucaipa Subbasin, including the thickness of the principal aquifer and location of fault structures that defined the boundaries of the hydrogeologic subareas. Figure 2-22, Geologic Map with Delineations of Geologic Cross-Sections, shows the orientations of cross-sections A–A′ through E–E′ in the Subbasin. Each cross-section identifies the depth to bedrock, the apparent thicknesses of the San Timoteo Formation, the Sedimentary deposits of Live Oak Canyon, and younger alluvium based on lithologic logs recorded when drilling wells and exploratory borings in the Subbasin.

Cross-Section A–A′ traverses northeast to southwest across the Yucaipa Subbasin between the Wilson Creek and Oak Glen Creek spreading basins, parallels the Chicken Hill Fault, and runs through the Western Heights subarea and terminates in the Live Oak subarea. (Figure 2-22). The A–A′ profile indicates a gradual thickening of the principal aquifer from approximately 0 feet at the base of the San Gabriel Mountains to 1,200 feet near the intersection of the Chicken Hill Fault and South Mesa Barrier (Figure 2-23, Geologic Cross-Section A–A′). A marked drop to bedrock occurs in the Western Heights subarea to approximately 2,000 feet below NAVD88, a drop of approximately 3,000 feet. Well WHWC-11 was drilled to 1,720 feet bgs, the deepest well in the Subbasin, but no bedrock was encountered to that depth. Bedrock gradually rises to the southwest in the Western Heights subarea until it markedly drops again south of the Banning Fault.

Cross-Section B–B′ is based on investigative work conducted by GSSI and shows the basin profile perpendicular to the northeast-southwest orientation of the Yucaipa Subbasin and cross-section A–A′ (Figure 2-22). Cross-section B–B′ starts in the Crafton Hills and traverses southeast across the Yucaipa Regional Park, the Oak Glen Creek spreading basins, and into the Yucaipa Hills (Figure 2-24, Geologic Cross-Section B–B′). Profile B–B′ crosses the Crafton, Gateway, Wilson Creek and Oak Glen subareas. The thickest section of the Principal aquifer lies in the Gateway subarea where bedrock was encountered at 1,210 feet bgs while drilling YVWD-53.

Cross-Section C–C′ begins in the Crafton Hills and traverses south through the Crafton, Wilson Creek, Calimesa, and Live Oak subareas (Figure 2-22). The cross-section intersects the Chicken Hill Fault, the South Mesa Barrier and Banning Fault, plus Oak Glen Creek and Yucaipa Creek before terminating in the San Timoteo Badlands. The principal aquifer thickens along this profile south of the South Mesa Barrier in the Calimesa subarea. The thickest section is located near the Banning Fault where the principal aquifer is approximately 4,500 feet thick (Figure 2-25, Geologic Cross-Section C–C′). The two deepest wells drilled in the Calimesa subarea are South Mesa-09, drilled down to 1,400 feet bgs, and YVWD-49, drilled down to 1,200 feet bgs. Drilling logs for both wells indicated that no bedrock was encountered down to their respective total depths.

Cross-Section D–D′ begins at Crafton Hills College in the northern most point of the Western Heights subarea and runs south through Western Heights, crosses the Chicken Hill Fault into the Calimesa subarea, and then crosses the Banning Fault into the Live Oak subarea before terminating in the San Timoteo Badlands near San Timoteo Creek (Figure 2-22). The D–D′ profile crosses Oak Glen Creek and Yucaipa Creek (approximately 3,600 feet upstream of their confluence). The principal aquifer thickens to approximately 3,000 feet in the Western Heights subarea, before the bedrock drops markedly south of the Banning Fault to a depth at approximately 5,000 feet below NAVD88, or an alluvial thickness of approximately 7,000 feet (Figure 2-26, Geologic Cross-Section D–D′).

Cross-Section E–E′ begins in the Live Oak subarea and traverses east through the Calimesa and Oak Glen subareas before terminating in Wildwood Canyon (Figure 2-22). The E–E′ profile indicates a gradual thinning of the principal aquifer from east to west from the Live Oak subarea to Wildwood Canyon (Figure 2-27, Geologic Cross-Section E–E′). The thickness of the principal aquifer along this profile was estimated from results of the USGS gravity survey. The deepest well set at the USGS Equestrian Park site, well #1, encountered bedrock at 850 feet bgs.

2.6.2 Three-Dimensional Hydrogeologic Conceptual Model

A 3-dimenisonal block diagram of a portion of the Yucaipa Valley is shown in Figure 2-28. The conceptual model is orientated northeast to southwest and is bounded to the west and south by geologic cross-sections D–D′ and E–E′, and to the north and east by the Crafton Hills, San Bernardino Mountains, and Yucaipa Hills. The San Bernardino Mountains, Crafton Hills and Yucaipa Hills contributed to the alluvial sediments filling the Subbasin and are the sources of runoff to the major drainages: Wilson Creek, Oak Glen Creek, and Yucaipa Creek. The East Branch Extension of the SWP pipeline extends from the Crafton Hills Reservoir to Bryant Street and south with connections to the Wilson Creek spreading basins and YVWD's YVWRFF. The drop-down basin structure of the Yucaipa Subbasin is the result of tectonic activity between the major right-slip faulting along the San Andreas and San Jacinto fault zones. Movement along these fault structures affected groundwater flow, which, in part, led to the designation of hydrogeologic subareas in the Yucaipa Subbasin. The principal aquifer consists of the Sedimentary Deposits of Live Oak Canyon and the underlying San Timoteo Formation. The bottom of the principal aquifer is defined by San Gabriel Mountain-type bedrock north of the Banning Fault and by Peninsular Ranges-type bedrock south of the Banning Fault.

2.6.3 Data Gaps

The primary data gaps in the hydrogeologic conceptual model are as follows:

- Distributed measurements of aquifer properties in the principal aquifer. Representative estimates of aquifer properties, like hydraulic conductivity and storage, may be obtained from aquifer tests conducted at wells completed only in the principal aquifer. The information from aquifer tests is limited. Additional tests will provide critical information to enhance the characterization of the aquifer and improve the results of the USGS numerical model used for the water budget analysis for the Subbasin.
- Non-representative and/or inaccurate measurements of low-flow stream flow at the SBCFCD gauging stations. Accurate measurements of stream flow in Wilson Creek, Oak Glen Creek and Yucaipa Creek, at locations upstream and downstream of major reaches, will enhance our understanding of surface water runoff and leakage from the creeks to the underlying groundwater basin.
- Spatial limitations on groundwater elevation data. There are no wells completed in the principal aquifer in the eastern half of the Calimesa subarea and most of the Live Oak subarea. Groundwater elevation data collected in these areas will enhance our understanding of mountain front recharge to the Calimesa subarea from the adjacent Yucaipa Hills, and the influence of stream leakage from the Yucaipa Creek along its reach in the Live Oak subarea.
- Current groundwater elevation data demonstrating the influence of the Casa Blanca Barrier, Oak Glen Fault, and the Crafton Hills Fault Zone in the Live Oak subarea on groundwater flow.
- Confirmation of whether groundwater-dependent ecosystems (GDEs) identified as “potential GDEs” are groundwater dependent or not. Confirmation, for example, may come from the advancement of a boring to a depth greater than 30 feet bgs to characterize soil conditions and whether the water table was encountered (see Section 2.7.8).
- Limited to no information received to date by the Yucaipa GSA for private well users actively producing groundwater in the Subbasin. The Yucaipa GSA will continue to make efforts to contact existing and potential private well users to obtain information on well construction, production, and water quality to help inform that condition of the Subbasin.

The data gaps listed above create uncertainty in the understanding of the impacts of surface water and groundwater level changes on changes in storage in the aquifer. Additional aquifer tests, groundwater elevation data, and stream flow gauging stations in the future would help reduce the uncertainty associated with these data gaps.

2.7 Current and Historical Groundwater Conditions

The Emergency Groundwater Sustainability Plan regulations (Section 354.16) state that each Plan, “shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information.” The following section characterizes historical and current groundwater elevations, and the influence of climate and groundwater production on fluctuations in groundwater elevations observed since the 1965 water year. The following section also, per SGMA requirements, addresses seawater intrusion (Section 2.7.3), groundwater quality issues that may affect supply and beneficial uses of groundwater (Sections 2.7.4 through 2.7.6), land subsidence that may permanently affect aquifer storage (Section 2.7.7), and groundwater-surface water interactions and the identity of groundwater-dependent ecosystems that rely on shallow groundwater (Section 2.7.8).

2.7.1 Groundwater Elevation Data

The water purveyors YVWD, WHWC, South Mesa, and South Mountain measure DTW at their wells monthly. The DTW are either measured using an electric tape or an airline. The electric tape, or DTW sounder, is a double-wired and graduated tape fitted with a weighted probe at the end of the tape that houses a water sensor. The accuracy of the electric tape sounder is +/− 0.01 foot (Cunningham and Schalk 2011). The airline involves the pressurization of a dedicated tube, or airline, to displace water from it. The pressure required to displace all air is equivalent to the height of water above the bottom of the airline, which is then converted to a DTW. The accuracy of the airline ranges between +/− 0.1 to 1 foot (Cunningham and Schalk 2011). All DTW measurements are referenced to a surveyed measuring point that was referenced to the National Geodetic Vertical Datum of 1929 (NGVD29) or the NAVD88. Elevations referenced to the NGVD29 datum were converted to the NAVD88 datum using the U.S. Army Corps of Engineers software program, Corpscon 6.0 (ACOE 2004). This is a publicly owned, free software program that converts coordinates and vertical elevations between various datums used in the United States.

The USGS, in cooperation with SBVMWD, constructed a network of multiple-well monitoring sites to characterize groundwater conditions in the San Bernardino Basin Area and Yucaipa Subbasin (Mendez et al. 2018). The USGS installed four multiple-well monitoring sites in the Yucaipa Subbasin: Wilson Creek (YVWC), 6th and E (YV6E), Dunlap Acres (YVDA), and Equestrian Park (YVEP). These multiple-well monitoring sites were constructed as nested wells in one boring with each well completed with 20 feet of screen set at various depths below land surface.

Each well at the monitoring sites was equipped with dedicated, non-vented pressure transducers that were programmed to measure and record pressures every hour. The measured pressures represented the pressure exerted on the transducer by the height of water above it plus atmospheric pressure. The USGS installed a barometer at each monitoring site to adjust the non-vented pressure readings by subtracting atmospheric pressure. The resulting pressure represented the height of water above the pressure, which was then converted to an elevation referenced to NAVD88. Water level data was downloaded from the USGS website (USGS 2021). USGS noted that the accuracy of the measurements recorded by the dedicated pressure transducers is to the nearest hundredth of a foot (USGS 2021).

Other sources of groundwater elevation data include the draft USGS integrated hydrologic numerical model and the CASGEM website, which includes a selection of YVWD wells and one City of Redlands well. The groundwater elevation data collected from these two sources was compared to the groundwater elevation data obtained directly from the water purveyors. YVWD received a grant from the Bureau of Reclamation to install additional remote telemetry systems at YVWD wells, which will allow the remote collection of groundwater level data at these wells. Installation will take place in 2022.

2.7.1.1 Current Groundwater Levels

The current condition for groundwater levels in the Yucaipa Subbasin is represented by static water levels measured in September 2018, the last month of the 2017–2018 water year. Groundwater levels in the Yucaipa Subbasin are influenced by precipitation and subsequent runoff directly in the Subbasin, and by stormwater runoff originating in the surrounding San Bernardino Mountains, Yucaipa Hills, and Crafton Hills. Precipitation in the 2017–2018 water year ranged between 5.43 inches at SBCFCD station 3023 in the Live Oak subarea and 7.52 inches at SBCFCD station 3126A in the Calimesa subarea, which were approximately 45% of the mean annual rainfall estimated at these stations. The 2017–2018 water year was characterized as a “dry” water year type. The preceding 2016–2017 water year was characterized as an “above normal” water year type with precipitation ranging from 14.42 inches at SBCFCD station 3023 to 21.49 inches at SBCFCD station 3126A.

Groundwater level data was provided by the City of Redlands (majority owner of South Mountain), South Mesa, WHWC, and YVWD. DTW at all wells were measured using either an electric water level sounder, dedicated pressure transducers that measured absolute or gauge pressure, or dedicated airlines that measured the pressure of water exerted above. All DTW measurements were converted to elevations referenced to the North American Vertical Datum of 1988 (NAVD88).

Static groundwater levels measured in September 2018, which represents the current water year low, ranged from 1,723.93 feet above NAVD88 at well WHWC-11 in the Western Heights subbasin to 3,331.80 feet above NAVD88 at well YVWD-14 in the Oak Glen subbasin (Figure 2-29, September 2018 Groundwater Elevations within the Yucaipa Subbasin). In general, groundwater flowed from the northeast to the southwest in the Yucaipa Subbasin. The hydraulic gradient in the principal aquifer was estimated between groundwater elevations measured at wells YVWD-13, South Mesa-11, and WHWC-10. Their respective groundwater elevations in September 2018 were 3,160.89 feet above NAVD88, 2,096.14 feet above NAVD88, and 1,766.04 feet above NAVD88. The estimated hydraulic gradient was 0.0471 feet/foot with the groundwater flow direction to the southwest at an azimuth of 236°.

Static groundwater levels measured in March 2018 represent the current water year high. Groundwater levels ranged from 1,743.93 feet above NAVD88 at WHWC-11 to 3,297.90 feet above NAVD88 at YVWD-14 (Figure 2-30, March 2018 Groundwater Elevations within the Yucaipa Subbasin). Groundwater flowed from northeast to southwest. The hydraulic gradient in the principal aquifer was estimated between groundwater elevations measured at wells YVWD-13, South Mesa-11, and WHWC-10. Their respective groundwater elevations in March 2018 were 3,156.38 feet above NAVD88, 2,098.14 feet above NAVD88, and 1,762.04 feet above NAVD88. The estimated hydraulic gradient was 0.0469 feet/foot with the groundwater flow direction to the southwest at an azimuth of 236°.

Areas of hydraulic depression were observed in the Western Heights, Calimesa, and Gateway subareas where approximately 77% of the total groundwater produced from the principal aquifer occurred in the Yucaipa Subbasin (Figures 2-29 and 2-30). The hydraulic depression in the Western Heights subarea was centered on wells WHWC-02A, WHWC-11, WHWC-12, and WHWC-14, the only four active wells since 2007. These four wells produced approximately 1,900 AF in the 2018 WY. The hydraulic depression in the Calimesa subarea was located in an area that included wells YVWD-02, YVWD-12, and YVWD-24. These three wells produced approximately 1,600 AF in the 2018 WY. The hydraulic depression in the Gateway subarea was centered around YVWD-46, which produced approximately 870 AF in the 2018 WY.

2.7.1.2 Historical Groundwater Levels

The earliest groundwater elevation data was collected in the 1920s. The first recorded static groundwater elevation was at YVWD-37 at 2,556 feet above NAVD88 in April 1921. This well is located in the northern part of the Crafton subarea. YVWD-02, which was installed in 1921 in the Calimesa subarea, had a static groundwater elevation at 2,273.9 feet above NAVD88 in February 1926. Historically, groundwater elevations in the Yucaipa Subbasin have ranged from 1,350.63 feet above NAVD88 at well GWMW-5B in the Live Oak subarea (approximately 4,500 feet upstream from the farthest downstream end of the Yucaipa Subbasin) to 3,355.80 feet above NAVD88 at well YVWD-14 in the Oak Glen subarea (Figure 2-31, Historical Groundwater Elevations in the Yucaipa Subbasin).

2.7.1.2.1 Historical High Groundwater Elevations

In the 50-year historical period from 1966 to 2016, the highest static groundwater elevations (i.e., historical high) observed in the Calimesa, Wilson Creek, and Gateway subareas occurred in the spring of 1988 (Figure 2-32, Historical High (Spring 1998) Groundwater Elevations in the Yucaipa Subbasin). Static groundwater elevations in the Subbasin ranged from 3,165.89 feet above NAVD88 at YVWD-13 in the Oak Glen subarea to 1,793.70 feet above NAVD88 at WHWC-02A in the Western Heights subarea (Figure 2-31). The hydraulic gradient in the principal aquifer in the spring of 1988, estimated between static groundwater elevations measured at wells YVWD-13 (3,165.89 feet above NAVD88), South Mesa-11 (2,164.54 feet above NAVD88), and WHWC-10 (1,813.25 feet above NAVD88), was 0.0448 feet/foot. The groundwater flow direction was to the southwest at an azimuth of 239 degrees. The hydraulic depressions in the Calimesa, Western Heights and Gateway subareas were not as pronounced as noted for the current conditions in September 2018 even though total pumping from those three subareas in the 1988 WY was approximately 2,400 AF more than in the 2018 WY (Figure 2-19). This was attributed to groundwater elevations being approximately 50 feet higher than levels observed in September 2018 (Figure 2-29).

2.7.1.2.2 Historical Low Groundwater Elevations

The lowest groundwater elevations (i.e., historical low) observed in the Subbasin occurred in the Fall of 2007. The historical low in groundwater elevations occurred right before the marked increase in SWP water imported into the Subbasin by YVWD in the 2007 WY (Figure 2-21), and subsequent decline in groundwater production from 13,000 AFY in the 2007 WY to 10,000 AFY in the 2009 WY (Figure 2-18). Static groundwater elevations in the Subbasin ranged from 3,346.50 feet above NAVD88 at YVWD-13 in the Oak Glen subarea to 1,728.90 feet above NAVD88 at WHWC-14 in the Western Heights subarea (Figure 2-33, Historical Low (Fall 2007) Groundwater Elevations in the Yucaipa Subbasin). The hydraulic gradient in the principal aquifer in Fall 2007, estimated between static groundwater elevations measured at wells YVWD-13 (3,172.89 feet above NAVD88), South Mesa-11 (2,053.14 feet above NAVD88), and WHWC-10 (1,759.04 feet above NAVD88), was 0.049 feet/foot. The groundwater flow direction was to the southwest at an azimuth of 232°.

The areas of hydraulic depression observed in the Western Heights, Calimesa and Gateway subareas in the Spring of 1988 and September 2018 were more pronounced in the Fall of 2007 (Figure 2-33). Approximately 73% of the total groundwater produced from the principal aquifer occurred in these three subareas (Figure 2-19). The hydraulic depression in the Western Heights subarea was centered on wells WHWC-02A, WHWC-11, WHWC-12, and WHWC-14, the only four active wells since 2007. These four wells produced approximately 2,700 AF in the 2007 WY. The hydraulic depression in the Calimesa subarea was located in an area that included wells YVWD-02, YVWD-12, and YVWD-24. These three wells produced approximately 2,600 AF in the 2007 WY. The hydraulic depression in the Gateway subarea was centered around wells YVWD-18 and YVWD-46, which produced approximately 1,800 AF in the 2007 WY.

2.7.1.3 Groundwater Level Trends

A declining trend in groundwater elevations was observed at wells YVWD-02, YVWD-37, YVWD-04, YVWD-05, YVWD-11, and YVWD-13 from the 1920s to 1970 (Figure 2-31). The declining trend was attributed to further expansion and development in the Plan Area after 1945, which led to an increase in groundwater production from the principal aquifer to meet the increasing local water demand (YVWD 2008). The latter part of that period from 1945 to 1965 was relatively dry with annual precipitation typically below mean annual rainfall, as evidenced by the declining trend in the cumulative departure from mean monthly precipitation (Figure 2-2). Only one "wet" water year type (1958 WY) and one "above normal" water year type (1962 WY) were observed from 1953 to 1965 (Figure 2-3).

Increasing trends in groundwater elevations were observed in the Calimesa, Wilson Creek, and Gateway subareas from 1970 to 1988. The increasing trends were attributed to groundwater production in these subareas declining to or below their respective estimated safe yields and the Subbasin experiencing a relatively wet period from 1978 to 1983 that increased the natural recharge to the aquifer. For example, the static groundwater elevation at well YVWD-10 in the Calimesa subarea increased approximately 75 feet from 2,103 feet above NAVD88 in 1970 to a peak elevation at 2,174 feet above NAVD88 in March 1988 while groundwater production declined from 4,350 AF in 1972 to 3,500 AF in 1982 (Figure 2-34, Annual Groundwater Production by Water Year and Groundwater Elevations in the Calimesa Subarea). This coincided with a relatively wet period from 1978 to 1983 when precipitation in the Subbasin was 130% or more of normal annual precipitation in 5 of the 6 years in that period (Figure 2-35, Historical Groundwater Elevations vs. Water Year Type in the Yucaipa Subbasin).

Marked increases in groundwater elevations were observed in the Wilson Creek and Gateway subareas from 1978 to 1988. These increases were attributed to declines in groundwater production to below the estimated safe yields[1] for each subarea and the wet water year types from 1978 to 1983 (Figure 2-36, Annual Groundwater Production by Water Year and Groundwater Elevations in the Wilson Creek Subarea, and Figure 2-37, Annual Groundwater Production by Water Year and Groundwater Elevations in the Gateway Subarea). The Western Heights subarea is the only subarea in the Subbasin where groundwater elevations declined from 1970 to 1988 (Figure 2-38). Groundwater production in the Western Heights subarea averaged 2,370 AFY in that period, which was above the estimated safe yield of 2,100 to 2,270 AFY (Table 2-6).

Further expansion and development in Yucaipa after 1985 increased the water demand to where local groundwater production from the early 1990s to the mid-2000s markedly exceeded the estimated safe yield of 9,640 AFY for the Subbasin (Figures 2-18 and 2-19). Additionally, the area experienced a drier climatic period from 1984 to 1990 when annual precipitation ranged between 68% and 99% of mean annual precipitation (Figure 2-35). Consequently, the Calimesa subarea experienced a declining trend in groundwater elevations of approximately 100 feet from 1989 to 2005 (Figure 2-34). This declining trend occurred despite the "above normal" and "wet" water year types from 1991 to 1998 when the average annual precipitation was 140% of the mean annual precipitation of 15.86 inches (Figure 2-35). The declining trend in groundwater elevation was attributed to groundwater production from this subarea at approximately 6,000 AFY, or almost double the estimated safe yield for the Calimesa subarea, in the late 1990s and early 2000s (Figure 2-34).

Groundwater elevations in the Wilson Creek and Gateway subareas were influenced by climatic conditions where groundwater level declines were observed during the relatively dry period from 1984 to 1990 with subsequent increases in groundwater levels during the wet period from 1991 to 1998 (Figure 2-35). Marked declines in

1 Estimated safe yields represent the safe yield values calculated by GSSI (2014a).

groundwater elevations of approximately 100 feet in the Wilson Creek and Gateway subareas were observed after 2000 when groundwater production exceeded the estimated safe yield in both subareas (Figures 2-36 and 2-37), and the water year types from 1999 to 2002 were characterized as mostly “dry” or “critically dry” (Figure 2-35). Groundwater elevations in these two subareas by 2005 to 2007 were back down to levels previously observed in the late 1960s to early 1970s.

The declining trends in groundwater elevations observed in the Yucaipa Subbasin ceased by 2006 to 2007 with the importation of SWP water to the Subbasin as a supplemental water source. Total production from the Yucaipa Subbasin steadily declined from a peak of 15,200 AF in the 2002 WY to 13,200 AF in the 2007 WY, but then markedly dropped to 11,400 AF in the 2008 WY and 10,200 AF in the 2009 WY when total production was approximately the estimated safe yield for the Subbasin (Figure 2-18). The marked decrease in groundwater production in the 2008 WY and 2009 WY coincided with a marked increase in SWP water imported into the Subbasin during those years. YVWD imported approximately 7,000 AF of SWP water in the 2008 WY and 2009 WY, up from 3,500 AF the year prior (Figure 2-21). Groundwater elevations recovered approximately 100 feet to 200 feet in the Wilson Creek and Gateway subareas (Figures 2-36 and 2-37), and approximately 50 feet in the Calimesa subarea (Figure 2-34). The steady decline in groundwater elevation in the Western Heights subarea ceased by 2010. WHWC began purchasing SWP water from YVWD in 2008, which supplemented WHWC’s water supply and led to a reduction in groundwater production beginning in the 2009 WY to rates below an estimated safe yield of 2,100 AF (Figure 2-38, Annual Groundwater Production by Water Year and Groundwater Elevations in the Western Heights Subarea).

The drought from the 2012 WY to 2018 WY included water year types that were mostly characterized as “dry,” with the 2017 WY as “above normal” and the subsequent 2018 WY characterized as “critically dry” (Figure 2-35). Despite the drought, increasing trends in groundwater elevations were observed in the Calimesa, Wilson Creek, Gateway, and Western Heights subareas (Figures 2-34 to 2-38). Groundwater elevation increases continued in the 2018 WY during this “critically dry” year as YVWD imported 15,300 AF of SWP water in the 2017 WY, of which 6,600 AF was discharged to the Wilson Creek spreading basins, and 10,200 AF in the 2018 WY, of which 870 AF was discharged to the Wilson Creek and Oak Glen Creek spreading basins (Figures 2-21 and 2-35). Consequently, groundwater production in the 2017 WY and 2018 WY from these four subareas and the Yucaipa Subbasin were below their respective estimated safe yields. Currently, groundwater elevations in the Yucaipa Subbasin are at levels previously observed in the 1960s and 1970s before groundwater production increased during the expansive growth in the 1990s and 2000s.

2.7.2 Estimate of Groundwater in Storage

GSSI (2021) conducted a study to estimate the volume of groundwater in storage at the end of the 2016 WY. GSSI (2021) used the integrated Santa Ana River (SAR) numerical model as a tool to estimate the volume in storage. The SAR model was developed with collaboration by stakeholders in the Santa Ana River basin and peer reviewed by outside technical experts, including the USGS. The SAR model includes the full alluvial thickness of the Subbasin, in that the bottom of the SAR model is defined by the contact between bedrock and the overlying alluvium (Mendez et al. 2016). The SAR model is a more appropriate tool to estimate the total volume of groundwater in storage than the YIHM because the USGS, in its recent design and calibration iterations of the YIHM, truncated the bottom of the YIHM at approximately 1,900 feet bgs. This depth was based on the deepest well (WHWC-11 at 1,710 feet bgs) located in the Subbasin. The USGS truncated the YIHM to maintain reasonable transmissivity values in the active part of the aquifer. The YIHM is the appropriate tool to evaluate changes in storage in the Subbasin as a function of watershed processes (e.g., rainfall, stream flow), well production and the potential impacts of climate change in the future; whereas, the SAR model was the appropriate tool to estimate the total volume of groundwater in storage.

GSSI (2021) provided estimates of the volume in storage at the end of the 2016 WY for each subarea and the management areas (Section 2.9) defined in the Subbasin. The volume in storage estimates are summarized in Table 2-8. The estimated volume in storage at the end of the 2016 WY was used to calculate the annual volume in storage using the water balance results by the YIHM for the historical, current, and future baseline simulations (Section 2.8).

Historical changes to groundwater in storage within the Yucaipa Subbasin were estimated using the YIHM, a numerical flow model designed by the USGS to simulate the interaction between surface water and groundwater across the Yucaipa Watershed (Alzraiee et al. 2020). Details of the YIHM development, representation of groundwater processes, and resulting estimates of groundwater storage changes are described in Section 2.8.

Table 2.8. Estimated Volume of Groundwater in Storage in the Yucaipa Subbasin

Hydrogeologic Subarea	Groundwater in Storage in Sept. 2016 (acre-feet)	Management Area	Groundwater in Storage in Sept. 2016 (acre-feet)
Triple Falls Creek	7,000	North Bench	243,000
Crafton	73,000		
Gateway	41,000		
Wilson Creek	79,000		
Oak Glen	43,000		
Western Heights	409,000	Western Heights	409,000
Calimesa	638,000	Calimesa[1]	799,000
Singleton	13,000		
Live Oak	930,000	San Timoteo	782,000
Total Volume	**2,233,000**	N/A	**2,233,000**

Note:
1 The Calimesa Management Area includes approximately 460 acres of the northeastern portion of the Live Oak subarea.

2.7.3 Seawater Intrusion

The Yucaipa Subbasin is located approximately 50 miles east of the Pacific Ocean. The lowest elevation of the base of the principal aquifer (contact with the underlying crystalline bedrock) is 1,000 feet above NAVD88, which is approximately 1,000 feet above mean sea level. Therefore, the Yucaipa Subbasin is not threatened by seawater intrusion nor the potential for seawater intrusion in the future. DWR, when ranking the Subbasin as a “high” priority basin, did not assign any points in the category for salt intrusion impacting water quality. This GSP will not consider seawater intrusion as a sustainability indicator to evaluate sustainability of the Yucaipa Subbasin (see Chapter 3, Sustainable Management Criteria).

2.7.4 Groundwater Quality

The Emergency Groundwater Sustainability Plan regulations (Section 354.16 [d]) state that each Plan “shall provide a description of groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.” The following provide a description of the general geochemistry in the Yucaipa Subbasin and the physical features/processes that influence groundwater quality.

2.7.4.1 General Geochemistry

Cromwell et al. (2020a) reviewed general water geochemistry data collected during previous investigations conducted by the USGS. There are four general types of groundwater in the Yucaipa Subbasin: (1) calcium-bicarbonate (Ca-HCO_3) groundwater that is sourced from direct precipitation and natural recharge from the adjacent San Bernardino Mountains, Yucaipa Hills and Crafton Hills; (2) sodium-sulfate (Na-SO_4) groundwater that derives from subsurface flow through the adjacent crystalline bedrock; (3) imported SWP water originating from northern California that has a higher chloride (Cl^-) concentration than ambient groundwater; and (4) sulfate-rich, Ca-HCO_3 groundwater in a perched aquifer system within the Western Heights subarea. Most groundwater in the Yucaipa Subbasin has similar major ionic composition (Ca-HCO_3) and is characteristic of groundwater sourced from direct precipitation and natural recharge (via runoff) from the surrounding hills (Cromwell et al. 2020a). This is corroborated by an analysis of the ratios of the stable isotopes of hydrogen and oxygen. Cromwell et al. (2020a) found "a consistent grouping of stable isotopic values [that indicated] that most groundwater in the aquifer has a consistent source of recharge." The isotopic analysis also indicated that "groundwater from natural recharge quickly infiltrated in the aquifer, and was not subject to evaporation" (Cromwell et al. 2020a).

Cromwell et al. (2020a) noted that groundwater from deep wells completed near the base of crystalline bedrock had concentrations of sulfate, sodium, and potassium that were "about 6 and 15 times higher than respective concentrations in the [corresponding] shallower well." The deeper nested wells completed by the USGS in the Calimesa subarea (6th Street and Equestrian Park) had sulfate concentrations ranging from 120 milligrams per liter (mg/L) to 630 mg/L; whereas sulfate concentrations at the shallower nested wells ranged from 25 mg/L to 45 mg/L. Well YVWD-24, completed in the Calimesa subarea with the lower portion of the well screen in fracture crystalline bedrock, had sulfate concentrations in the deeper sections of the well screen at 370 mg/L compared to 28 mg/L approximately 100 feet higher in the screen interval.

Cromwell et al. (2020a) reported that SWP water imported from northern California had chloride concentrations ranging from 66 to 109 mg/L, which was more than 10 times higher than ambient concentrations observed at wells near the Oak Glen and Wilson Creek spreading basins. Increasing trends in chloride concentration were observed at wells near these spreading basins after 2008 when SWP water was used to artificially recharge the groundwater basin.

The perched aquifer in the Western Heights subarea appears to have been influenced by previous agricultural practices that increased concentrations of chloride, fluoride, sulfate, and bicarbonate above ambient concentrations observed in the rest of the Yucaipa Subbasin (Cromwell et al. 2020a). Moreland (1970) noted that this subarea in the past experienced artesian conditions with flows occurring at springs and areas influenced by the Chicken Hill Fault. The artesian conditions were attributed to an extensive, fine-grain layer at approximately 300 feet bgs. The perched aquifer has a different chemical signature than groundwater in the principal aquifer below it.

2.7.4.2 Total Dissolved Solids and Nitrate

The Regional Water Quality Control Board (RWQCB) Santa Ana Region recognized in the 1975 and 1983 Basin Plans that the most serious water quality issue to the Santa Ana River Basin "was the buildup of dissolved minerals, or salts, in the ground and surface waters" (RWQCB 2019a). The RWQCB (2019a) acknowledged that water quality sampling and computer modeling projected increasing trends in the concentrations of total dissolved solids and nitrate to where their respective concentrations would exceed water quality objectives. The historical use of water for irrigation purposes, particularly for citrus that demanded large volumes of applied water, was a main contributor to increasing concentrations of TDS and nitrate. The RWQCB (2019a) recognized the need to implement salt and nutrient management plans to control the salt and nutrient loading to the basin, and, therefore, incorporated measures to improve the quality of the water supply (including the importation of SWP water), developing waste discharge regulatory strategies, and recharge projects and encourage the use of recycled water to offset potable water used for irrigation purposes (RWQCB 2019a).

In the course of considering the adoption of the 1995 Basin Plan, a number of water supply and wastewater agencies requested a review of the TDS and nitrate water quality objectives defined in the Basin Plan. Consequently, the Nitrogen/Total Dissolved Solids Task Force was created to reassess the groundwater objectives and the TDS/Nitrogen Management Plan in the Basin Plan (RWQCB 2019a). YVWD participated as a member of the Nitrogen/TDS Task Force to evaluate the impacts of total inorganic nitrogen and TDS on water resources in the Santa Ana Watershed. YVWD collected groundwater and surface water quality data from 1994 to 2004, which was used to characterize ambient conditions in the watershed and were the basis for the RWQCB to update the Basin Plan in 2004 (RWQCB 2004).

The 2004 Basin Plan update included the creation of new groundwater management zones (GMZs) based on previously defined groundwater subbasin boundaries, revised water quality objectives for TDS and nitrate-nitrogen in groundwater, revised wasteload allocations for TDS and nitrogen, and revised beneficial uses and objectives for TDS and nitrogen in surface waters. Additionally, the 2004 Basin Plan set "maximum benefit" objectives for TDS and nitrate-nitrogen in the Chino North, Cucamonga, San Jacinto Upper Pressure, Yucaipa, Beaumont, and San Timoteo GMZs. These maximum benefit objectives are less stringent than anti-degradation objectives, which are based on historical water quality data and only apply to regions in which the responsible parties have demonstrated appropriate protection of beneficial use and maintenance of water quality consistent with maximum benefit to the people of the State of California.

In 2014, the RWQCB adopted order number R8-2014-0005, an amendment to the Basin Plan that revised the maximum benefit commitments in the Yucaipa, San Timoteo, and Beaumont GMZs and expanded the boundary of the Beaumont management zone farther east to match the hydrogeologic boundary. The previous boundary was a jurisdictional boundary that corresponded to the boundary between the Santa Ana regional board and the Colorado River regional board. The modified maximum benefit commitments assure reliable water supplies to meet present and anticipated future demands. One of the commitments in the 2014 Basin Plan amendment was to establish a maximum benefits monitoring program to characterize water quality conditions with biweekly surface water sampling and semi-annual groundwater sampling. The following two sections discuss the water quality data collected since 1994 to characterize nitrate and TDS conditions in the Yucaipa Subbasin.

2.7.4.2.1 Total Dissolved Solids

Concentrations of TDS in the Subbasin from 1993 to 2018 ranged from 130 to 1,500 mg/L (Figures 2-39 to 2-41). The highest TDS concentrations (>1,000 mg/L) were detected at five monitoring wells at the former Yucaipa Landfill site, which is south of and adjacent to the Yucaipa Regional Park in the Crafton subarea, and at the two deepest nested wells at the USGS 6th Street site in the Calimesa subarea (Figure 2-42, Maximum Total Dissolved Solids Concentrations Detected in Groundwater Wells). The high TDS concentrations at the former Yucaipa Landfill are attributed to past disposal activities associated with the site (Figure 2-39). The former Yucaipa Landfill is an inactive municipal solid waste facility that was operated by the County of San Bernardino as a Class III Disposal Site from 1963 to 1980. The site underwent remediation and closure construction in 1997 (Geo-Logic 2018). Currently, there is no active remediation at the site for inorganic constituents in groundwater. There is active remediation to extract and treat landfill gas and an enhanced bioremediation program to treat organic constituents of concern in groundwater (Geo-Logic 2018). Groundwater at the former landfill is encountered at depths ranging from 65 to 215 feet bgs, and groundwater flow is generally to the southwest (Geo-Logic 2018).

TDS concentrations at the two deep USGS nested wells at the 6th Street site ranged from 1,030 mg/L to 1,120 mg/L (Figure 2-40). These higher concentrations are attributed to the wells being completed near the base of the crystalline bedrock where concentrations of sulfate, sodium and potassium were markedly higher than concentrations observed in shallower wells screened in the principal aquifer (Cromwell et al. 2020a).

The TDS concentration in the rest of the Yucaipa Subbasin, outside the former Yucaipa Landfill and the USGS 6th Street monitoring sites, ranged from 130 mg/L to 690 mg/L with an average of 324 mg/L (Figures 2-40 and 2-41). The maximum benefit water quality objectives for the Yucaipa and San Timoteo GMZs are 370 mg/L and 400 mg/L, respectively. Groundwater in the principal aquifer has an average TDS concentration below the maximum benefit water quality objectives. Only a few well locations outside the Yucaipa Landfill had maximum TDS concentrations detected greater than 400 mg/L (Figure 2-43, Maximum Total Dissolved Solids Concentrations Detected in Groundwater Wells). A secondary MCL for TDS, which has been established as a guideline to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor, is 1,000 mg/L. No public water supply wells have produced water with TDS concentrations greater than 1,000 mg/L (Figure 2-41).

YVWD discharges tertiary treated recycled water from the Wochholz Regional Water Recycling Facility (WRWRF) to San Timoteo Creek approximately 2.5 miles upstream from where the creek enters the Plan Area. YVWD installed a reverse osmosis (RO) treatment system at the WRWRF in 2013, but it was not used until the desalter and brine disposal facilities were completed and operational in 2016. The RO concentrate, containing the constituents removed from the water, is disposed outside the Plan Area via the Yucaipa Valley Regional Brine Line, which was completed in 2012. The RO permeate is recombined with the WRWRF microfiltration effluent (which does not pass through the RO membranes) to dilute this effluent stream to meet the TDS maximum benefit objectives for the Yucaipa and San Timoteo GMZs.

Under the 2014 Basin Plan amendment, the desalter and brine disposal facilities were required to be operational by June 30, 2015. The District obtained the required permits to operate these facilities and continues to purchase additional brine line capacity as needed to provide for future expansion of the desalting facilities. These facilities were put into operation on July 25, 2016. Consequently, the mean monthly TDS concentration of the WRWRF effluent discharged to San Timoteo Creek beginning August 2016 has ranged from 210 to 480 mg/L with a mean monthly TDS concentration of 286 mg/L (Figure 2-44, Total Dissolved Solids and Monthly Discharges of Recycled Water at WRWRF Outfall).

In summary, higher concentrations of TDS observed in the Subbasin are attributed to local influences by previous operations at the former Yucaipa Landfill or to the chemical composition of crystalline bedrock at the bottom of the principal aquifer. High TDS concentrations at the former Yucaipa Landfill were observed in shallow groundwater and did not affect water quality at nearby wells screened in the principal aquifer. The implementation of RO treatment at the YVWD WRWRF facility has reduced the TDS concentration in recycled water to an average of <300 mg/L. YVWD is serving some recycled water to its customers, with plans to increase the usage of recycled water, for irrigation purposes. The application of recycled water for irrigation purposes has not increased TDS concentrations in the principal aquifer. Therefore, there are no TDS water quality issues that may affect the long-term supply and beneficial uses of groundwater produced from the principal aquifer.

2.7.4.2.2 Nitrate

The presence of nitrate in groundwater is the result of agricultural activity (fertilizer application and animal waste), other applied irrigation practices where fertilizer is used and human wastewater (septic systems or wastewater discharge). Nitrate concentrations are reported as either nitrate as nitrogen (as N) or nitrate as nitrate (as NO_3). The California MCL for nitrate (as N) is 10 mg/L (the MCL is 45 mg/L for nitrate [as NO_3]). The Basin Plan water quality objective, which is based on the maximum benefit water quality objective, for nitrate (as N) in groundwater in the Yucaipa and San Timoteo GMZs (which constitute the Yucaipa Subbasin) is 5.0 mg/L.

Nitrate (as N) concentrations in the Yucaipa Subbasin since 1994 have ranged from <0.05 mg/L to 21 mg/L (Figures 2-45 to 2-47). The maximum nitrate concentration of 21 mg/L was observed in April 2009 at the shallowest nested well at the USGS Dunlap location, which is in the Western Heights subarea (Figure 2-46). The screen interval for this well (USGS Dunlap 05) is 230 to 250 feet bgs. This depth interval is in the perched water table where water quality has been influenced by previous agricultural activities and the continuing use of septic systems. In comparison, well WHWC-14, which is 50 feet from USGS Dunlap 05 and is screened from 410 to 1,090 feet bgs in the principal aquifer, had a nitrate (as N) concentration in May 2009 at 2.1 mg/L. The maximum nitrate (as N) concentration ever detected at WHWC-14 was 2.8 mg/L in May 2016 (Figure 2-47). The marked difference in concentration between the perched aquifer and the underlying principal aquifer indicated that the confined layer of fine-grained sediment marking the boundary between the two aquifers limits the vertical migration of lower quality water to the principal aquifer.

Other areas in the Yucaipa Subbasin where concentrations of nitrate (as N) exceeded the MCL include the former Yucaipa Landfill, well WHWC-12 in the Western Heights subarea, and South Mountain well Hog Canyon 2 in the Calimesa subarea (Figure 2-48, Maximum Nitrate Concentrations Detected in Groundwater Wells). Nitrate (as N) concentrations at the former Yucaipa Landfill have ranged from <0.008 mg/L to 12.5 mg/L (Figure 2-45). The bottom elevations of the screens set for the monitoring wells at the former landfill range from 52 feet bgs to 300 feet bgs, with well screen lengths ranging from 15 feet to 30 feet. The highest nitrate (as N) concentrations were detected at the shallowest wells with screen intervals between 52 feet bgs to 108 feet bgs. The nearest water supply well to the former landfill is YVWD-55, which is approximately 2,000 feet southeast of the former landfill. YVWD-55 is screened from 400 feet bgs to 1,030 feet bgs. Nitrate (as N) at YVWD-55 has ranged from 2.3 mg/L to 5.5 mg/L from 2006 to 2018 (Figure 2-47). It does not appear that the water quality at YVWD-55 has been influenced by the former landfill.

In the Western Height subarea, only one well, WHWC-12, had nitrate (as N) concentrations detected greater than the MCL at 10.4 mg/L (Figure 2-47). Nitrate (as N) has not been greater than 10 mg/L at this well since July 2009. The South Mountain well, Hog Canyon 2, had a nitrate (as N) concentration detected at 11.7 mg/L in 2011, but this well is used for irrigation supply only and is not contributing water to the City of Redlands' drinking water supply system. No other public water supply well has had nitrate (as N) concentrations greater than the MCL of 10 mg/L (Figure 2-47).

In 2009, YVWD implemented a denitrification process at the WRWRF that removed a significant amount of nitrate from the treated effluent (i.e., recycled water) that was discharged to San Timoteo Creek. The nitrate-nitrogen concentration of recycled water discharged from the WRWRF to San Timoteo Creek has averaged 2.8 mg/L since 2009 (Figure 2-49, Nitrate (as N) and Monthly Discharges of Recycled Water from WRWRF to San Timoteo Creek). The maximum benefits water quality objective for nitrate (as N) in groundwater is 5.0 mg/L. Nitrate (as N) in the Yucaipa Subbasin has been detected above the 5.0 mg/L concentration in the Calimesa, Western Heights, Gateway, Crafton, and Oak Glen subareas (Figure 2-50, Maximum Nitrate Concentrations Detected in Groundwater Wells). Most wells show a steady or declining trend in nitrate (as N) concentrations since 2010 (Figure 2-47). The exception being at wells YVWD-02, YVWD-12, and South Mesa-16 in the Calimesa subarea where increasing trends in nitrate (as N) concentrations have been observed since 2008 (Figure 2-51, Water Quality Hydrographs – Calimesa Subarea). The Yucaipa GSA will continue monitoring nitrate concentrations at these and other wells in the Calimesa subarea and investigate the potential reasons for these observed increasing trends. Increasing nitrate (as N) concentrations were not observed in the other subareas of the Yucaipa Subbasin.

In summary, nitrate concentrations observed in the Subbasin have, in general, remained steady at <10 mg/L after agricultural practices in the Plan Area decreased significantly after the 1970s and septic systems were replaced with sanitary sewer services in the 1980s, with the exception of the Western Heights subarea. Higher nitrate (as N) concentrations were observed in the shallow, perched aquifer in the Western Heights subarea and in shallow groundwater at the former Yucaipa Landfill. Water quality in the principal aquifer was not influenced by nitrate concentrations in the shallow groundwater at these two locations. The recently observed increasing trends at some wells in the Calimesa subarea will continue to be monitored to evaluate potential causes. However, there are no nitrate water quality issues that may affect the long-term supply and beneficial uses of groundwater produced from the principal aquifer.

2.7.5 Contaminated Surface Water and Groundwater Sites

2.7.5.1 303(d) Listed

The reach of the San Timoteo Creek within the Yucaipa Subbasin is included in the list of impaired surface waters (i.e., 303 (d) listed reaches) compiled by the State Water Resources Control Board (SWRCB) in 2016 (Figure 2-52, 303(d) Listed Waters). The impairment listed for San Timoteo Creek is indicator bacteria E. coli and total coliform (SWRCB 2017). The presence of indicator bacteria is associated with contamination from human or animal wastewater. The 303(d) report does not investigate potential sources for elevated indicator bacteria in San Timoteo Creek.

2.7.5.2 Contaminated Soil and Groundwater Sites

Sites with impacted soil and groundwater in the Subbasin and that are actively being remediated were identified from the SWRCB GeoTracker website (SWRCB 2021) and the California Department of Toxic Substances Control EnviroStor Website (DTSC 2021). Cases that were closed by the supervisory agency were not investigated. Three active cleanup sites within the Subbasin were identified in the GeoTracker and EnviroStor databases (Figure 2-53, Cleanup Sites).

Conditions at the three cleanup sites described in more detail below have not affected water quality in the principal aquifer. Remediation activities implemented at the former Yucaipa Landfill will contain and treat shallow contaminated groundwater at the property; contamination at the other two sites affected only soil and not groundwater (J and J Texaco) or the perched water table in the Western Heights subarea and not the underlying principal aquifer (Sorenson Engineering).

2.7.5.2.1 Former Yucaipa Landfill

San Bernardino County performs quarterly and semi-annual groundwater and soil gas monitoring, including groundwater quality sampling at 27 monitoring wells at the former Yucaipa Landfill site located in the Crafton subarea (Figure 2-53). The sampling program includes analyzing groundwater samples for concentrations of nitrate, sulfate, TDS, select metals, and volatile organic compounds (VOCs). Tetrachloroethylene (PCE), along with its breakdown products (including trichloroethylene), are the primary contaminants of concern (COCs) at the former Yucaipa Landfill site. The County of San Bernardino implemented enhanced in-situ bioremediation in 2018 to reduce VOC concentrations in groundwater (Geo-Logic 2018). Enhanced remediation appears to have reduced VOCs in groundwater (Geo-Logic 2020). PCE was not detected at the farthest downgradient monitoring wells at the site in January 2020 (Geo-Logic 2020).

2.7.5.2.2 J and J Texaco

The J and J Texaco site is located at 34253 Yucaipa Boulevard in the Wilson Creek subarea (Figure 2-53). Contamination was discovered at the site during the removal of underground storage tanks in 1998 (Frey 2019). COCs included total petroleum hydrocarbons–diesel, total petroleum hydrocarbons–gasoline, methyl tert-butyl ether, and other fuel oxygenates. Contamination at the site was greatest between 60 to 90 feet bgs, with detectable concentrations of COCs down to 180 feet bgs and no COCs detected from 200 to 270 feet bgs (Frey 2019). No groundwater was encountered from ground surface to 270 feet bgs. Remediation at the site included soil vapor extraction and a catalytic oxidizer from March 2006 to December 2012 (Frey 2019). Confirmation soil sampling in 2019 indicated minor residual concentrations of total petroleum hydrocarbons–gasoline and methyl tert-butyl ether between 70 and 115 feet bgs. Groundwater was not encountered during confirmation soil sampling. The RWQCB issued a letter in November 2019 stating that “groundwater was not impacted due to the unauthorized release” (RWQCB 2019b). The site is in the process of being closed under the low-threat closure policy by the RWQCB (RWQCB 2020).

2.7.5.2.3 Sorenson Engineering

The Sorenson Engineering facility is located at 32032 Dunlap Boulevard in the Western Heights subarea (Figure 2-53). The site has been an industrial facility since 1961 (Apex 2018). COCs include PCE, trichloroethylene, and other chlorinated hydrocarbons that have been detected in soil, soil gas, and shallow groundwater at the site (Apex 2018). The COCs originated from former leaking underground storage tanks that were removed from the site in 2000. The groundwater gradient at the site is generally to the northeast (Apex 2020). Groundwater monitoring wells at the Sorenson site have well screen intervals of 10 to 20 feet in length and are typically set between 30 and 65 feet bgs (Apex 2018). The shallow groundwater contamination occurs in the perched aquifer characterized in the Western Heights subarea (see Section 2.7.4.1, General Geochemistry). Remediation at the site is expected to start by the fourth quarter of 2020 and will consist of a dual extraction system to remove VOCs from soil and groundwater (Apex 2020).

Since 2017, PCE concentrations have ranged from non-detect to 9,200 micrograms per liter (μg/L), which was detected at a well located approximately 300 feet northeast of the former underground storage tanks. Deeper monitoring wells with screen intervals set at approximately 120 to 195 feet bgs are located approximately 0.25 miles northeast of the former underground storage tanks. These wells are set in a deeper portion of the perched aquifer, but PCE concentrations have attenuated over the last few years to concentrations at or below the MCL of 5 μg/L (Apex 2020).

WHWC wells WHWC-2A, WHWC-10, WHWC-11, WHWC-12, and WHWC-14, which constitute the entire pumping program for WHWC, are located approximately 0.5 miles northeast from the Sorenson site. These wells are screened from 330 feet bgs to 670 feet bgs (WHWC-10) to 705 feet bgs to 1690 feet bgs (WHWC-11) in the principal aquifer. Groundwater samples collected at these wells by WHWC in 2016 to 2018 were analyzed for concentrations of, among other constituents, PCE, and trichloroethylene. All samples were non-detect for these VOCs. These results indicate that VOC contamination at the Sorenson Engineering site has not impacted water quality in the principal aquifer at the WHWC water supply wells.

2.7.6 Oil and Gas Wells

A search for oil and gas wells on the California Geologic Energy Management Division (CalGEM; formerly the Division of Oil, Gas, and Geothermal Resources [DOGGR]) well finder tool indicated no active oil and gas wells and one idle well within the Subbasin (CalGEM 2020). The idle well was located near the boundary between the Gateway and Crafton subareas (Figure 2-54, Oil and Gas Wells). The well was installed in 1928 (Appendix 2-B). It appears that the well was intended to be an oil well, but no production from the well was recorded. Well logs indicate that the well was completed to a depth of 2,164 feet bgs. There is no well destruction report on record. The well was located in what is currently a residential community. Water quality sampling at wells YVWD-37 and YVWD-53, which are near the location of the idle well, had TDS concentrations that ranged from 200 to 330 mg/L, which are similar to the average basin-wide concentration of 324 mg/L (Figure 2-41). It does not appear that the idle oil well influenced water quality in the Yucaipa Subbasin.

2.7.7 Land Subsidence

Land subsidence is the result of the compaction of unconsolidated alluvial sediments following the lowering of groundwater levels by pumping, the vertical displacement by tectonic activities, or the underlying compaction of petroleum reservoirs. The compaction of fine-grain sediments is irrecoverable and results in a permanent reduction in the specific storage of an aquifer. The USGS maintains a website titled, “Areas of Land Subsidence in California” (USGS n.d.) that identifies an area called “Yucaipa Valley” that experienced land subsidence due to groundwater pumping. The area designated as Yucaipa Valley includes the Plan Area, plus the cities of Redlands, Highland, San Bernardino, Rialto, Fontana, and parts of Beaumont. The USGS website notes the following in describing the Yucaipa Valley area that experienced land subsidence (USGS n.d.):

> The Yucaipa Valley, in southwestern San Bernardino County, is a small, tectonically formed trough mostly filled with silt and clay. The valley has a long history of water development. The first irrigation ditch was constructed in 1819 to support farming and cattle raising. By 1909, about 95 percent of the area’s water supply was used for agricultural irrigation. (Yucaipa Valley Water District web page, https://www.yvwd.dst.ca.us/index.aspx?page=133, accessed January 13, 2014). Irrigation wells to support agriculture and post-World War II urbanization contributed to groundwater-level declines of more than 35 m [115 feet] by 1952. In January 1952, a 600-m-long fissure opened about 5 km (3.1 mi) west of the town of Yucaipa (Holzer, 1984, citing Burnham, unpublished report, 1952). Hydrogeologic studies were not performed to determine whether historically low groundwater levels in 1952 triggered the fissure or if tectonics caused or contributed to its formation. Managers at the Yucaipa Valley Water District are not aware of the location of the fissure reported by Burnham (1952, unpublished report) and have not observed other fissures in Yucaipa Valley (Jack Nelson, Yucaipa Valley Water District, oral commun., January 2014).

The 600-meter-long fissure may be attributed to tectonic activity associated with the Crafton Hills Fault Zone (the 3.1-mile distance west of Yucaipa places the fissure at approximately the boundary between Yucaipa Valley and the Crafton Hills). Cromwell et al. (2020a) state that "displacements of these normal-slip faults led to tectonic subsidence in the Yucaipa Valley watershed, downdropping crystalline basement rocks and facilitating the accumulation of the Sedimentary deposits of Live Oak Canyon and younger surficial materials."

Recent land subsidence data for the Yucaipa Subbasin was obtained from the SGMA Data Portal (DWR 2021). Vertical ground surface displacement estimates were derived from Interferometric Synthetic Aperture Radar data that is collected by the European Space Agency Sentinel-1A satellite and processed by TRE ALTAMIRA Inc. (CNRA 2021). The Interferometric Synthetic Aperture Radar data is included as part of DWR's SGMA technical assistance to provide important SGMA-relevant data to Groundwater Sustainability Agencies (GSAs) for GSP development and implementation. The Sentinel-1A Interferometric Synthetic Aperture Radar data was based on a rasterized dataset estimating land subsidence in the Yucaipa subbasin from June 2015 to October 1, 2018. Image resolution is approximately 100 meters (330 feet). The estimated range of subsidence during this period ranged from 0.0 feet to 0.054 feet, or 0.65 inches (Figure 2-55, Land Subsidence). This is an insignificant decline in land surface and is not attributed to declining groundwater elevations as the Yucaipa Subbasin experienced stable or recovering water levels from June 2015 to October 2018 as groundwater extractions declined because imported SWP water supplemented the local water supply.

DWR, when ranking the Subbasin as a "high" priority basin, did not assign any points in the category for impacts caused by land subsidence. Here, land subsidence, in the context of groundwater sustainability and managing groundwater resources in a basin, is attributed to the compaction of aquifer systems caused by significant lowering of groundwater elevations. Because groundwater elevations are increasing from recently observed historical lows, there exists the potential for land subsidence to occur should groundwater levels fall below the historical lows over a long period. The potentiality of land subsidence will be evaluated against groundwater elevations observed in the Subbasin, particularly when levels fall below historical lows.

2.7.8 Groundwater–Surface Water Connections

Wilson Creek, Oak Glen Creek, and Yucaipa Creek are the major surface water drainages in the Yucaipa Subbasin that may have a hydrologic connection with the underlying principal aquifer. However, no direct investigations have been conducted to characterize the relationship between surface water flows in these drainages with the underlying groundwater. Groundwater elevation data collected at wells YVWD-13, YVWD-20, YVWD-44, YVWD-53, South Mesa-06, and South Mesa-17, all located near these drainages, indicated depths-to-water greater than 200 feet bgs, except well YVWD-13 where the depth-to-water averaged 26 feet bgs in the last 10 years. YVWD-13 is located near the Yucaipa Hills in the higher elevations of the Oak Glen subarea. The well is screened from 26 to 415 feet bgs, which includes the younger alluvium influenced by surface water flows in Oak Glen Creek and extends into the crystalline bedrock by 100 feet.

Two shallow paired observation wells were installed adjacent to San Timoteo Creek: one just upstream of its confluence with Yucaipa Creek and other installed approximately 1,600 feet downstream of where Alessandro Road crosses San Timoteo Creek. The paired wells at each location were spaced approximately 10 feet apart and vertically offset by 10 feet. Limited groundwater elevation data collected at these wells indicated that the reach of San Timoteo Creek upstream of its confluence with Yucaipa Creek was a gaining stream where groundwater discharged to surface water. Hydraulic heads measured at the deeper well were higher than hydraulic heads measured at the shallower well. The reach downstream of Alessandro Road was characterized as a losing stream.

The best available estimates for groundwater-surface water connections derive from the preliminary USGS integrated hydrological numerical model (Alzraiee et al. 2020). The numerical model simulates the amount of runoff originating from precipitation over the San Timoteo Wash watershed and computes leakage from flows in the creeks to the underlying aquifer.

2.7.8.1 Groundwater Dependent Ecosystems

A GDE is defined under SGMA as an ecological community or species that depends on groundwater emerging from aquifers or on groundwater that occurs near the ground surface (23 CCR, Section 351 [m]). GDEs encompass a wide range of natural communities, such as seeps, springs, wetlands, lakes, terrestrial vegetation, rivers, streams, and estuaries.

The Natural Communities Commonly Associated with Groundwater (NCCAG) dataset is provided by DWR as a reference dataset and starting point for the identification of GDEs in groundwater basins (DWR 2018). Because the scale of the NCCAG dataset is statewide (i.e., coarse), and consists of a compilation of vegetation and surface hydrology features (e.g., wetlands) mapping, it does not incorporate local, basin-specific groundwater conditions such as aquifer characteristics or current data on depths-to-groundwater. Therefore, the dataset is most appropriately used as an indicator of where GDEs, as defined by SGMA, are potentially present. A local, basin-specific analysis is required to verify which features mapped in the NCCAG dataset are dependent on groundwater emerging from aquifers (e.g., seeps, springs) or on groundwater occurring shallower than 30 feet bgs.

2.7.8.1.1 Overview of the NCCAG Dataset within the Plan Area

The GDE characterization described in this GSP focuses on NCCAG indicators mapped within the Plan Area. The NCCAG dataset identified 37 habitats within the Plan Area that consist of common phreatophytes (Table 2-9; Figure 2-56, Groundwater Dependent Ecosystems Mapped by DWR in the Plan Area). The most prominent phreatophytes in the Plan Area are coast live oak and Riversidean alluvial scrub. These two vegetation types cover approximately 330 acres of the Plan Area and are predominantly located at higher elevations and along the banks of unlined stream channels.

Due to the variety of ecosystems identified in the NCCAG dataset, the NCCAG individual indicators were aggregated into larger "GDE Evaluation Units" within the Plan Area. The potential interactions between groundwater and the habitats within each GDE Evaluation Unit are evaluated in Section 2.7.8.1.3.

Table 2-9. Vegetation Types and Coverage in the Plan Area

Vegetation Type	No. of Mapped Communities	Average root depth (feet)	Area (acres)
Coast live oak	15	36	189
Common elderberry	1	3	15
Fremont cottonwood	5	9.8–16.4	86
Mule fat	1	1.97	<1
Riversidean alluvial scrub	8	N/A	179
Red willow	3	6.89	3

Table 2-9. Vegetation Types and Coverage in the Plan Area

Vegetation Type	No. of Mapped Communities	Average root depth (feet)	Area (acres)
Scalebroom	1	N/A	<1
Willow	3	2–15	74

Sources: Steinberg 2002 (coast live oak); Fryer 2008 (common elderberry); Taylor 2000 (Fremont cottonwood); Stromberg 2013 (mult fat and red willow); CH2MHill 2003 and Lite and Stromberg 2005 (willow).
Note: N/A = not applicable.

2.7.8.1.2 Methods for Identifying Groundwater Dependent Ecosystems

GDE Evaluation Units in the Plan Area were characterized by reviewing the NCCAG dataset alongside measured groundwater elevations, aerial photographs, and Landsat[2] data analyzed by The Nature Conservancy (TNC). TNC used Landsat data to calculate historical variations in the Normalized Derived Vegetation Index (NDVI) and Normalized Derived Moisture Index (NDMI) (Klausmeyer et al. 2019). TNC calculated average values of NDVI and NDMI between July 9 and September 7 of each year to estimate vegetation health during the driest period of the year, when the overlying habitats are most likely to depend on groundwater. Groundwater elevation measurements, aerial photographs, lithological data, and NDVI and NDMI indicators were reviewed following the guidance developed by TNC (2019). TNC's (2019) guidelines follow the outline provided by DWR in its GSP Regulations (23 CCR, Section 350).

The analysis of groundwater elevation measurements, aerial photographs, and NDVI and NDMI data focused on the period between 2009 and 2019. During this period, groundwater production in the Yucaipa Subbasin decreased as supplemental SWP water was imported into the Plan Area (Figure 2-21). This period also corresponded with a drier than average hydrologic period when average water year precipitation in the basin was approximately 12.03 inches per year, compared to the long-term water year precipitation average of 15.86 inches per year. Seven of the ten water years between 2009 and 2019 were characterized as "below normal," "dry," or "critically dry" water year types (Figure 2-3).

GDE Evaluation Units were characterized as:

1. Groundwater dependent ecosystems
2. Ecosystems that are <u>not</u> groundwater dependent
3. Potential groundwater dependent ecosystems

Habitats mapped in the NCCAG dataset were characterized as groundwater dependent ecosystems if:

1. NDVI and NDMI were positively correlated with static groundwater elevations measured in the principal aquifer; and
2. Groundwater levels measured at nearby wells <0.5 miles from the GDE Evaluation Unit Boundary were shallower than the average rooting depth of the habitat mapped in the NCCAG database (TNC 2020).

2 The Landsat mission is the longest running satellite monitoring program used to capture space-based images of the Earth's surface every 16 days. Landsat is managed by NASA and records visible, near-infrared, middle-infrared, and thermal wavelengths reflected from the Earth's surface. TNC aggregated this data to generate the NDVI and NDMI.

Average root depths were collected from the Fire Effects Information System, a database managed by USDA Fire Service that provides references on the general biology and ecology of organisms in North America (USDA 2020). When average rooting depth was not available, the mapped NCCAG indicators were considered groundwater dependent if static groundwater levels at nearby wells were shallower than 30 feet bgs. This criterion for groundwater depth is identified by TNC as representative groundwater conditions that sustain common phreatophytes (TNC 2019).

Ecosystems were characterized as not groundwater dependent if groundwater level trends were not correlated with NDVI and NDMI trends, the habitats persisted during periods where underlying groundwater was deeper than the overlying vegetation's average rooting depth or previous site investigations indicated that the habitats were sustained by surface water. As noted above, when average rooting depth was not available, it was assumed that static groundwater levels shallower than 30 feet bgs were indicative of groundwater conditions that supply water to the overlying habitat.

Ecosystems were characterized as potentially groundwater dependent if the source of water sustaining the habitat was not identifiable and/or groundwater levels underlying the habitat have not been measured and are unknown. GDE Evaluation Units that were farther than 0.5 miles from the nearest groundwater extraction well were characterized as not likely impacted by current production within the Plan Area.

2.7.8.1.3 Groundwater Dependent Ecosystem Characterization

This section describes the characterization of each GDE Evaluation Unit within the Plan Area. The section first describes habitats in the Plan Area that are groundwater dependent, followed by a description of habitats that are potentially groundwater dependent, and lastly a description of the habitats that are not groundwater dependent. Data supporting the categorization of each GDE Evaluation Unit is provided within each subsection.

2.7.8.1.4 Groundwater Dependent Ecosystems in the Plan Area

There are three GDE Evaluation Units within the Plan Area that are groundwater dependent (green habitat areas in Figure 2-57, Characterization of Groundwater Dependent Ecosystems in the Plan Area). These habitats lie along the banks of Oak Glen Creek in the northern part of the Oak Glen subarea, Wildwood Canyon Creek in the southeastern part of the Oak Glen subarea, and San Timoteo Creek in the Live Oak subarea. The GDEs adjacent to Oak Glen Creek and Wildwood Canyon Creek occur along the upstream reaches of these creeks. The GDE located along San Timoteo Creek is located downstream of its confluence with Yucaipa Creek.

Groundwater underlying these habitats is encountered at depths shallower than 30 feet bgs. Data describing the average rooting depth for the prominent vegetation communities in these environments indicates that the main root systems may extend below the water table (USDA 2020).

Groundwater is extracted from the principal aquifer within 0.5 miles of the GDEs adjacent to Oak Glen Creek. However, habitat health, as indicated by trends in NDVI and NDMI, has not declined as a result of historical and current extraction (Klausmeyer et al. 2019).

The three GDE Evaluation Units are characterized in the following subsections.

2.7.8.1.4.1 Oak Glen Creek near the Triple Falls Creek Subarea

The NCCAG dataset identified two coast live oak vegetation communities and one riparian mixed hardwood community located near the border of the Oak Glen and Triple Falls Creek subareas (Figure 2-57). Aerial imagery from Google Earth of these habitats indicates that they lie along the northern reaches of the Oak Glen Creek, which conveys surface runoff from the San Bernardino Mountains to its confluence with Wilson Creek. The Fire Effects Information System database indicates that the main roots of coast live oak may extend 36 feet bgs (Steinberg 2002). The Fire Effects Information System database does not have information on average root depths for the Riparian Mixed Hardwood.

NDVI and NDMI trends at these habitats range from moderately increasing to largely decreasing. The largest decreases are in the northernmost coast live oak habitat. NDVI and NDMI at that riparian mixed hardwood has moderately increased since 2009. Annual precipitation during this period was generally less than the 33-year average of 14 inches between 1985 and 2018.

Groundwater levels are measured at two wells within 0.5 miles of these mapped habitats: YVWD-25 (screened at 45 to 55 feet bgs) and the Chlorinator Well (unknown screen interval). The shallowest depth to groundwater recorded at YVWD-25 was 7 feet bgs on April 26, 2005, and the maximum depth to water measured at YVWD-25 was 43 feet bgs on November 24, 2007. Both measurements were collected during a period when YVWD-25 was actively extracting water. The shallowest static water level measured at YVWD-25 was 22.5 feet bgs in February 2006. Static water levels have not been measured at YVWD-25 since November 2015.

Static groundwater levels have been measured at the Chlorinator well since January 1987. Between January 1987 and February 2018, the shallowest static water level recorded at the Chlorinator well was 13 feet bgs, measured in February 1993. The deepest static groundwater level measured at the Chlorinator well was 60 feet bgs, measured in November 2006. Since 2015, average depth to groundwater measured at the Chlorinator well was approximately 49 feet bgs.

YVWD-25 is an active well that produces groundwater under the direct influence of surface water (see Section 2.5.4.1). YVWD-25 has produced an average 274 AFY since 2001. Between 2001 and 2013, NDVI and NDMI increased; this increase was correlated with above average annual precipitation for this 12-year period.

Because water levels measured at the Chlorinator well and YVWD-25 have been measured shallower than 30 feet bgs, the coast live oak and riparian mixed hardwood habitats located along the border between the Oak Glen and Triple Falls Creek subareas were characterized as groundwater dependent. However, the fact that NDVI and NDMI increased between 2001 and 2013, a period when YVWD-25 was actively producing an average 274 AFY, indicates that continued production at YVWD-25 at current production rates will not adversely impact the health of these mapped habitats. If future production is expected to exceed historical extractions in the region, additional field work may be required to characterize the impact that proposed pumping rates will have on the coast live oak and riparian mixed hardwood.

2.7.8.1.4.2 Wildwood Canyon State Park

The NCCAG dataset identified multiple coast live oak habitats located along the Wildwood Canyon Creek near Wildwood Canyon State Park (Figure 2-57). Aerial photographs indicate that these habitats predominantly border Wildwood Canyon Creek but also extend south into undeveloped lands that border the local residential community.

NDVI moderately increased across the majority of this habitat between 2009 and 2018, while NDMI moderately decreased. During this period, annual precipitation was generally lower than the 33-year average of 14 inches between 1985 and 2018.

Static groundwater levels have been measured within 0.5 miles of this habitat at YVWD-28 since May 2004. Static groundwater elevations at this well have ranged from 50 feet bgs, measured on December 14, 2018, to 8 feet bgs, measured on June 20, 2011. Prior to 2018, static groundwater was encountered at an average elevation of approximately 13 feet bgs, and between 2008 and 2018, static groundwater levels measured at YVWD-28 fluctuated between 8 and 18 feet bgs.

Because static groundwater levels measured at YVWD-28 are shallower than the average rooting depth of coast live oak, the habitats mapped by the NCCAG dataset near the Wildwood Canyon State Park were characterized as GDEs.

2.7.8.1.4.3 San Timoteo Creek within the Live Oak Subarea

The NCCAG dataset identified five vegetation communities associated with common phreatophytes along the San Timoteo Creek in the Live Oak subarea (Figure 2-57). These vegetation communities consist of willow and Fremont cottonwood. Aerial photographs suggest that these habitats are densely vegetated and that they have not been altered by land development.

NDVI and NDMI trends vary spatially across the five habitats. These trends range from large decreases to large increases. The aggregate trend for these five habitats shows that NDVI and NDMI both increased between 2009 and 2018. During this period, annual precipitation was generally lower than the 33-year average of 14 inches between 1985 and 2018.

Static groundwater elevations near these habitats were measured at 11 monitoring wells: GWMW-1 (screened at 45 to 60 feet bgs), GWMW-2 (screened at 55 to 70 feet bgs), GWMW-3 (screened at 45 to 60 feet bgs), GWMW-5A (screened at 120 to 140 feet bgs), GWMW-5B (screened at 285 to 305 feet bgs), OW-2P (screened at 5 to 20 feet bgs), OW-3P (screened at 5 to 20 feet bgs), OW-5A (screened at 5 to 10 feet bgs), OW-5B (screened at 15 to 20 feet bgs), OW-6A (screened at 6 to 11 feet bgs), and OW-6B (screened at 16 to 21 feet bgs). Monitoring wells GWMW-5A and GWMW-5B are a nested well pair that provide information on the vertical hydraulic gradient near the outlet of San Timoteo Creek to Redlands. Wells OW-5A and OW-5B and wells OW-6A and OW-6B were both nested observation well pairs that provided estimates of the vertical hydraulic gradients along San Timoteo Creek near, and downstream of, the confluence of San Timoteo Creek and Yucaipa Creek. Wells OW-2P, OW-5A, OW-5B, OW-6A, and OW-6B no longer exist, as they were destroyed either by flooding of San Timoteo Creek following major precipitation events or by grading activities that cleared large areas of habitat where the wells were located.

Groundwater elevations measured at all eleven wells were shallower than 30 feet bgs. The maximum depth to water measured at these wells was 23.9 feet bgs, measured at GWMW-5A on September 27, 2016. Upstream of GWMW-5A, the principal aquifer occurs under artesian conditions. Groundwater levels measured at OW-6A and OW-6B on August 7, 2018, were both above ground surface, indicating that this reach of San Timoteo Creek was a gaining stream with groundwater discharging to San Timoteo Creek at this location.

Local groundwater elevation data that indicate the presence of shallow groundwater and an interconnected groundwater-surface water system demonstrates that the Fremont cottonwood, common elderberry, and willow habitats located along the San Timoteo Creek are groundwater dependent ecosystems.

2.7.8.1.5 Potential Groundwater Dependent Ecosystems in the Plan Area

There are two GDE Evaluation Units within the Plan Area that are potentially groundwater dependent (yellow habitat areas in Figure 2-57). These GDE Evaluation Units lack data characterizing the interaction between groundwater and habitat health. Groundwater is not currently extracted within 0.5 miles of these habitats; therefore, current production is not expected to negatively impact these environments. If future additional extractions are proposed within 0.5 miles of these habitats, additional field work may be necessary to characterize the potential groundwater dependence of the habitats described below.

2.7.8.1.5.1 Calimesa and Singleton Subareas

The NCCAG identified three different vegetation communities located in the eastern portions of the Calimesa and Singleton subareas (Figure 2-57). These vegetation communities consist of coast live oak, Fremont cottonwood, and red willow. Aerial photographs of these habitats indicate that they are located along earthen surface depressions that carry surface runoff from the hills that border the Calimesa and Singleton subareas to the east into the central portion of the Subbasin.

Groundwater levels are not measured within 0.5 miles of these habitats. Because there is limited data characterizing the potential interaction between groundwater and these ecosystems, the Fremont cottonwood, red willow and coast live oak communities were characterized as potential GDEs.

2.7.8.1.5.2 Yucaipa Creek

The NCCAG identified two different vegetation communities located near Yucaipa Creek and upstream of the confluence of Yucaipa Creek with San Timoteo Creek that are potentially groundwater dependent (Figure 2-57). These vegetation communities consist of common elderberry and Fremont cottonwood. Aerial photographs of these habitats from Google Earth indicate that they are located along surface depressions that divert surface runoff to the Yucaipa Creek, as well as along the banks of the Yucaipa Creek, upstream of its confluence with the San Timoteo Creek.

Groundwater levels were measured within 0.5 miles of the Yucaipa Creek habitats at OW-5A (screened at 5 to 10 feet bgs), OW-5B (screened at 15 to 20 feet bgs), and OW-2P (screened at 5 to 20 feet bgs). These wells were located along the San Timoteo Creek and are more representative of groundwater-surface water interactions along the San Timoteo Creek than of groundwater conditions in the principal aquifer underlying these habitats.

Because there is a lack of site-specific data near the habitats located along the Yucaipa Creek, the common elderberry and Fremont cottonwood ecosystems at these locations were characterized as potentially groundwater dependent.

2.7.8.1.6 Habitats in the Plan Area that are not Groundwater Dependent

A comparison of aerial photographs, groundwater elevations, NDVI and NDMI trends and rooting depth information indicates that six GDE Evaluation Units mapped within the NCCAG dataset are not groundwater dependent (e.g., white habitat areas in Figure 2-57). These local data demonstrate that groundwater in the principal aquifer does not provide a source of water supply to the mapped ecosystems. A detailed discussion of the separation between groundwater and the six habitats is provided below.

2.7.8.1.6.1 Crafton Hills Subarea

The NCCAG dataset identified one coast live oak habitat and one Riversidean alluvial scrub habitat located along the foothills of the Crafton Hills (Figure 2-57). Aerial photographs of these habitats indicate that they are located directly north of Yucaipa Regional Park. Land use surrounding these mapped habitats has not changed in the last 15 years. The Fire Effects Information System database has not estimated average root depths for Riversidean alluvial scrub.

Between 2009 and 2018, NDVI and NDMI trends at the Riversidean alluvial scrub habitat show little to no change, while NDVI and NDMI trends at the coast live oak habitat show moderate declines. During this period, annual precipitation was generally lower than the 33-year average of 14 inches between 1985 and 2018.

Static groundwater levels are actively measured at two wells within 0.5 miles of these mapped habitats: YVWD-37 (unknown screen interval), and YVWD-09 (screened at 120 to 706 feet bgs). The shallowest depth to water measurement at these two wells was 88 feet bgs, measured on February 17, 2018, at YVWD-09. Static groundwater levels at YVWD-09 have been measured as deep as 359 feet bgs (measured on July 2, 1973). Static groundwater levels at both YVWD-09 and YVWD-37 have been increasing since 2010. The NDVI and NDMI indicators are not correlated with the trend in rising groundwater elevations.

Groundwater is not actively extracted from any well within 0.5 miles of these mapped habitats.

Because static groundwater levels have not been measured shallower than 88 feet bgs, the Riversidean alluvial scrub and coast live oak habitats located in the Crafton Hills sub-basin were characterized as habitats that are not groundwater dependent.

2.7.8.1.6.2 Wilson Creek Spreading Basins

The NCCAG dataset identified a Riversidean alluvial scrub habitat located along the periphery of the Wilson Creek spreading basins as groundwater dependent (Figure 2-57). Aerial photographs indicate that the footprint of this habitat aligns with the boundary of the westernmost spreading basin, which has been unaltered over the last 15 years.

Between 2009 and 2018, NDVI trends at this habitat have moderately increased, while NDMI trends show little to no change. Annual precipitation during this period was generally lower than the 33-year average of 14 inches between 1985 and 2018.

Static groundwater levels are actively measured within 0.5 miles of this habitat at well YVWD-53 (screened at 450 to 970 feet bgs) and at the USGS Wilson Creek nested well cluster. Static groundwater levels have been measured at YVWD-53 since January 1993 and depths-to-water have ranged from 222 feet bgs (measured on February 18, 2018) to 554 feet bgs (on September 24, 2003). Groundwater is actively extracted at wells YVWD-53 and YVWD-44 (screened at 275 to 650 feet bgs). Between 2001 and 2018, YVWD-44 and YVWD-53 extracted a combined rate of approximately 1,100 AFY of groundwater from the principal aquifer. Throughout this period, both NDVI and NDMI increased at the Riversidean alluvial scrub habitat.

Because static groundwater levels have not been measured shallower than 222 feet bgs and habitat health increased during periods of active production, the Riversidean alluvial scrub habitat located along the Wilson Creek spreading basins was characterized as a habitat that is not groundwater dependent.

2.7.8.1.6.3 Oak Glen Creek

The NCCAG dataset identified Riversidean alluvial scrub habitats along Oak Glen Creek that may be groundwater dependent (Figure 2-57). Aerial photographs indicate that these habitats are located along the boundary between the Wilson Creek and Gateway subareas. Aerial photographs indicate that a large portion of the habitat near the intersection of Bryan Street and Eucalyptus Avenue was developed in 2009.

NDVI and NDMI trends between 2009 and 2018 vary spatially across the habitats and range from moderately increasing to moderately decreasing. During this period, annual precipitation was generally lower than the 33-year average of 14 inches between 1985 and 2018.

Static groundwater levels are actively measured within 0.5 miles of these habitats at YVWD-53 (screened at 450 to 970 feet bgs), YVWD-07 (screened at 135 to 645 feet bgs), YVWD-46 (screened at 340 to 1130 feet bgs), YVWD-18 (screened at 290 to 584 feet bgs), YVWD-56 (screened at 512 to 832 feet bgs), YVWD-05 (screened at 190 to 470 feet bgs), and the USGS nested well cluster at Wilson Creek (screened at 350 to 370, 500 to 520, 640 to 660, and 820 to 840 feet bgs). The shallowest groundwater elevation measured from this group of wells was 137 feet bgs at YVWD-05 on April 3, 1977. Static groundwater elevations measured at the USGS Wilson Creek monitoring wells indicate that water levels are currently deeper than 250 feet bgs.

Groundwater is actively extracted within 0.5 miles of this habitat at wells YVWD-46, YVWD-18, YVWD-56, and YVWD-55. Between 2001 and 2018, these wells extracted a combined average annual extraction rate of 2,600 AFY. During this period, NDVI increased and NDMI showed little to no change.

Because static groundwater levels have not been measured shallower than 137 feet bgs and habitat health increased during periods of active production, the Riversidean alluvial scrub habitat located along the Oak Glen Creek was characterized as a habitat that is not groundwater dependent.

2.7.8.1.6.4 Wildwood Canyon Near the Boundary Between the Oak Glen and Calimesa Subareas

The NCCAG dataset identified a coast live oak habitat located along Yucaipa Creek out of Wildwood Canyon that may be groundwater dependent (Figure 2-57). Aerial photographs indicate that this habitat is more densely populated on the southern bank of the creek and is bordered on the north and south by residential communities. Development of the residential community located north of the creek began in 2002, and the residential community located south of the creek was present in 1995. This section of Yucaipa Creek is unlined and carries surface water runoff from the hills in Wildwood Canyon State Park through the Calimesa subarea before discharging to San Timoteo Creek.

NDVI and NDMI trends between 2009 and 2018 show little to no change. During this period, annual precipitation was generally lower than the 33-year average of 14 inches between 1985 and 2018.

Static groundwater levels are actively measured within 0.5 miles of this habitat at well YVWD-27 (screened at 164 to 314 feet bgs) and have historically been measured at wells YVWD-27A (screened at 160 to 207 feet bgs), YVWD-15 (screened at 50 to 129 feet bgs), and YVWD-26 (unknown screen interval). From this set of wells, the shallowest depth to water was recorded at YVWD-27, at a depth of 44 feet bgs on June 17, 2011. Groundwater levels at YVWD-27 between 2009 and 2018 declined from approximately 56.4 feet bgs in January 2009 to the current level of 129 feet bgs measured on December 16, 2018.

Groundwater is actively extracted within a 0.5-mile distance from this habitat at YVWD-27. Between 2001 and 2018, YVWD-27 extracted an average of approximately 100 AFY. During this period, NDVI and NDMI both increased.

This coast live oak community located along Yucaipa Creek near the boundary between the Calimesa and Oak Glen subareas was characterized as a habitat that is not groundwater dependent. This characterization was based on data showing that groundwater levels have not been measured shallower than 44 feet bgs, approximately 10 feet deeper than the coast live oak rooting depth (Fryer 2008), and that habitat health increased during a period of active extraction at YVWD-27.

2.7.8.1.6.5 Calimesa and Live Oak Subareas

The NCCAG dataset identified four coast live oak habitats and one red willow habitat located near the border of the Calimesa and Live Oak subareas (Figure 2-57). Aerial photographs indicate that the northernmost coast live oak habitats are located along the troughs of local surface depressions that likely carry surface water runoff derived from precipitation that falls on the local hills. The long branch of coast live oak and red willow just south of these two habitats is located along an earthen stream channel that is an extension of a lined stormwater channel in the Calimesa subarea. This earthen stream channel carries surface flows out of the Plan Area before discharging to San Timoteo Creek.

NDVI and NDMI in the northern coast live oak habitats show little to no change between 2009 and 2018. NDVI along the earthen stream channel that extends from the Calimesa subarea to the Plan Area boundary increased between 2009 and 2018; NDMI at this habitat has not changed. During this period, annual precipitation was generally lower than the 33-year average of 14 inches between 1985 and 2018.

Static groundwater elevations were measured within 0.5 miles of these habitats at seven wells: South Mesa-05 (screened at 264 to 514 feet bgs), South Mesa-07 (screened at 242 to 800 feet bgs), South Mesa-09 (screened at 250 to 985 feet bgs), South Mesa-11 (unknown screen interval), South Mesa-12 (screened at 250 to 770 feet bgs), South Mesa-16 (unknown screen interval), and South Mesa-17 (screened at 350 to 885 feet bgs). From this set of wells, the shallowest depth to water was measured at a depth of 193 feet bgs at South Mesa-12 on March 1, 1992. At this well, static water levels have been measured as deep as 319 feet bgs. Between 2001 and 2018, static groundwater levels at these seven wells were measured at an average depth of approximately 275 feet bgs.

Groundwater is actively extracted within 0.5 miles of these habitats at the seven wells listed above, as well as at SMWC-05 (screened at 264 to 514 feet bgs). Extractions from the South Mesa wells between 2001 and 2018 averaged approximately 2,050 AFY. During this period, NDVI and NDMI increased at each habitat located along the border of the Live Oak and Calimesa subareas.

2.7.8.1.7 Summary of GDEs in the Plan Area

The Plan Area includes diverse communities of habitats that are sustained by infiltrating surface water, precipitation, and shallow groundwater. The NCCAG database identified 37 unique vegetation community indicators commonly associated with phreatophytes (Figure 2-56). The natural communities underlying these indicators were characterized as either groundwater dependent, potentially groundwater dependent, or not groundwater dependent. This characterization was based on a review of local groundwater elevations, groundwater extraction history, aerial photographs, and satellite data[3] prepared by TNC.

[3] Landsat data was analyzed by The Nature Conservancy to quantify time-varying trends in Normalized Derived Vegetation Index (NDVI) and Normalized Derived Moisture Index (NDMI).

Three groups of habitats mapped by the NCCAG dataset contain vegetation that rely on groundwater as a source of water supply (e.g., green habitat areas in Figure 2-57). These habitats are located along Oak Glen Creek, Wildwood Canyon Creek, and San Timoteo Creek and consist of coast live oak, riparian mixed hardwood, Fremont cottonwood, and willow.

The groundwater-dependent ecosystem located along Oak Glen Creek is comprised of coast live oak. A review of ecological data describing coast live oak indicates that the root system may extend to depths greater than 36 feet bgs (Steinberg 2002). NDVI at this location has generally increased over the last decade, while NDMI has generally decreased. The decreased moisture content (NDMI) is reflective of the lower-than average annual precipitation during this period compared to the 33-year average between 1985 and 2018. The increasing NDVI during periods of decreasing NDMI suggest that the habitat is sustained by water other than surface water flows in Oak Glen Creek.

Groundwater elevations measured at YVWD-25 (screened at 45 to 55 feet bgs) and the Chlorinator well (unknown screen interval) indicate that the groundwater table underlying the habitat is shallower than 30 feet bgs. Groundwater elevations measured at YVWD-25 during periods when the well was active have been measured as shallow as 7 feet bgs (measured on April 26, 2005). At the Chlorinator well, static water levels have been measured as shallow as 13 feet bgs. Groundwater elevations at these depths likely occur within the root zone of the Coast Live Oak that lines Oak Glen Creek. YVWD-25 has produced an average of 274 AFY since 2001. Between 2001 and 2018, NDVI increased, indicating that the health of the coast live oak ecosystem was not impacted by production at YVWD-25. Therefore, future pumping at YVWD-25 under historical production rates are not expected to impact the habitat along Oak Glen Creek. If additional production is planned for the future, further characterization of the local conditions underlying the coast live oak may be warranted.

The groundwater dependent ecosystem that borders the Wildwood Canyon State Park is composed of coast live oak (Figure 2-57). Similar to the NDVI and NDMI trends in the habitats along Oak Glen Creek, NDVI in the Wildwood Canyon State Park GDE increased between 2009 and 2018, while NDMI decreased. As noted above, annual precipitation during the period between 2009 and 2018 was generally lower than the 33-year precipitation average between 1985 and 2018. Static groundwater levels near this habitat have been measured at YVWD-28 since May 2004. Groundwater levels at this well have fluctuated between 50 feet bgs and 8 feet bgs. In 2018, groundwater elevations dropped below 40 feet bgs. However, prior to 2018, groundwater elevations averaged approximately 13 feet bgs. Water levels at this depth likely occur within the root zone of the coast live oak habitat. There are no active groundwater extraction wells located within 0.5 miles of this habitat that may impact future health of the coast live oak.

Lastly, the NCCAG dataset identified a densely vegetated community of willow and Fremont cottonwood located along San Timoteo Creek downstream of its confluence with Yucaipa Creek (Figure 2-57). NDVI and NDMI both increased between 2009 and 2018, indicating that moisture content (a measure of surface water availability in the habitat) and habitat greenness have both increased over the past decade. Static groundwater elevations were measured at 11 monitoring wells that extend from the confluence of Yucaipa Creek and San Timoteo Creek downstream to the boundary of the Plan Area. Since 2016, static groundwater levels measured at all 11 wells were not measured deeper than approximately 24 feet bgs. Further, measurements at a set of nested wells located along this reach of San Timoteo Creek indicate that groundwater is under artesian conditions; these pressurized conditions may indicate that groundwater actively discharges to San Timoteo Creek along this reach.

The shallow and artesian groundwater conditions located along this reach of San Timoteo Creek indicate a complex groundwater–surface water connection underlying the Willow and Fremont cottonwood habitats mapped by the NCCAG dataset. As indicated by the NDVI and NDMI data, current private well extractions that may occur near these habitats have not impacted habitat health. Accordingly, private well extractions that remain at historical groundwater extraction rates are not expected to impact the future water supplies for the Willow and Fremont cottonwood that border this reach of San Timoteo Creek.

The remaining habitats that were mapped within the NCCAG dataset were characterized as either potentially groundwater dependent or not groundwater dependent. The natural communities that reside in these habitats have not been impacted by historical groundwater extractions from the principal aquifer in the Plan Area.

2.8 Water Budget Analysis

The Emergency Groundwater Sustainability Plan regulations Section 354.18 (a) state that each Plan "shall include a water budget for the basin that provides an accounting and assessment of the total volume of groundwater and surface water entering and leaving the basin, including historical, current, and projected water budget conditions, and the change in volume of water stored."

This section describes the sources of groundwater recharge and discharge to the Yucaipa Subbasin, and the historical, current, and projected water budget analyses. The historical water budget was prepared for the 50-year period starting in water year 1965 and ending water year 2014 (October 1, 1965, to September 30, 2014). Current conditions in the Subbasin were characterized by quantifying the water budget for the period from the 2015 WY through 2018 WY (October 1, 2014, to September 30, 2018). Three future scenarios (Section 2.8.7.3, Projected Water Budget) were assessed to characterize projected conditions in the Subbasin. These scenarios characterize projected water budgets for the period extending from the 2019 WY through the 2069 WY (October 1, 2018, to September 30, 2069). Individual components of the water budget are described in units of AF or AFY.

Estimates of the individual water budget components for the historical and current conditions in the Subbasin are based on simulation results from the YIHM (Alzraiee et al. 2020). The YIHM is a numerical surface water and groundwater model developed by the USGS to simulate the effects of native and non-native water supplies and demands on groundwater conditions across the entire Yucaipa Valley watershed. An overview of the YIHM is provided in Section 2.8.1. Individual water budget components were extracted from the YIHM based on the B118 boundary for the Yucaipa Subbasin. These components were extracted from the version of the YIHM provided to the Yucaipa GSA in May 2021.

Sections 2.8.2 and 2.8.3 provide a detailed description of the sources of groundwater recharge and discharge in the Subbasin. These sections also provide a description of the methods used by the YIHM to represent each process. Quantitative assessments of the historical, current, and projected water budgets are provided in Section 2.8.7. These sections are accompanied by tabular and graphical representations of the historical, current, and future water budgets, which are included as an attachment to this GSP in Appendix 2-C.

2.8.1 Integrated Surface Water and Groundwater Numerical Model

The YIHM is a numerical flow model that simulates the interaction between surface water and groundwater processes across the Yucaipa Valley watershed (Alzraiee et al. 2020). Surface water processes in the YIHM are simulated using the USGS modular modeling code, Precipitation Runoff Modeling System (PRMS). Groundwater processes are simulated using the USGS finite-difference modeling code, MODFLOW-NWT. These two codes are integrated using the USGS code, GSFLOW, which allows for the simultaneous computation of surface water processes, groundwater processes, and their interactions.

The YIHM active model domain is approximately 78,100 acres and covers over 90% of the Yucaipa Subbasin (blue fill in Figure 2-58, Yucaipa Integrated Hydrologic Model Active Model Domain). Regions of the Subbasin not included in the active model domain are shown in yellow fill in Figure 2-58. Areas of the Subbasin that are not simulated in the YIHM are located along the bedrock expression along the southeastern boundary of the Singleton Subarea.

The YIHM was designed to evaluate water supplies, demands, and changes in storage in the Yucaipa Subbasin between January 1, 1947, and December 31, 2014. The YIHM utilizes daily time steps to simulate surface water processes, and monthly stress periods to simulate changes in groundwater stresses (e.g., pumping, aquifer recharge). The PRMS model was calibrated using geospatial data of potential evapotranspiration and solar radiation compiled by the California Irrigation Management Information System (CIMIS). The MODFLOW model was calibrated using transient groundwater elevation and drawdown measurements from about 250 wells in the Yucaipa Valley watershed (Alzraiee et al. 2020). A more detailed overview of the YIHM model calibration is provided in Section 2.8.8, Characterization of Model Sensitivity and Predictive Uncertainty.

Sections 2.8.1.1 and 2.8.1.2 provide a brief overview of the general structure of the YIHM and describe how the surface water and groundwater processes communicate throughout the simulation. Methods for constraining individual components of the watershed and groundwater models are described in Sections 2.8.2 and 2.8.3, as well as in the USGS report documenting the YIHM development, included in Appendix 2-D.

2.8.1.1 Watershed Model

Watershed processes simulated in the YIHM include precipitation, evapotranspiration, surface water runoff, and soil zone processes. Variations in both the rate and location of each process is controlled by user-defined climatic conditions, land surface properties, and soil characteristics.

Data constraining land surface properties, soil characteristics, and climatic conditions were aggregated from a combination of measured data and geospatial datasets. Geospatial datasets used during the development of the YIHM included LANDFIRE data for vegetation coverage, National Land Coverage Database for the distribution of impervious land coverage, soil maps from the USDA Soil Survey Geographic (SSURGO) Database, and land surface elevations from the National Elevation Dataset 10-meter digital elevation model (Alzraiee et al. 2020). These data were mapped onto the YIHM model grid and used to generate estimates of PRMS-specific parameters that constrain surface water runoff properties, surface water flow directions, vegetation coverage and evapotranspiration demands, and soil zone storage and conductivity. Measured climate data from the NOAA climate station located in the City of Redlands (station ID: 47306 Redlands) was used for the precipitation and temperature inputs throughout the simulation.

Simulation results from the watershed model of the YIHM provide estimates of three key quantities that help constrain natural groundwater supplies and demands in the Yucaipa Valley watershed: (1) the volumes and rates of surface water runoff across the watershed, (2) the volumes and rates of precipitation infiltration beyond the soil zone, and (3) the evapotranspiration demands based on local land surface properties and climate conditions.

2.8.1.1.1 Surface Water Runoff

The PRMS model simulates precipitation at the grid-cell level and preforms a water balance calculation that meets evapotranspiration demands, fills surface depressions and plant canopy storage, and allows for precipitation to infiltrate into underlying soils. Precipitation that is in excess of these demands is routed downhill to adjacent model cells as surface runoff before discharging to the stream segment that drains the local sub-watershed.

In addition to runoff derived from excess precipitation, the PRMS module of the YIHM allows water stored in the soil zone to discharge to ground surface and contribute to local runoff. This occurs when land surface topology changes such that the elevation of soil water column is higher than the elevation of the neighboring model cell. The direction of surface water and soil water flow is constrained by the local topology of the watershed. Flow directions were calculated in the YIHM using the USGS Cascade Routing Tool software (Henson et al. 2013).

The total summation of precipitation excess and soil zone discharges to land surface are added as streamflow inputs to the MODFLOW streamflow routing package as part of the GSFLOW integration process. Stream flows are subsequently routed downstream, where they either recharge groundwater, are consumed by evapotranspiration, or are fed by groundwater discharging to land surface (Section 2.8.2.4, Stream Flow Leakage, and Section 2.8.3.3, Subsurface Outflows).

2.8.1.1.2 Volumes and Rates of Precipitation Infiltration Beyond the Soil Zone

Precipitation that is not evaporated, stored in surface depressions or the vegetation canopy, or lost to surface runoff will infiltrate into soils that underlie land surface. Once in the soil zone, water can flow downhill to neighboring model cells, discharge to land surface, be consumed by evapotranspiration, or infiltrate into the groundwater domain. The soil zone is a key link between surface water and groundwater processes in the YIHM and acts as a buffer between infiltrating surface water and precipitation recharge to the principal aquifer. The rate and relative magnitude of each process is influenced by local topography and soil characteristics.

Soil zone characteristics were constrained in the YIHM using the USDA SSURGO database (Alzraiee et al. 2020). This database provides estimates of soil composition, available water holding capacity, saturated hydraulic conductivity, and soil depth across the Yucaipa Valley Watershed. The SSURGO database estimates these soil properties over much larger spatial scales than the YIHM model grid and therefore does not capture local variability that may affect infiltration rates. To account for this, the soil-zone parameters generated using SSURGO data were used as initial estimates of soil properties and were adjusted during model calibration.

Calibrated soil-zone properties in the PRMS model were used to constrain equations that control the rate at which soil water discharges to underlying groundwater. In addition to incorporating local soil characteristics, these water-transfer equations incorporate information on the underlying groundwater elevations to constrain exchange rates between the PRMS and MODFLOW domains. When the soil zone is shallower than the water table, water that leaves the PRMS model to enter the groundwater domain is added to the unsaturated zone. Flow through the unsaturated zone is simulated using MODFLOW-NWT. When the groundwater table is extends into the soil zone, soil water is discharged directly to the saturated zone.

2.8.1.1.3 Evapotranspiration Demands Based on Local Land Surface Properties and Climate Conditions

The YIHM estimates evapotranspiration (ET) demands across the Yucaipa Valley watershed using a modified Jensen-Haise formulation for potential evapotranspiration (PET). This formulation estimates PET based on average air temperature, solar radiation, and two empirical parameters that incorporate the effects of altitude, vapor pressure, and plant coverage (Markstrom et al. 2015).

Average air temperatures in the YIHM were constrained using daily values of minimum and maximum temperature measured at the NOAA Redlands climate station (station ID: 47306 Redlands). Minimum and maximum daily air temperature were mapped across the YIHM model domain using monthly temperature adjustment factors calculated using Parameter-evaluation Regressions on Independent Slopes Model (PRISM) monthly normal temperature minimum and maximum datasets.

Monthly minimum and maximum temperature averages generated by PRISM indicate that temperature varies non-linearly with elevation in the Yucaipa Valley Watershed. To represent this non-linearity, the YIHM uses temperature lapse rates to scale temperature at four different elevation thresholds in the watershed. The first group is for all model cells at an elevation between approximately 1,300 feet above NAVD88 and approximately 3,300 feet above NAVD88; the second group corresponded to all cells between approximately 3,300 feet above NAVD88 and 5,900 feet above NAVD88; the third group corresponded to all cells between approximately 5,900 feet above NAVD88 and approximately 8,800 feet above NAVD88. Temperature lapse rates for each grouping were calculated by generating linear regressions between PRISM monthly normal temperature values at elevation using all model cells that corresponded to each elevation grouping. Values of the temperature lapse rates used in the model are shown in Table 2C-1 of Appendix 2-C.

Coefficients of the modified Jensen-Haise equation that incorporate the effects of altitude, vapor pressure, and plant coverage on PET were adjusted during calibration of the PRMS model. Calibration of PRMS-estimated PET was preformed using PET data collected at four climate measurement stations within the CIMIS.

As Markstrom et al. (2015) discuss, evapotranspiration demands are met using both the groundwater and surface water models in GSFLOW. First, ET demands are met by removing water from the soil zone in the PRMS model; any remaining ET demands are met by water stored in the unsaturated and saturated zones of the MODFLOW model. Importantly, ET demands in the YIHM are allowed to change at the daily time-scale and directly impact the volume of water stored in the soil zone throughout the simulation; these time and location-dependent variations in ET demands and soil zone storage directly impact estimates of precipitation recharge in the Yucaipa Valley watershed.

2.8.1.2 Groundwater Numerical Model

The YIHM uses MODFLOW-NWT to characterize human-derived groundwater supplies and demands, surface water-groundwater interactions through streams, and subsurface interactions with adjacent basins. These interactions are constrained by local aquifer properties and the implementation of time-varying boundary conditions that represent anthropogenic recharge sources, extractions, and subsurface flows into and out of the Subbasin. Boundary conditions that represent anthropogenic recharge and discharge sources change at a monthly time-step, and natural recharge and discharge sources (such as streamflow interactions) are computed at the daily time scale.

A detailed description of how the YIHM constrains each recharge and discharge component from the groundwater system is provided in Sections 2.8.2 and 2.8.3, respectively.

2.8.2 Inflows to the Groundwater System

This section presents the sources of groundwater recharge to the Yucaipa Subbasin as well as a description of how each source is modeled in the YIHM. Average annual values of recharge by source are provided in Sections 2.8.2.1 through 2.8.2.5. These average annual values were extracted from the YIHM based on the B118 Yucaipa Subbasin boundary and represent 50-year average recharge rates computed using simulation results from the 1965 WY to 2014 WY.

2.8.2.1 Deep Percolation of Precipitation

Precipitation was simulated in the YIHM using a combination of precipitation measurements from the NOAA climate station located in Redlands (station ID: 47306 Redlands) and monthly normal precipitation values generated using the PRISM. The PRISM-generated monthly normal values were mapped onto the YIHM grid and used to calculate monthly precipitation adjustment factors that scaled precipitation from the NOAA station across the watershed. Monthly precipitation adjustment factors were calculated by dividing the PRISM monthly normal values associated with each model cell by the monthly normal value calculated from precipitation measurements collected at the NOAA station in Redlands.

Depending on the local soil storage capacity, a portion of the precipitation at each YIHM model cell will infiltrate into the soil zone, where it is either stored, lost to evapotranspiration, routed downhill, or allowed to migrate vertically into the groundwater domain. Groundwater levels vary throughout the Subbasin, from near ground surface to hundreds of feet below ground surface. As a result, infiltrating precipitation that leaves the soil zone will either enter the unsaturated zone or will directly recharge the saturated zone of the principal aquifer.

The volume of water that enters the saturated zone, either from the unsaturated zone or directly from the soil zone, was calculated throughout the historical period by the YIHM. During the period from the 1965 WY to 2014 WY, the YIHM estimates that direct precipitation provided approximately 6,100 AFY of groundwater recharge to the Subbasin (Appendix 2-C, Table 2C-2). This historically accounted for an average of approximately 17% of the average annual recharge to the Subbasin.

2.8.2.2 Return Flows

The principal aquifer in the Subbasin is also recharged from anthropogenic sources of water that originate as septic system discharges, irrigation return flows, and leaks in the municipal supply delivery system (Cromwell et al. 2020a). These sources of anthropogenic recharge are collectively referred to as *return* flows in this Plan. Return flows to the Yucaipa Subbasin vary in both time and location and are predominantly driven by land use change, water consumption and conservation patterns, and residential wastewater discharge practices.

2.8.2.2.1 Septic System Discharges

Prior to 1986, septic tanks were the primary method for disposal of residential wastewater in the Subbasin (YVWD 2010). In 1986, a sewer network was constructed to convey residential wastewater to the WRWRF, where it is treated and discharged to the San Timoteo Creek. While the majority of the residences in the Subbasin are connected to the sewer network, several areas in the Subbasin, including much of the Western Heights subarea, continue to utilize septic systems for residential wastewater disposal.

Residential wastewater discharges from septic systems were estimated in the YIHM using historical population estimates and an average septic discharge rate of 70 gallons per day per person (Umari et al. 1995). The YIHM estimated the location of septic discharges using land use data compiled from GIRAS, NLCD, and LANDFIRE (Alzraiee et al. 2020). Prior to 1986, land use data designated as “Developed” in the geospatial data were assumed to use septic systems for wastewater disposal (Cromwell et al. 2020a). Since 1986, the USGS has identified parcels that are likely using septic systems by combining the land use data with geospatial data provided by Yucaipa Valley Water District on their Sewer Network Service Area (Cromwell et al. 2020a). Regions of the Subbasin that are outside the Sewer Network Service Area were assumed to use septic systems as the primary method for disposal of residential wastewater (Cromwell et al. 2020a).

2.8.2.2.2 Irrigation Return Flows

A portion of the locally pumped groundwater, potable water, and recycled water delivered to customers in the Subbasin used for outdoor irrigation will infiltrate beyond the root zone and provide a source of groundwater recharge. The location and extent of these return flows depend on local land use properties, irrigation systems, and climatic conditions that all impact evapotranspiration demands and water availability.

The YIHM simulates irrigation return flows from four primary sources: golf courses, parks, agriculture, and residential landscaping. The Subbasin has two golf courses: the Yucaipa Valley Golf Club and Calimesa County Club. About 4 AFY per irrigated acre is required to meet the water demands for turf grass at each golf course (USGA 2012). In calendar year 2019, about 215 AF of recycled water was applied to the Yucaipa Valley Golf Club. An average of 260 AFY of recycled water was delivered to the Calimesa County Club between 2010 and 2014 (Cromwell et al. 2020a). The YIHM assumes that 1.6 AFY per irrigated acreage is required for turf irrigation at parks and residential parcels.

Initial estimates of return flows from these applied water sources ranged from 15% to 30% of the total water applied at each location (Cromwell et al. 2020a). Irrigation return flows at agricultural parcels are estimated by the YIHM based on local PET, crop coefficients, available soil moisture, and water deliveries.

2.8.2.2.3 Imported Groundwater

Municipal water used for residential landscaping in the Subbasin is supplied by locally pumped groundwater, recycled water, imported surface water, and groundwater extracted from outside the Subbasin boundary. YVWD and South Mesa both operate wells outside the Subbasin Boundary and import some of the extracted groundwater to supplement water supplies within their respective service areas in the Plan Area. Some of the groundwater imported to the Subbasin by YVWD and South Mesa recharges the Subbasin as return flows via landscape irrigation.

YVWD operates 17 municipal water supply wells outside the Yucaipa Subbasin. These wells are located in the Yucaipa Hills, San Timoteo Subbasin, and San Bernardino Subbasin. The majority of these wells are used to serve communities within YVWD's service area that lie outside the Subbasin; therefore, return flows from groundwater extractions at these wells do not directly recharge the Subbasin. YVWD historically imported groundwater extracted from YVWD-16, YVWD-48, and YVWD-61 to supplement municipal supplies in the Subbasin. When operational, these wells supplemented water supplies to communities located in the Oak Glen, Wilson Creek, Gateway, Calimesa, and Singleton subareas.

South Mesa operates well South Mesa-04, which is located outside the Yucaipa Subbasin and extracts groundwater from the San Timoteo Subbasin. Groundwater imported into the Subbasin by YVWD and South Mesa contribute to irrigation return flows.

Table 2C-3 in Appendix 2-C tabulates historical imported groundwater, as represented in the YIHM. Table 2C-3 does not include YVWD extractions from outside the Subbasin that are not served within the Subbasin boundaries. The data presented in Table 2C-3 indicates that the YIHM simulates YVWD importing groundwater to the Subbasin to supplement the municipal supply beginning in 1981 via operation of YVWD-16. In 1993, YVWD began importing groundwater extracted from YVWD-61. YVWD began importing water from YVWD-48 in the 2001 WY.

The YIHM simulates South Mesa importing groundwater to the Subbasin beginning in the 1988 WY via South Mesa-04. The YIHM simulated South Mesa importing groundwater into the Subbasin between the 1988 WY and 2014 WY at an average rate of approximately 480 AFY. South Mesa reports that South Mesa-04 began operating in 1956. The average production rate of South Mesa-04 reported by South Mesa from 1988 to 2014 is approximately 460 AFY.

2.8.2.2.4 Groundwater Under the Influence of Surface Water

Water produced from YVWD-25 is delivered to the OGSWFF, where it is treated and subsequently used to supplement municipal supplies in YVWD's service area. Between the 2001 WY and 2014 WY, YVWD-25 produced an average of approximately 294 AF of water annually (Appendix 2-C, Table 2C-6). A portion of the water produced by YVWD-25 will recharge groundwater as return flows to the Subbasin. Recharge from water supplied by YVWD-25 is incorporated into the return flow estimates calculated by the YIHM.

2.8.2.2.5 Surface Water Diversions

YVWD historically diverted an average 40 AFY from the 2001 WY to 2018 WY at the Oak Glen Creek diversion point, and an average of 70 AFY from the 2001 WY to 2009 WY at the Birch Creek diversion point (Appendix 2-C, Table 2C-6). No surface water has been diverted from Birch Creek since the 2009 WY. Surface water diversions from Oak Glen Creek have declined to approximately 1 AFY or less since the 2018 WY. Surface water diverted from these two diversion points is directed to the OGSWFF for treatment and subsequent distribution into YVWD's drinking water system. A portion of the surface water diverted recharged groundwater as return flows to the Subbasin. The recharge from diverted surface water is incorporated into the return flow estimates calculated by the YIHM.

2.8.2.2.6 Municipal System Leaks

The YIHM estimates that municipal water system leakage ranges from about 15% to 30% of the total pumping required to meet municipal water demands.

2.8.2.2.7 Net Recharge from Return Flows

The net recharge from septic system return flows, irrigation return flows, surface water diversions, municipal system leaks, and residential landscaping is simulated in the YIHM using the MODFLOW specified-flux well (WEL) package. The MODFLOW WEL package applies a user-defined flux of water to the top layer of the YIHM model domain. The net recharge rate assigned to each model cell in the YIHM is the summation of septic system discharges, irrigation return flows, and municipal water system leakage.

The YIHM estimates that these three sources of water provided an average of approximately 2,800 AF of recharge to the Subbasin annually (Appendix 2-C, Table 2C-2). Historically, this accounted for approximately 8% of the average annual recharge to the Subbasin.

2.8.2.3 Indirect Precipitation and Mountain Front Recharge

The Yucaipa Subbasin is surrounded by alluvial deposits and consolidated rock that act as a source of recharge to the Subbasin. Recharge from these sources is driven by precipitation that falls outside the Subbasin boundaries and percolates into the aquifer system that underlies each of these environments. Indirect precipitation recharge and mountain front recharge occurs along the southern, northern, western, and eastern boundaries of the Subbasin through the San Bernardino Subbasin, San Timoteo Subbasin, San Bernardino Mountains, Crafton Hills, and Yucaipa Hills. Sections 2.8.2.3.1 and 2.8.2.3.2 describe the mechanisms through which these sources recharge the Subbasin, and Section 2.8.2.3.3 describes the historical contribution of these sources to overall recharge within the Subbasin.

2.8.2.3.1 Mountain Front Recharge and Underflows from Crystalline Basement

The Yucaipa Subbasin is underlain by crystalline bedrock that is exposed at land surface in the Yucaipa Hills, Crafton Hills, and San Bernardino Mountains. Precipitation that falls in these regions will either be stored in the overlying soils, be lost via evapotranspiration, runoff into streams that flow into the Subbasin, or infiltrate into the crystalline basement. Underflows from the crystalline basement provide recharge to the Subbasin along the Subbasin boundaries. Surface water runoff conveyed into the Subbasin boundaries may recharge the Subbasin as stream leakage or be lost via evapotranspiration.

In addition to the crystalline bedrock expressions that border the north, east, and west, the Subbasin is bordered on the south by the San Timoteo Badlands, which contains surface expressions of the Sedimentary Deposits of Live Oak Canyon and San Timoteo Formation. Precipitation runoff and subsurface inflows that originate in the San Timoteo Badlands provide additional recharge to the Subbasin through the Live Oak Subarea.

Deep percolation of precipitation into the crystalline bedrock and San Timoteo Badlands is simulated directly in the YIHM. The YIHM represents bedrock and San Timoteo Formation characteristics using similar aquifer properties as the principal aquifer in the Subbasin. The YIHM assumes that groundwater stored in the San Timoteo Badlands and crystalline bedrock is in complete hydraulic communication with the Subbasin. Groundwater elevations in the crystalline basement or San Timoteo Badlands that are higher than the adjacent groundwater elevations in the principal aquifer will cause subsurface flows into the Subbasin that act as a source of recharge.

2.8.2.3.2 Subsurface Inflows from Adjacent Basins

The Yucaipa Subbasin is bordered by the San Timoteo Subbasin, both the adjudicated (Beaumont Watermaster) and non-adjudicated portions, to the southeast and by the adjudicated San Bernardino Subbasin to the southwest and northwest. The Yucaipa Subbasin, San Timoteo Subbasin, and San Bernardino Subbasin are locally disconnected by bedrock expressions in the Crafton Hills and Yucaipa Hills but may be hydraulically connected where these crystalline rocks are overlain by older alluvium and deposits from the Sedimentary Deposits of Live Oak Canyon.

Inflows from adjacent Subbasins into the Yucaipa Subbasin are not gauged but have been previously estimated at approximately 150 acre-feet per year (Rewis et al. 2006).

The YIHM estimates subsurface flows between the Yucaipa Subbasin and San Bernardino Subbasin using the MODFLOW General Head Boundary condition (GHB) package. General Head Boundaries in the YIHM are located along the jurisdictional boundaries between the Yucaipa Subbasin and San Bernardino Subbasin. Each general head boundary was assigned a groundwater elevation that was held constant through time. The value of the groundwater elevation assigned to each model cell located along the boundary was determined using measured groundwater elevations from two nearby groundwater monitoring wells.

Subsurface flows across each general head boundary are controlled by the pre-defined groundwater elevation at the boundary condition, the simulated groundwater elevation at the adjacent model cell in the YIHM, and a conductance parameter that describes the conductivity of the subsurface materials along the boundary. Conductance values were estimated during model calibration.

The Yucaipa Subbasin, San Timoteo Subbasin, and Beaumont Basin are hydrogeologically connected through the sedimentary deposits of the Live Oak Canyon. The YIHM simulates groundwater flow within the sedimentary deposits of the Live Oak Formation across the entire Yucaipa Valley Watershed. Underflows and subsurface exchanges between the Yucaipa Subbasin and San Timoteo Subbasin are internally calculated by the YIHM.

2.8.2.3.3 Subsurface Inflows

Simulation results from the YIHM indicate that an average of approximately 13,800 AFY of groundwater flowed into the Subbasin via subsurface exchanges with the surrounding mountains, hills, and groundwater basins (Appendix 2-C, Table 2C-2). The YIHM indicates that the largest source of subsurface inflow to the Subbasin occurs via underflow from the San Timoteo Subbasin through the San Timoteo Badlands (Figure 2-59, Subsurface Inflows and Outflows Simulated by the YIHM). Between 1965 and 2014, results from the YIHM indicate that underflow from the San Timoteo Subbasin provided an approximate average 6,500 AF of recharge to the Subbasin annually. This accounted for approximately 20% of the total average annual recharge to the Subbasin.

Along the northern boundaries of the Subbasin, the YIHM indicates that mountain front recharge from the San Bernardino Mountains and Yucaipa Hills provided approximately 2,300 AFY and 3,500 AFY of recharge to the Subbasin, respectively (Figure 2-59). Combined, these two sources accounted for approximately 17% of the average annual recharge to the Subbasin.

2.8.2.4 Stream Flow Leakage

The Yucaipa Valley Watershed is drained by a network of streams and creeks that convey surface water runoff from the San Bernardino Mountains, Yucaipa Hills, and San Timoteo Badlands to San Timoteo Creek before discharging to the San Bernardino Subbasin. The primary drainage features in the Subbasin are Wilson Creek, Oak Glen Creek, Yucaipa Creek, and San Timoteo Creek. The headwaters of Oak Glen Creek and Wilson Creek originate in the San Bernardino Mountains and the headwaters of Yucaipa Creek originate in the Yucaipa Hills. The San Timoteo Creek is the major drainage feature of the San Timoteo Wash watershed and enters the Subbasin in the Live Oak subarea.

Stream flows are actively measured within the Subbasin by SBCFCD along Oak Glen Creek and Yucaipa Creek and downstream of the Subbasin by the USGS along the San Timoteo Creek (see Section 2.3, Surface Water and Drainage Features). Stream gauges installed along Oak Glen Creek and Yucaipa Creek were designed by SBCFCD to measure peak flow events during large storms; measurements collected at these gauges during low-intensity precipitation events are of variable quality and uncertain (see Section 2.3.1, Characterization of Flow).

The YIHM simulates streamflow, stream flow leakage, and groundwater discharges to streams in the Yucaipa Valley watershed using the MODFLOW stream flow routing package. Estimates of surface runoff generated from the PRMS module of the YIHM are used as inputs to the MODFLOW stream flow routing package, which then routes surface water flow downhill before discharging out of the Subbasin. Because surface water flow measurements at the SBCFCD stream flow measurement gauges are impacted by silting/debris buildup, the YIHM's ability to simulate measured stream flows was down-weighted during the model calibration process.

Simulated stream stage and underlying groundwater elevations change in both location and time based on regional groundwater and climatic conditions. Groundwater discharges to streams and stream leakage are calculated in the YIHM by multiplying the difference between simulated stream stage and groundwater elevation with a streambed conductance parameter that characterizes stream bed conductivity. Streambed conductance is not measured and was adjusted during model calibration to provide a better fit to groundwater elevations measured near streams in the Subbasin. Because the YIHM was not calibrated to streamflow measurements, and the interaction between surface water and groundwater is highly non-linear, estimates of stream leakage from the YIHM are uncertain.

The YIHM estimates that stream leakage provided an average of approximately 11,800 AFY of recharge to the Subbasin (Appendix 2-C, Table 2C-2). This historically accounted for approximately 34% of the average annual recharge to the Subbasin. The YIHM indicates that most of the stream leakage in the Subbasin occurs in the Live Oak and Gateway subareas.

2.8.2.5 Imported Water from State Water Project

SBVMWD imports SWP water into the San Bernardino Valley for municipal, agricultural, and domestic supplies. SBVMWD is California's fifth largest State Water Contractor, with an annual maximum entitlement of 102,600 acre-feet (SBVMWD et al. 2017). YVWD began importing SWP water, purchased from SBVMWD, in the 2003 WY (Appendix 2-C, Table 2C-4). SWP water imported to the Yucaipa Subbasin recharges the principal aquifer either as return flows or via infiltration through the Oak Glen Creek and Wilson Creek spreading basins (see Section 2.5.4.2, Surface Water Diversions). Return flows from imported water used for municipal supplies are included in the return flow estimates calculated by the YIHM and presented in Section 2.8.2.2.

The YIHM assumes that all imported water delivered to the Oak Glen Creek and Wilson Creek Spreading Basins recharges the Subbasin. In addition to SWP water, YVWD delivers excess municipal supplies produced at the YVRWFF to the spreading basins (Appendix 2-C, Table 2C-5). The YIHM represents these infiltration basins using a network of 19 wells that inject spreading water into the saturated zone of the YIHM model domain. Because the Oak Glen Creek and Wilson Creek spreading basins are also used to capture runoff during large storm events, the total volume of water injected by these 19 wells exceeds the total volume of water delivered to the Wilson Creek and Oak Glen Creek spreading basins.

Table 2C-5 summarizes historical measured and simulated spreading volumes in the YIHM at the Oak Glen Creek and Wilson Creek spreading basins between water years 2001 and 2019. Spreading between the 2015 WY and 2019 WY represents current conditions in the Subbasin. The difference between reported and simulated recharge rates at the Oak Glen Creek and Wilson Creek spreading basins between the 2001 WY and 2014 WY is approximately 600 AFY (Appendix 2-C, Table 2C-5). Documentation of the YIHM model development attributes this difference to storm flow diversions at the two basins (Cromwell et al. 2020a).

2.8.3 Outflows from the Groundwater System

This section outlines the sources of groundwater discharge from the Yucaipa Subbasin and provides a description of how each discharge source is simulated in the YIHM. Average annual values of discharge by source are provided in Subsections 2.8.3.1 through 2.8.3.4. These average annual values were extracted from the YIHM based on the B118 Yucaipa Subbasin boundary and represent the 50-year average from the 1965 WY through 2014 WY.

2.8.3.1 Groundwater Production in the Yucaipa Subbasin

Groundwater from the Yucaipa Subbasin is extracted by municipal water suppliers and private well owners. Municipal suppliers in the Subbasin include YVWD, WHWC, and South Mesa. South Mountain operates two irrigation supply wells. In addition to municipal suppliers, groundwater is also extracted from the Subbasin via private well owners that utilize groundwater to supplement local domestic and irrigation demands. A description of historical municipal and private well extractions is described in Section 2.5.3, Groundwater Production Wells, and presented in tabular form in Table 2C-7 of Appendix 2-C.

Throughout the historical simulation, groundwater extractions by municipal suppliers and private well extractors averaged approximately 9,600 and 1,900 AFY, respectively (Appendix 2-C, Table 2C-7). YVWD has historically been the largest producer of groundwater in the Subbasin, extracting an average of approximately 5,100 AFY. Between the 1965 WY and 2014 WY, South Mesa and WHWC produced an average of approximately 2,100 AFY and 1,900 AFY from the Subbasin, respectively.

South Mountain extracted an average of approximately 650 AFY from the Subbasin between the 1965 and 2006 WY. Between the 2007 WY and 2013 WY, South Mountain did not extract groundwater from the Subbasin. In the 2014 WY, South Mountain extracted approximately 200 AF of groundwater from the Subbasin through the operation of the Chicken Hill Well.

The YIHM simulates groundwater extractions from 32 privately owned wells in the Subbasin. Private well extractions were highest in the 1960s (Appendix 2-C, Table 2C-7) and steadily declined throughout the historical period. In the 1965 WY, private well extractions accounted for approximately 35% of the total groundwater extracted from the Subbasin. By the 2014 WY, private well extractions accounted for approximately 5% of the total extractions from the Subbasin.

2.8.3.2 Groundwater under the Influence of Surface Water

Well YVWD-25 has produced groundwater under the direct influence of surface water from nearby Oak Glen Creek to the OGSWFF at an average rate of 274 AFY since 2001. The YIHM includes production by YVWD-25, which is accounted for as a groundwater extraction from the flow regime. However, the water produced by YVWD-25 is groundwater under the direct influence of surface water and is not factored into the water budget analysis for the Subbasin as a groundwater withdrawal.

2.8.3.3 Subsurface Outflows

As discussed in Section 2.8.2.3, Indirect Precipitation and Mountain Front Recharge, the Yucaipa Subbasin is hydraulically connected to varying degrees with the San Bernardino Subbasin, San Timoteo Subbasin, and Beaumont Basin (Figure 2-59). The YIHM estimates that an average of approximately 16,200 AF of groundwater flows out of the Subbasin as subsurface outflows (Appendix 2-C, Table 2C-2). Subsurface outflows from the Subbasin have historically accounted for approximately 46% of the total outflows from the Subbasin. Of this, the YIHM indicates that approximately 9,100 AFY flowed out of the Subbasin through the Live Oak subarea into the San Timoteo Subbasin (Appendix 2-C, Table 2C-22; Figure 2-59). The remaining subsurface outflows to the San Bernardino Subbasin, Beaumont Subbasin, and surrounding hills are summarized in Table 2C-22 (Appendix 2-C; Figure 2-59).

2.8.3.4 Groundwater Discharges to Streams

Groundwater in the Yucaipa Subbasin discharges to Oak Glen Creek, Wilson Creek, Yucaipa Creek, and San Timoteo Creek when underlying groundwater elevations are above the bottom elevation of each stream channel. Groundwater conditions that cause this are influenced by local pumping, climatic conditions, upstream stream leakage, and subsurface inflows from adjacent Subbasins, crystalline bedrock, and the San Timoteo Badlands.

Groundwater discharges to streams in the Subbasin were estimated using the YIHM. As discussed in Section 2.8.2.4, the YIHM simulates surface water-groundwater interactions using the MODFLOW streamflow routing (streamflow routing) package. Stream leakage and groundwater discharges are calculated at each time step in the YIHM using computed groundwater elevations, stream stages, and calibrated values of streambed conductance.

The YIHM estimates that an average of approximately 4,000 AF of groundwater discharged to streams in the Subbasin annually between the 1965 WY and 2014 WY (Appendix 2-C, Table 2C-2). Historically, this accounted for approximately 11% of the average annual groundwater outflows from the Subbasin. Results from the YIHM indicate that the majority of groundwater discharges to streams occurs in the Oak Glen subarea.

As noted in Section 2.8.2.4, the uncertainty in streamflow measurements in the Subbasin affect the quantitative assessment of the YIHM's representation of groundwater-surface water interactions in the Subbasin. Accordingly, estimates of groundwater discharges to streams calculated by the YIHM are a large source of uncertainty in the YIHM-estimated water budget for the Subbasin. Estimates of groundwater-surface water interactions will be refined in the future as stream flow gauging stations are installed in the Subbasin.

2.8.3.5 Evapotranspiration

A portion of the water stored in the soil zone, unsaturated zone, and shallow groundwater table will be consumed by ET. ET rates vary in both location and time, and are influenced by climatic conditions, soil and unsaturated zone properties, and overlying vegetation coverage.

The YIHM was used to calculate PET across the Yucaipa Valley watershed using the modified Jensen-Haise formulation. This formulation for PET incorporates the effects of plant coverage, average daily air temperature, solar radiation, altitude, and air vapor pressure. Estimates of PET calculated by the YIHM were calibrated using geospatial data from the CIMIS. The YIHM simulates ET by removing water from the soil zone, unsaturated zone, and groundwater to meet local PET demands.

The YIHM estimates that an average of approximately 3,500 AF of groundwater was removed via ET annually between the 1965 WY and 2014 WY (Appendix 2-C, Table 2C-2). Historically, this accounted for approximately 10% of the average annual groundwater outflows from the Subbasin. Simulation results from YIHM indicate that the largest groundwater losses from ET occur in the Live Oak and Oak Glen subareas. Both subareas have historically experienced shallow groundwater conditions (Section 2.5.1) and are the largest contributors to groundwater-surface water interactions in the Subbasin.

2.8.4 Change in Annual Volume of Groundwater in Storage

Historical annual changes in groundwater in storage were calculated by the YIHM from the 1965 WY through 2014 WY. Estimates of the annual change in groundwater in storage were extracted from the YIHM using the B118 Subbasin boundary shown on Figure 1-1. Historical change in volume of groundwater in storage is presented over the entire historical period and further aggregated by water year type. Water year type definitions are provided in Section 2.2.1.4.

Throughout the 50-year historical record, the YIHM estimates that groundwater in storage declined by an average of approximately 400 AFY (Appendix 2-C, Table 2C-2).

The YIHM estimates that groundwater in storage decreased by an average of approximately 8,700 AFY in critically dry water years and increased by approximately 6,800 AFY in wet water years. During dry, below normal, normal, and above normal water years, the YIHM estimates that groundwater in storage decreased by approximately 3,000, 1,500, 1,300, and 600 AFY, respectively.

Figure 2-60 shows historical cumulative change in groundwater in storage in the Subbasin. Between the 1965 WY and 1977 WY, groundwater in storage fluctuated between a surplus of groundwater in storage of approximately 2,200 AF and a deficit of groundwater in storage of approximately 6,800 AF. Groundwater in storage increased between the 1977 WY and 1987 WY to a surplus of approximately 50,000 AF in response to consecutive wet and above normal water years and groundwater extraction rates that remained at, or below, the estimated sustainable yield of the Subbasin (see Section 2.8.6, Estimate of Sustainable Yield).

Groundwater in storage declined between the 1987 WY and 2009 WY to a net deficit of approximately 26,600 AF. Groundwater in storage has increased since 2009 due to the importation of SWP water as a supplemental water supply that reduced groundwater production from the Subbasin and provided some artificial recharge to the Subbasin. At the end of the historical period, the YIHM estimates that the Subbasin experienced a net deficit of groundwater in storage of approximately 18,300 AF.

2.8.5 Quantification of Overdraft

DWR has designated the Yucaipa Subbasin as a high-priority basin. The GSP Emergency Regulations require that the water budget "include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions" if the Basin is found to experience overdraft (23 CCR, Section 354.18, Water Budget). Groundwater overdraft is defined in DWR Bulletin 118 (DWR 2003) as:

> …the conditions of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years.

Simulation results from the YIHM indicate that the Subbasin is not in overdraft. Figure 2-60 shows the cumulative change in groundwater in storage across the Subbasin and demonstrates that the Yucaipa Subbasin has historically experienced periods of groundwater storage decline, driven both by climatic conditions across the Yucaipa Watershed and by periods of groundwater extractions that exceeded the sustainable yield, followed by recovery of groundwater in storage. Recent operations within the Subbasin have resulted in an increasing trend in the volume of groundwater in storage, indicating that the Subbasin is not in overdraft (Figure 2-60). The interpretation of these simulation results as indicative of non-overdraft conditions is supported by increasing groundwater elevation trends observed in the Yucaipa Subbasin.

Water levels collected across the Subbasin show that groundwater elevations have fluctuated throughout the historical period; these water level fluctuations vary in both time and location. In the Crafton, Triple Falls Creek, Live Oak, Singleton, and Oak Glen subareas, water levels throughout the historical period either remained constant or increased, indicating that these subareas did not experience overdraft conditions between the 1965 WY and 2014 WY. Similarly, in the Gateway and Wilson Creek subareas, water levels measured at YVWD-18 and YVWD-07 fluctuated between 2,300 and 2,400 feet above NAVD88 and did not show long-term declines indicative of overdraft. In the Calimesa subarea, water levels increased during the historical period to approximately 2,150 to 2,200 feet above NAVD88 in the late 1980s and then decreased to approximately 2,050 feet above NAVD88 by 2006. Following this decline, water levels in the Calimesa subarea have been rising and are currently near the historical average water levels in the subarea. These periodic water level fluctuations in the Calimesa subarea are not indicative of overdraft conditions.

Water levels in the Western Heights subarea generally declined from 1965 into the early 2000's. Between the 1965 WY and 2008 WY, the YIHM estimates that groundwater in storage was declining at an average rate of approximately 800 AFY per year. During this same period, groundwater extractions from the Western Heights subarea averaged approximately 2,500 AFY. Since 2008, water levels in the Western Heights subarea have either stabilized or increased. Water level trends in the Western Heights subarea following 2008 indicate that the subarea is not experiencing overdraft conditions.

2.8.6 Estimate of Sustainable Yield

GSP Emergency Regulations Section 354.18(b)(7) states that each Plan shall use the water budget to develop an estimate of the Sustainable Yield for the basin. The SGMA legislation defines the sustainable yield of the basin as, "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from groundwater supply without causing undesirable results" (Section 107271, Definitions [w]).

Undesirable results are defined under SGMA as significant and unreasonable impacts to six different sustainability indicators:

- Chronic Lowering of Groundwater Levels
- Reduction of Groundwater in Storage
- Degradation of Water Quality
- Land Subsidence
- Depletion of Interconnected Surface Water (GDEs)
- Seawater Intrusion

As described in Section 2.7.3, Seawater Intrusion, and Section 2.7.4, Groundwater Quality, seawater intrusion and degradation of water quality are not sustainability indicators applicable to the Yucaipa Subbasin. Additionally, historical operations within the Subbasin have not impacted habitat health at the groundwater dependent ecosystems located in the Oak Glen subarea and Live Oak subarea (Section 2.7.8, Groundwater–Surface Water Connections). Historical land subsidence was attributed to tectonic activity in the Plan Area and not attributed to declining groundwater levels. Because of this, the historical estimate of sustainable yield presented in this Plan focuses on avoiding significant and unreasonable chronic lowering of groundwater levels and reduction of groundwater in storage (and to the potential of land subsidence should groundwater levels fall below the historical lows for a significant period of time). A more detailed discussion of undesirable results associated with these sustainability indicators are provided in Chapter 3 of this Plan.

The historical sustainable yield of the Yucaipa Subbasin was estimated using simulation results from the YIHM from the 1965 WY to 2014 WY. During this period, average annual net stream leakage, precipitation recharge, surface water spreading, and return flows, provided approximately 7,830 AFY, 6,100 AFY, 310 AFY, and 2,830 AFY of recharge to the Subbasin. Over the same period, net subsurface interactions and evapotranspiration resulted in an average annual outflow of groundwater from the Subbasin of 2,390 AFY and 3,460 AFY, respectively. In addition to this, approximately 220 AFY of percolating surface water is extracted from the Subbasin and 20 AFY of groundwater discharges to land surface. Summing these average annual water budget components leaves a surplus of approximately 10,980 AFY, which could be extracted from the Subbasin without causing a net loss of groundwater in storage. **The estimated sustainable yield of 10,980 AFY avoids undesirable results associated with chronic lowering of groundwater levels and reduction of groundwater in storage by ensuring that long-term operations within the Subbasin results in no net-change of groundwater in storage.**

Previous investigations of safe yield for the Yucaipa Subbasin are in general agreement with the historical estimate of sustainable yield presented in this Plan (Appendix 2-C, Table 2C-8). In their 2014 study of safe yield for the Yucaipa Subbasin, GSSI estimated the Subbasin safe yield using three different methods that relied on measured groundwater elevations, groundwater extractions rates, and a hydrologic water balance computed using the US EPA's watershed modeling software, Hydrologic Simulation Program (GSSI 2014a). Measured groundwater elevations and groundwater extraction rates were analyzed using the Zero-Net Draft Method and Hill Method described in GSSI (2014a). GSSI's estimate of safe yield for the Subbasin using these three methods ranged from approximately 9,600 FY to 9,700 AFY. These estimates of safe yield do not include an estimate of safe yield for the Live Oak and Singleton subareas (Section 2.5.2.1).

Future conditions in the Subbasin may deviate from historical conditions due to increasing water demands, availability of recycled water for municipal supply, impacts of climate change on temperature and precipitation, and availability of SWP water. The final estimate of sustainable yield for the Subbasin will consider the historical yield of the Subbasin but will also be defined to prevent the undesirable results of future significant and unreasonable groundwater storage declines, chronic lowering of water levels, and impacts to groundwater dependent ecosystems. These will be assessed using the future simulations discussed in Section 2.8.7.3; the ability for the Subbasin to operate at the historical sustainable yield while avoiding undesirable results in the future will be described in Chapter 3 of this GSP.

2.8.7 Quantification of Historical, Current, and Projected Water Budgets

Each GSP is required to include an accounting of the total annual volume of surface water and groundwater entering and leaving the basin during historical, current, and projected conditions (23 CCR 354.18). Historical conditions for the Plan Area were defined using data for the period between the 1965 WY and 2014 WY. Current conditions for the Plan Area were defined using data for the period between the 2015 WY and 2018 WY. The projected water budgets were prepared for 51-year period from the 2019 WY through 2069 WY. The historical, current, and projected future baseline water budgets for the Plan Area are presented in Figure 2-61. A summary of the water budget for the historical, current, and projected water budgets are provided in Sections 2.8.7.1, 2.8.7.2, and 2.8.7.3.

2.8.7.1 Historical Water Budget

Section 354.18(c) (2) of the GSP Emergency Regulations state that historical water budget information shall be, "used to evaluate availability of reliability of past surface water supply deliveries and aquifer response to water supply and demand trends relative to water year." The water budget discussed in this section provides a historical accounting of surface water availability, groundwater inflows, groundwater outflows, and corresponding changes to the volume of groundwater in storage between the 1965 WY and 2014 WY. Estimates of the individual water budget components are based on simulation results from the YIHM.

Table 2C-9 of Appendix 2-C tabulates the water year type distribution between the 1965 WY and 2014 WY in the Subbasin. Climate during this 50-year period was generally dry, with 31 out of the 50-year historical record characterized as "normal," "below normal," "dry," and "critically dry" water year types. Over the same period, 19 water years were characterized as "above normal" or "wet" water year types.

2.8.7.1.1 Historical Surface Water Availability

Table 2C-10 of Appendix 2-C shows historical surface water availability in the Yucaipa Subbasin from the 2001 WY through 2014 WY. Historical surface water supplies included SWP water purchased from SBVMWD and imported to the Subbasin by YVWD and surface water diversions from Oak Glen Creek and Birch Creek.

2.8.7.1.1.1 State Water Project Water

YVWD began importing SWP water into the Subbasin in the 2003 WY. Between the 2003 WY and 2014 WY, YVWD imported an average of approximately 5,000 AF of SWP water to the Subbasin. SWP water imports during this period ranged from 855 AF in water year 2003 to 9,394 AF in the 2012 WY. The 2012 WY was a "dry" water year type.

SWP Water imports to the Subbasin were historically highest during dry water years. During the prolonged dry period between the 2012 WY and 2014 WY, YVWD imported an average of approximately 7,900 AF of SWP water annually.

The majority of SWP water imported to the Subbasin by YVWD is used to supplement annual municipal supplies via treatment at the YVWRFF and distribution into the drinking water supply. Imported water that is in excess of YVWD's service area demands is discharged to the Wilson Creek and Oak Glen spreading basins to artificially recharge the Subbasin. YVWD delivered SWP water to the Wilson Creek and Oak Glen Creek spreading basins in the 2011 WY, 2012 WY, and 2013 WY, which ranged from approximately 1,700 AF to 3,400 AF (Appendix 2-C, Table 2C-5).

2.8.7.1.1.2 Surface Water Diversions from Oak Glen Creek and Birch Creek

Between the 2001 WY and 2014 WY, YVWD diverted an average of approximately 92 AF of surface water from Oak Glen Creek and Birch Creek annually (Appendix 2-C, Tables 2C-6 and 2C-10). Surface water diversions during this period ranged from approximately 206 AF in 2005 to 8 AF in 2012. Data for surface water diversions along Oak Glen Creek and Birch Creek were not available prior to 2001.

Surface water has not been diverted from Birch Creek since 2009 due to maintenance issues with the surface water transmission lines between Birch Creek and the OGSWFF (personal correspondence with YVWD, 2020). Prior to 2009, diversions from Birch Creek ranged from 148 AF in the 2006 WY to 9 AF in the 2008 WY.

2.8.7.1.1.3 Inflows to Groundwater System

Between the 1965 WY and 2014 WY, the YIHM estimates that groundwater in the Yucaipa Subbasin was recharged at an average rate of approximately 34,900 AFY (Appendix 2-C, Table 2C-2). Average annual groundwater recharge to the Subbasin varied by water year type: during critically dry water years, the YIHM estimates that the Subbasin was recharged at an average rate of approximately 29,900 AFY, and during wet water years, the YIHM estimates that the Subbasin was recharged at an average rate of approximately 42,900 AFY.

The largest sources of groundwater recharge were stream leakage, subsurface inflows from the San Timoteo Badlands, and deep percolation of precipitation (Appendix 2-C, Table 2C-2). These three sources of recharge accounted for approximately 35%, 19%, and 17% of the average annual recharge to the Subbasin, respectively. Results from the YIHM indicate that subsurface inflows from the San Timoteo Badlands do not vary by water year type (Appendix 2-C, Table 2C-2). The YIHM estimates that stream leakage during critically dry water years provided an average of approximately 10,700 AF of recharge to the Subbasin annually. During wet water years, the YIHM estimates that stream leakage provided an average of approximately 13,800 AF of recharge to the Subbasin annually.

Groundwater recharge from deep percolation of precipitation averaged approximately 6,100 AFY (Appendix 2-C, Table 2C-2). During wet water years, the YIHM estimates that precipitation provides an average of approximately 12,100 AFY of recharge to the Subbasin (Appendix 2-C, Table 2C-2). In critically dry water years, the YIHM estimates that precipitation provided approximately 2,500 AFY of recharge to the Subbasin.

Groundwater recharge from return flows (Section 2.8.2.2) fluctuated throughout the historical period. Between the 1965 WY and 1989 WY, return flows increased from approximately 2,000 AFY to 6,000 AFY (Appendix 2-C, Table 2C-2). Following the 1989 WY, return flows declined to a recharge rate of 1,000 AFY through the 1992 WY. Recharge from return flows increased after the 1992 WY to a value of approximately 4,000 AF in the 2014 WY. Simulation results from the YIHM indicate that return flows historically provided approximately 8% of the average annual recharge to the Subbasin and are not correlated with water year type.

2.8.7.1.1.4 Outflows from Groundwater System

Between the 1965 WY and 2014 WY, the YIHM estimates that an average of approximately 35,200 AF of groundwater was removed from the Subbasin annually (Appendix 2-C, Table 2C-2). Average annual groundwater outflows from the Subbasin were not historically correlated with water year type.

The largest sources of groundwater outflows during the historical period were groundwater extractions, subsurface underflows to the San Timoteo Badlands, underflows to the San Bernardino Basin, and groundwater discharges to streams. The YIHM estimates that subsurface flows to the San Timoteo Badlands and San Bernardino Basin averaged approximately 9,100 AFY and 4,000 AFY, respectively (Appendix 2-C, Table 2C-2). Results from the YIHM indicate that subsurface flows out of the Subbasin are not correlated with water year type (Appendix 2-C, Table 2C-2).

The YIHM estimates that an average of approximately 4,000 AFY of groundwater discharged to streams in the Subbasin (Appendix 2-C, Table 2C-2). Groundwater discharges to streams during critically dry and wet years averaged approximately 3,200 AFY and 5,400 AFY, respectively.

Between the 1965 WY and 2014 WY, groundwater extractions in the Subbasin averaged approximately 11,300 AFY (Appendix 2-C, Tables 2C-2 and 2C-7). Private well extractions were historically highest in the 1960s, where they accounted for an average of approximately 35% of the total extractions within the Subbasin. Private well extractions have steadily decreased to approximately 5% of the total extractions in the Subbasin in the 2014 WY.

Figure 2-60 shows historical groundwater extraction rates in the Subbasin between the 1965 WY and 2014 WY. Between the 1983 WY and 2002 WY, groundwater extraction rates increased from 8,400 AFY to approximately 15,400 AFY to meet increasing demands in the Subbasin. In the 2003 WY, YVWD began importing SWP water into the Subbasin to supplement municipal supplies. Following these imports, groundwater extraction rates across the Subbasin declined.

2.8.7.1.1.5 Change in Groundwater Storage

Throughout the historical period, the YIHM estimates that groundwater in storage declined at an average annual rate of 370 AFY. Over the 50-year historical period, this resulted in a cumulative loss of groundwater in storage of approximately 18,300 AF from the start of the 1965 WY. A detailed discussion of storage change trends and relationship to water year type is provided in Section 2.8.4, Change in Annual Volume of Groundwater in Storage.

2.8.7.2 Current Water Budget

GSP Emergency Regulations Section 354.18(c)(1) states that each Plan shall characterize "current groundwater inflows and outflows for the Basin using the most recent hydrology, water supply, water demand, and land use information." To characterize current conditions in the Basin, the YIHM was extended to simulate conditions in the Subbasin between January 1, 2015, and September 30, 2018.

Data on groundwater extractions and imported water supplies were provided by YVWD, WHWC, South Mesa, and South Mountain for the 2015 WY through 2018 WY. These data were used to update groundwater pumping and spreading volumes in the current condition simulations performed using the YIHM. Private well extractions across the Yucaipa Valley watershed were estimated using the 2014 WY groundwater extraction rates. Private wells that did not operate in the 2014 WY did not extract groundwater from the Subbasin during the current condition simulations.

Return flows and general head boundary conditions were held constant at the 2014 WY rates and conditions.

Precipitation in the current condition simulation was based on the precipitation measurements collected at the NOAA climate measure station in Redlands. The NOAA climate station in Redlands stopped collecting minimum and maximum temperature measurements in May 2015. Because minimum and maximum temperature measurements were not available at this station during water years 2015 through 2018, temperature conditions in the current condition simulation were constrained using minimum and maximum temperature values measured at the NOAA climate station located at Mill Creek (station ID: USR000CMCB Mill Creek BDF California, CA US; see Section 2.2.2, Temperature). A linear regression was developed between historical minimum and maximum temperatures measured at the Mill Creek and Redlands station to extrapolate temperature data from the Mill Creek station to the Redlands location. The lapse rates defined in the historical simulation of the YIHM were then used to extrapolate the resulting minimum and maximum air temperature data onto the YIHM model grid.

Average groundwater inflows, outflows, and changes in storage between the 2015 WY and 2018 WY were used to characterize the current water budget conditions in the Subbasin.

The 2015, 2016, 2017, and 2018 water years were characterized as below normal, dry, above normal, and critically dry water year types, respectively (Appendix 2-C, Table 2C-11). During this period, the Subbasin received an average 12.3 inches of rain per year.

2.8.7.2.1 Surface Water Availability

State Water Project Water

Between the 2015 WY and 2018 WY, YVWD imported an average 9,100 AF of SWP water to the Subbasin annually (Appendix 2-C, Table 2C-4). Surface water imports were highest in 2017, when YVWD imported approximately 15,300 AF of SWP water to the Subbasin. The 2017 WY was an above normal water year type.

During this period, YVWD delivered imported SWP water to the Oak Glen Creek and Wilson Creek spreading basins in the 2017 WY and 2018 WY (Appendix 2-C, Table 2C-5). In the 2017 WY, YVWD recharged approximately 6,500 AF of SWP water via the spreading basins, and in the 2018 WY, YVWD recharged approximately 1,700 AF of SWP water via the spreading basins.

Surface Water Diversions from Oak Glen Creek

Between the 2015 WY and 2018 WY, YVWD diverted an average 213 AF of surface water from Oak Glen Creek (Appendix 2-C, Table 2C-6). The majority of these diversions occurred through the operation of YVWD-25, which diverted an average of 206 AFY during this period.

No surface water was diverted from Birch Creek between the 2015 WY and 2018 WY.

2.8.7.2.2 Inflows to Groundwater System

Results from the YIHM under current conditions indicate that the Subbasin was recharged at an annual average rate of approximately 36,000 AFY (Appendix 2-C, Table 2C-11). The largest sources of recharge between water years 2015 and 2018 were stream leakage and underflows from the San Timoteo Badlands. Stream Leakage provided an average of approximately 11,700 AFY of recharge to the Subbasin between the 2015 WY and 2018 WY. Subsurface inflows from the San Timoteo Badlands provided an average of approximately 6,700 AFY of recharge. These two recharge sources accounted for 33% and 18% of the average annual recharge, respectively.

Recharge from precipitation provided an average of approximately 5,500 AFY of recharge to the Subbasin and ranged from approximately 2,900 AF in water year 2015 to 10,000 AF in the 2017 WY (Appendix 2-C, Table 2C-11). Groundwater recharge from irrigation return flows, septic system discharges, and leaks in the municipal supply lines provided an average of approximately 4,000 AFY of recharge to the Subbasin (Appendix 2-C, Table 2C-11). Between the 2015 WY and 2018 WY, recharge at the Oak Glen Creek and Wilson Creek Spreading Basins ranged from a minimum of 6 AF to a maximum of approximately 6,600 AF (Appendix 2-C, Table 2C-11).

2.8.7.2.3 Outflows from Groundwater System

The YIHM estimates that outflows from the groundwater system between the 2015 WY and 2018 WY averaged approximately 33,500 AFY. This is approximately 1,600 AFY less than average annual outflows from the groundwater system compared to historical conditions (Appendix 2-C, Table 2C-11).

The largest sources of groundwater outflows from the Subbasin were subsurface discharges to the San Timoteo Badlands and groundwater extractions. Subsurface underflows to the San Timoteo Badlands averaged approximately 9,200 AFY and groundwater extractions averaged approximately 8,100 AFY.

During this period, YVWD extracted an average of approximately 4,000 AFY from the Subbasin, South Mesa extracted an average of approximately 1,900 AFY from the Subbasin, and WHWC extracted approximately 1,600 AFY from the Subbasin. These combined extraction rates are approximately 20% lower than historical municipal extraction rates in the Subbasin.

The YIHM estimates that an average of approximately 4,100 AFY of groundwater discharged to streams between the 2015 WY and 2018 WY. Similar to historical conditions in the Subbasin, these discharges occurred predominantly in the northern reaches of the Oak Glen Subarea and in the Live Oak Subarea.

2.8.7.2.4 Change in Groundwater Storage

The YIHM estimates that groundwater in storage increased by an average rate of approximately 2,500 AFY from the 2015 WY to 2018 WY (Appendix 2-C, Table 2C-11).

Groundwater in storage increased by a total of approximately 10,000 AF between the 2015 WY and 2018 WY (Appendix 2-C, Table 2C-11). This cumulative increase of groundwater in storage leaves a deficit of approximately 8,300 AF of groundwater in storage compared to water year 1965 conditions.

2.8.7.3 Projected Water Budget

Each GSP is required to included projected water budgets in order to estimate "future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify uncertainties of these projected water budget conditions (22 CCR Section 254.18(c)3)." To assess future conditions, the projected water budgets are required to utilize a 50-year projection horizon that incorporates the most recent land use and population data, projected water demands, and surface water availability. Projected water budgets shall also be used to evaluate the potential impacts of climate change on operations within the Subbasin.

Projected water budgets for the Subbasin were generated using simulation results from the YIHM for three future scenarios: (1) Future Baseline, (2) Future Baseline with Climate Change I, and (3) Future Baseline with Climate Change II. Each scenario incorporated the same groundwater extraction and surface water spreading scenarios and utilized the hydrologic conditions recorded at the NOAA Redlands station from the 1963 WY to 2013 WY. This hydrologic record measured at the NOAA Redlands station was used to simulate projected conditions in the Subbasin from the 2019 WY through the 2069 WY. In the Future Baseline with Climate Change I scenario, the precipitation and temperature data collected at the NOAA Redlands station were adjusted using DWR 2030 Central Tendency precipitation and evapotranspiration climate change factors. In the Future Baseline with Climate Change II scenario, the precipitation and temperature data collected at the NOAA Redlands station were adjusted using DWR 2070 Central Tendency climate change factors. Under all three scenarios, land use was held constant and equal to land use in the 2014 WY.

During the period from 1962 through 2012, average annual precipitation, daily temperature maximum, and daily temperature minimum values measured at the NOAA Redlands station were 13.13 inches per year, 79°F, and 50°F, respectively. The application of DWR 2030 Central Tendency climate change factors decreased the average annual precipitation to 13.03 inches per year and increased the average daily temperature maximum and minimum to 83°F and 53°F, respectively. The application of DWR 2070 Central Tendency climate change factors decreased average annual precipitation to 12.5 inches per year and increased the average daily temperature maximum and minimum to 87°F and 55°F, respectively.

Groundwater extraction rates and imported surface water supplies available for groundwater recharge were held constant in all three future scenario simulations. Groundwater extraction rates were constrained by the historical estimate of Sustainable Yield for each Management Area defined in Section 2.9. Results from the historical model indicate that the sustainable yields for the Calimesa, Western Heights, North Bench, and San Timoteo Management Areas are 4,955 AFY, 1,760 AFY, 3,940 AFY, and 325 AFY, respectively (Appendix 2-C, Table 2C-12). Private wells that were active in the current condition simulation extracted groundwater in the future simulations at their 2014 groundwater extraction rates. Simulated extractions by YVWD, WHWC, South Mesa, and South Mountain were generated using the average water year 2015–2018 groundwater extraction distributions within each Management Area. Private well extractions in the San Timoteo Management Area, as simulated by the YIHM, ceased in water year 2006 (Section 2.9.4). Because there are no municipal extractions in this Management Area, groundwater production within the San Timoteo Management Area was not simulated under projected conditions. Therefore, the total projected groundwater extraction rate in the Subbasin was approximately 10,600 AFY, or 400 AFY less than the sustainable yield of the entire Subbasin. In addition to this, surface water diversions along Oak Glen Creek were simulated at a constant rate of approximately 190 AFY through the operation of YVWD Well 25.

Surface water spreading under projected conditions was held constant at the average 2011-2018 spreading rate of approximately 2,100 AFY. Based on data provided by YVWD, approximately 92% of the 2,100 AFY was recharged at the Wilson Creek spreading basins and the remaining 8% was recharged at the Oak Glen Creek spreading basins.

2.8.7.3.1 Future Baseline Scenario

Groundwater Inflows

The YIHM estimates that the Subbasin will receive approximately 41,500 AFY of recharge under Future Baseline conditions (Appendix 2-C, Table 2C-13). Approximately 14,000 AFY, or 34% of the total recharge, occurred in the form of stream leakage, and approximately 13,500 AFY, or 32% of the total recharge, occurred in the form of subsurface inflows from the mountain front and adjacent Subbasins. The YIHM estimates that precipitation within the Subbasin boundaries will provide approximately 7,900 AFY of recharge to the Subbasin.

The estimated average annual recharge to the Subbasin under Future Baseline conditions is approximately 6,600 AFY higher than historical conditions (Appendix 2-C, Table 2C-13). The increase in average annual recharge is due to the increase in return flows, stream leakage, precipitation recharge, and surface water spreading. Under the Future Baseline conditions, return flows are approximately 1,200 AFY higher than the historical average, stream leakage is approximately 2,200 AFY higher than the historical average, precipitation recharge is approximately 1,800 AFY higher than the historical average, and surface water spreading is approximately 1,800 AFY higher than the historical average. Conversely, subsurface inflows provide approximately 300 AFY less than the historical average.

Groundwater Outflows

As previously stated, groundwater extractions under the Future Baseline Scenario were held constant at approximately 10,600 AFY, which is approximately 400 AFY lower than the estimated sustainable yield of the North Bench, Calimesa, and Western Heights Management Areas. These extraction rates are approximately 800 AFY less than the historical average (Appendix 2-C, Table 2C-13).

Groundwater discharges to streams, subsurface discharges to adjacent subbasins, and evapotranspiration from shallow groundwater all occurred at higher rates in the Future Baseline simulation compared to their corresponding historical averages. Under the Future Baseline conditions, the YIHM calculates that approximately 4,800 AFY of groundwater will be consumed by evapotranspiration, approximately 18,600 AFY of groundwater will discharge to adjacent subbasins, consolidated bedrock, or the San Timoteo Badlands, and approximately 6,300 AF of groundwater will discharge to streams annually (Appendix 2-C, Tables 2C-13 and 2C-14). These estimates of evapotranspiration, subsurface discharges, and groundwater discharges to streams are higher than the historical average by approximately 1,400 AFY, 2,400 AFY, and 2,300 AFY, respectively. The increase in evapotranspiration, subsurface discharges, and groundwater discharges to streams is attributable to an increase in groundwater levels compared to historical low conditions across the Subbasin as a result of groundwater extractions that remain at the sustainable yield.

Although groundwater extractions are approximately 800 AFY less than the historical average under the Future Baseline conditions, the YIHM calculates that average annual groundwater discharges from the Subbasin will exceed historical conditions by approximately 5,400 AFY. As noted above, the increased outflows from the Subbasin are driven by subsurface outflows, evapotranspiration, and groundwater discharges to streams.

Changes in Groundwater in Storage

The YIHM simulation results indicate that operation of the Subbasin under the Future Baseline conditions results in an average increase in groundwater in storage of approximately 800 AFY (Appendix 2-C, Tables 2C-13 and 2C-14). Over the 51-year simulation period, this resulted in a net storage increase of approximately 42,300 AF. Combining this with YIHM simulation results for the current and historical conditions suggests that groundwater in storage in the Subbasin will be approximately 34,000 AF higher than the groundwater in storage at the beginning of the 1965 WY (Figure 2-62, Historical, Current, and Projected Storage Change in the Yucaipa Subbasin).

2.8.7.3.2 Future Baseline with Climate Change I

Groundwater Inflows

Under the Future Baseline with Climate Change I scenario, the YIHM estimates that the Yucaipa Subbasin will receive an average of approximately 39,900 AFY of recharge (Appendix 2-C, Table 2C-15). This is approximately 5,000 AFY higher than historical condition in the Basin and approximately 1,600 AFY lower than Future Baseline conditions without climate change (Appendix 2-C, Table 2C-14).

Application of the DWR 2030 Central Tendency climate change factors to the precipitation and temperature data measured at the NOAA Redlands station results in a decrease in average annual precipitation recharge, subsurface inflows, and stream leakage into the Subbasin compared to the Future Baseline scenario without climate change. Under the Future Baseline with Climate Change I conditions, the YIHM predicts that precipitation will provide approximately 7,300 AFY of recharge to the Subbasin, which is approximately 600 AFY less than the historical and Future Baseline average (Appendix 2-C, Table 2C-14). Reduced precipitation in the surrounding mountains, hills, and adjacent Subbasins resulted in an average subsurface inflows to the Subbasin of approximately 13,200 AFY, which is lower than subsurface inflow recharge rates simulated in both the Historical and Future Baseline simulations (Appendix 2-C, Table 2C-14). The YIHM simulation results indicate that operations under the Climate Change I scenario will result in approximately 13,300 AFY of stream leakage recharge to the Subbasin; this is approximately 2,200 AFY higher than the historical average and approximately 800 AFY lower than the Future Baseline estimate of stream leakage.

Groundwater Outflows

Groundwater extractions under the Future Baseline with Climate Change I scenario were held constant at 10,600 AFY (Appendix 2-C, Tables 2C-14 and 2C-15). The pumping distribution across the Subbasin in this scenario is equivalent to the extraction conditions described in Section 2.8.7.3.1.2, Groundwater Outflows.

Simulation results from the YIHM indicate that average annual groundwater outflows from the Subbasin are approximately 1,200 AFY less than Future Baseline conditions (Appendix 2-C, Table 2C-14). The YIHM predicts that the reduction in average annual groundwater outflows from the Subbasin is caused by a decrease in groundwater discharges to streams (Appendix 2-C, Table 2C-14). The reduction in groundwater discharges to streams is driven by lowering of groundwater elevations that result from a reduction in the average annual recharge from stream leakage, precipitation recharge, and subsurface inflows.

Changes in Groundwater in Storage

The YIHM simulation results indicate that reduced recharge under the Future Baseline with Climate Change I scenario results in an average annual increase in groundwater in storage of approximately 450 AFY. This is approximately half the rate of groundwater storage increase predicted by the YIHM under the Future Baseline conditions and results in a cumulative increase of groundwater in storage of approximately 23,300 AF between the 2019 WY and 2069 WY. Under these conditions, the YIHM predicts that groundwater in storage in the Subbasin will be approximately 19,300 AF higher than the volume in storage at the start of the 1965 WY (Figure 2-62).

2.8.7.3.3 Future Baseline with Climate Change II

Groundwater Inflows

Under the Future Baseline with Climate Change II scenario, the YIHM estimates that the Yucaipa Subbasin will receive an average of approximately 37,800 AFY of recharge (Appendix 2-C, Table 2C-16). This is approximately 2,900 AFY higher than historical conditions in the Basin and approximately 3,700 AFY lower than Future Baseline conditions without climate change (Appendix 2-C, Table 2C-14).

Similar to the Future Baseline with Climate Change I scenario, the application of the DWR 2070 Central Tendency climate change factors to the precipitation and temperature data measured at the NOAA Redlands station resulted in a reduction of average annual precipitation recharge, subsurface inflows, and stream leakage into the Subbasin compared to the Future Baseline scenario without climate change. Under the Future Baseline with Climate Change II conditions, the YIHM predicts that precipitation will provide approximately 6,500 AFY of recharge to the Subbasin, which is approximately 500 AFY higher than the historical average and approximately 1,400 AFY lower than the Future Baseline without climate change average (Appendix 2-C, Table 2C-14). Reduced precipitation in the surrounding mountains, hills, and adjacent Subbasins results in an average annual recharge from subsurface inflows to the Subbasin of approximately 12,800 AFY. The historical and Future Baseline estimates of subsurface inflows from the YIHM are approximately 13,800 AFY and 13,500 AFY, respectively. The YIHM simulation results indicate that operations under the Climate Change I scenario will result in approximately 12,300 AFY of stream leakage recharge to the Subbasin; this is approximately 500 AFY higher than the historical average and 1,700 AFY lower than the Future Baseline average.

Groundwater Outflows

Groundwater extractions under the Future Baseline with Climate Change II scenario were held constant at 10,600 AFY (Appendix 2-C, Table 2C-16). The pumping distribution across the Subbasin in this scenario is equivalent to the extraction conditions described in Section 2.8.7.3.1.2.

Simulation results from the YIHM indicate that average annual groundwater outflows from the Subbasin are approximately 2,800 AFY less than Future Baseline scenario (Appendix 2-C, Table 2C-14). The YIHM predicts that the reduction in average annual groundwater outflows from the Subbasin is largely caused by a decrease in groundwater discharges to streams (Appendix 2-C, Table 2C-14). The reduction in groundwater discharges to streams is driven by reduced groundwater elevations that result from a reduction in the average annual recharge contribution from stream leakage, precipitation recharge, and subsurface inflows described in Section 2.8.2, Inflows to the Groundwater System. In addition to causing a reduction of groundwater discharges to streams, the lowering of groundwater levels under the Future Baseline with Climate Change II scenario causes a reduction of approximately 900 AFY in subsurface outflows.

Changes in Groundwater in Storage

The YIHM simulation results indicate the reduced recharge under the Future Baseline with Climate Change II scenario results in an average annual decline in groundwater in storage of approximately 80 AFY. This results in a cumulative loss of groundwater in storage of approximately 4,200 AF between water years 2019 and 2069. Under these conditions, the YIHM predicts that groundwater in storage in the Subbasin will be approximately 12,600 AF lower than the volume in storage at the start of the 1965 WY (Figure 2-62).

2.8.8 Characterization of Model Sensitivity and Predictive Uncertainty

The YIHM was calibrated using a two-step approach that relied on three different toolsets to generate parameters that characterize watershed processes, groundwater flow, and storage within surface water domain, soil zone, unsaturated zone, and principal aquifer underlying the Subbasin. The three calibration tools included (1) the use of an Ensemble Smoother, which is a global optimization method that employs Bayes' Theorem to identify parameter values that have the highest likelihood of reproducing measured data; (2) the automated Parameter ESTimation software (PEST), a linear optimization solver that was used to refine estimates generated from the Ensemble Smoother; and (3) manual parameter adjustment. The application of these three approaches is described briefly in this Plan to contextualize the appropriateness of the YIHM for the development of historical, current, and projected water budgets and for assessment of projected conditions in relation to the sustainable management criteria outlined in Chapter 3. Further, the sensitivity analysis and parameter evaluation performed by Alzraiee et al (2020) during development of the YIHM is briefly discussed here to characterize model uncertainty and uniqueness.

Prior to calibration of the fully coupled GSFLOW model, Alzraiee et al (2020) calibrated the watershed model employed by the YIHM using manual parameter adjustment. The watershed model was calibrated in two steps; first, the model was calibrated by adjusting parameters in parameter group A (Appendix 2-C, Table 2C-17) to match average monthly measurements of PET and solar radiation collected at four stations monitored as part of the CIMIS. PET and solar radiation parameters were calibrated to measurements collected for the period from 2003 to 2015. Parameters characterizing soil zone storage and conductivity (parameter group B in Appendix 2-C, Table 2C-17) were then manually adjusted following the PET and solar radiation calibration to generate reasonable estimates of precipitation recharge to the watershed.

The second step in the YIHM calibration process involved estimating aquifer and boundary condition properties that control groundwater flow, surface water-groundwater interactions, migration rates through the unsaturated zone, and groundwater storage fluctuations (parameter groups C through H in Appendix 2-C, Table 2C-17) across the Yucaipa watershed. These parameters were estimated down to the grid-cell level using a combination of the Ensemble Smoother and PEST. The initial ensemble estimates of aquifer parameters analyzed with the Ensemble Smoother were conditioned using well-texture data and generated using the Geostatistical Library (GeoLib) software (Clayton and Journel 1998). These aquifer properties were refined using PEST's pilot point and kriging packages following the initial parameter estimation produced using the Ensemble Smoother. Both PEST and the Ensemble Smoother were used to minimize the weighted error between modeled and measured values of streamflow, groundwater elevations, drawdown, and pumping. Because streamflow measurements collected by SBCFCD are uncertain (e.g., see discussion in Section 2.8.2.4), the YIHM's ability to match measured flows at the five stream gauging stations within the model boundary was down-weighted throughout calibration.

Model-scale calibration residuals and scatter plot maps of model error demonstrate that the YIHM is highly accurate in simulating groundwater conditions in the Subbasin. The normalized root mean square error for the YIHM is 0.85%, which is well below the acceptable normalized root mean square error threshold of 10% (Anderson and Woessner 1992). Further, scatter plot maps of model error show that the YIHM error is relatively randomly distributed across the model domain, indicating that the development and calibration of the YIHM has not resulted in regional, systematic biases in model results. These simulation and calibration results provide confidence in the YIHM's ability to both characterize historical water budgets and project conditions within the Subbasin under various management and climate scenarios.

To further characterize confidence in the YIHM's construction and parameterization, Alzraiee et al (2020) performed a sensitivity and parameter identifiability analysis of the YIHM following calibration. Parameters included in the sensitivity and identifiability analyses included all parameters within parameter groups C through H shown in Appendix 2-C, Table 2C-17. The parameter sensitivity and identifiability analysis was performed using PEST to identify the sensitivity of the YIHM's predictions of stream flows, groundwater elevations, drawdown, and pumping to each parameter in parameter groups C through H (Appendix 2-C, Table 2C-17). Alzraiee et al (2020) report 20 parameters to which the YIHM's estimates of stream flow, groundwater elevations, drawdown, and pumping are most sensitive (Appendix 2-C, Table 2C-17). The top 10 of these parameters are composed predominantly of parameters that define streambed conductance along Oak Glen Creek, Wilson Creek, Yucaipa Creek, and smaller tributaries that convey water from the San Bernardino Mountains into the Subbasin. Following the streambed conductance parameters, the YIHM is most sensitive to parameter values that characterize groundwater flow across the Casa Blanca Barrier and the barrier that separates the Wilson Creek Subarea and Gateway Subarea. As an aggregate, these 10 parameters control (1) the volume, rate, and direction of surface water-groundwater interactions across the Subbasin and (2) the flow of groundwater in regions of the Subbasin where surface water-groundwater interactions are largest.

Characterization of parameter uniqueness and uncertainty was performed using PEST's parameter identifiability suite. Parameter identifiability is a metric that describes how well a parameter value is constrained by the set of data used for model calibration and parameter estimation. Results from this analysis indicate that the measured calibration data provide sufficient confidence in the calibrated streambed conductance values along the Oak Glen Creek and Wilson Creek. Streambed conductance values along the Yucaipa Creek and tributaries that drain the San Bernardino Mountains have a lower identifiability, indicating that estimates of surface water-groundwater interactions along these creeks are uncertain. The fault conductance parameters across the South Mesa Barrier and within the Crafton Hills Fault Zone are of similar identifiability as the streambed conductance parameters along the Yucaipa Creek and small tributaries that drain into the Subbasin.

The relatively low identifiability of these parameters compared to the YIHM's sensitivity to each parameter is driven by a correlation between parameters that arises during calibration. To assess the degree of parameter correlation, Alzraiee el al (2020) used PEST to compute the parameter correlation coefficient matrix for all parameters included in parameter groups C through H (Appendix 2-C, Table 2C-17). Results from the parameter correlation analysis indicate that the streambed conductance values along the Yucaipa Creek, San Gorgonio Creek, and Wallace Creek are strongly correlated to calibrated parameter values for the South Mesa Barrier conductance and calibrated estimates of specific yield across the Subbasin. Because these parameters are strongly correlated and have a lower identifiability than the model's sensitivity to each parameter, these sets of parameters should be interpreted as non-unique and uncertain.

The results from the sensitivity analyses largely identify the need to collect accurate stream flow measurements across the Subbasin. The fact that streambed conductance, specific yield, and fault conductance are strongly correlated indicates that the use of groundwater elevations as the primary calibration metric does not provide sufficient information to decouple the effects of surface water-groundwater interactions and flow across management area boundaries on storage change across the Subbasin. While the approach of down-weighting stream flow measurements during model calibration is appropriate given the quality and uncertainty in the corresponding measurements, additional data collection, incorporation into the model, and refinement of both the watershed and aquifer properties to reproduce stream flows will likely reduce uncertainty in the calibrated parameter estimates and corresponding model predictions.

2.9 Management Areas

SGMA allows GSAs to define management areas within a Plan Area "if the Agency [GSA] has determined that creation of management areas will facilitate implementation of the Plan [GSP]" (Section 354.20, CCR Title 23). In order to sustainably manage the groundwater resources of the Yucaipa Subbasin, the Subbasin was divided into four management areas (Figure 2-63, Geologic Map and Management Area Boundaries in the Yucaipa Subbasin). The boundaries of the management areas were based on the geologic structures (i.e., faults, hydraulic barriers) that influence groundwater flow and defined the hydrogeologic subareas in the Subbasin (Section 2.5.1), the distribution of water supply wells by the different water purveyors, and the identification and location of groundwater dependent ecosystems (GDEs) in the Subbasin. The geologic structures, or faults and hydraulic barriers, that influence groundwater flow across them (e.g., Chicken Hill Fault and South Mesa Barrier) are effective boundaries to establish management areas as groundwater production on one side of the structure will not significantly affect groundwater levels at wells located on the other side. Each management area will be assigned different minimum thresholds and measurable objectives that will define sustainability within their individual boundaries.

The following management areas, listed in order from the highest to lowest along the hydraulic gradient in the Subbasin, are based on the geologic structures that defined the hydrogeologic subareas in the Subbasin, the distribution of public water supply wells, and presence of GDEs:

1. North Bench Management Area
2. Calimesa Management Area
3. Western Heights Management Area
4. San Timoteo Management Area

The boundaries of the management areas in relation to the boundary of the Subbasin, the boundaries of the hydrogeologic subareas in the Subbasin, and the boundaries of the Groundwater Management Zones in the vicinity of the Subbasin are depicted on Figure 2-64.

2.9.1 North Bench Management Area

The North Bench Management Area includes the subareas located north of the South Mesa Barrier: Crafton, Wilson Creek, Gateway, Oak Glen and Triple Falls Creek (Section 2.5.1; Figure 2-63). YVWD is the only public water purveyor that owns and operates municipal water supply wells in this management area. YVWD also produces groundwater under the direct influence of surface water from Oak Glen Creek and diverts surplus SWP water to the Wilson Creek and Oak Glen Creek spreading basins within this management area.

The downward displacement of the South Mesa Barrier likely affects groundwater flow (Cromwell et al. 2020a). The South Mesa Barrier's influence on flow is evidenced by groundwater levels measured at YVWD-06 (approximately 1,300 feet north of the South Mesa Barrier) and the USGS 6th Street and E nested monitoring well cluster (approximately 1,200 feet south of the South Mesa Barrier). Water levels measured between 2005 and 2010 at YVWD-06 and the shallowest monitoring well in the USGS 6th Street and E cluster indicate that groundwater elevations north of the South Mesa Barrier are approximately 150 feet higher than elevations south of the Barrier (Figure 2-65, Groundwater Elevations across the South Mesa Barrier). This offset in static water levels indicates that the South Mesa Barrier influences flow within the Subbasin.

Simulation results from the YIHM indicate that recharge to the North Bench Management Area was an average 15,230 AFY (Appendix 2-C, Table 2C-22). The largest and most consistent sources of recharge to the North Bench Management Area are mountain front recharge and subsurface interactions with the San Bernardino Subbasin and San Timoteo Subbasin. Combined, these sources of recharge historically provided an average 6,174 AFY. Precipitation recharge fluctuates, on average, between 931 AFY to 7,853 AFY depending on the water year type. Critically dry water year types provided an average 931 AFY of precipitation recharge, whereas wet water year types provided an average 7,853 AFY. These sources of recharge are supplemented by surface water spreading at the Wilson Creek and Oak Glen Creek spreading basins (Appendix 2-C, Table 2C-19).

The average annual outflow from the North Bench Management Area is 14,739 AFY (Appendix 2-C, Table 2C-19). Groundwater in the North Bench Management Area is a source of groundwater recharge as subsurface flow to the Western Heights and Calimesa Management Areas (Appendix 2-C, Table 2C-22). Between the 1965 WY and 2014 WY, approximately 2,586 AFY and 286 AFY of groundwater flowed out of the North Bench Management Area to the Calimesa and Western Heights Management Areas, respectively. These underflows, on average, accounted for 35% of the total annual inflows to the Calimesa Management Area and 15% of the total annual inflows to the Western Heights Management Area (Appendix 2-C, Table 2C-22).

Between 1965 and 2014, groundwater was extracted from the North Bench Management Area at an average rate of 3,444 AFY (Appendix 2-C, Table 2C-22). **The estimated sustainable yield for the North Bench Management Area is 3,940 AFY** (subtracting the difference of 14,737 – 3,444 AFY from the average annual inflow of 15,231 AFY and accounting for surface water diversions). The average annual extraction rate of 3,444 AFY is approximately 490 AFY lower than the estimated sustainable yield for the Management Area, which resulted in an average annual increase in groundwater in storage of approximately 490 AFY (Appendix 2-C, Table 2C-19).

The water balance for the North Bench Management Area is greatly influenced by climate because of its higher elevation and being adjacent to the San Bernardino Mountains, the Crafton Hills and the Yucaipa Hills. This management area receives more rainfall and, therefore, runoff from the adjacent mountains and hills that include the headwaters for Wilson Creek and Oak Glen Creek. The influence of climate on groundwater levels and the volume in storage in this management area are evident in Figures 2-66 and 2-67, respectively. Figure 2-66 shows groundwater elevations observed since 1945, which experienced increasing trends during wet periods (e.g., 1978–1983, 1993–1998) and decreasing trends during droughts (e.g., 1984–1990, 1999–2004). The historical low in groundwater elevations was observed at the end of the 2007 WY (Figure 2-66). The historical high in groundwater elevation was observed either in 1985 or currently in 2018 (Figure 2-66). The simulated annual change in storage indicated a historical low in storage in 1965 at 220,000 AF; the historical high in storage was at approximately 257,000 AF at the end of the 1998 WY (Figure 2-67).

The North Bench Management Area contains two distinct groundwater dependent ecosystems that rely on shallow groundwater to maintain habitat health. These communities are located in the northern and southern reaches of the Oak Glen subarea, along Oak Glen Creek and along Yucaipa Creek near Wildwood Canyon. Historical operations in the North Bench Management Area did not impact the health of these communities (see Section 2.7.8).

Groundwater sustainability in the North Bench Management Area will be achieved by avoiding significant and unreasonable impacts to four sustainability criteria:

- Chronic declines in groundwater elevations
- Reduction of groundwater in storage
- Depletion of interconnected surface water-groundwater that sustains GDEs
- Potential land subsidence should groundwater levels fall below the historical low

Historical and projected water budgets and impacts to these sustainability indicators will be described in Chapter 3 of this GSP.

2.9.2 Calimesa Management Area

The Calimesa Management Area includes the Calimesa subarea, the Singleton subarea, and the northeastern portion of the Live Oak subarea (Section 2.5.1; Figure 2-63). The management area is structurally bound by geologic flow barriers to the west and north, and by the Yucaipa Hills on the east. The southwestern boundary of the Calimesa Management Area is defined by an extension of the San Gorgonio Fault Splay to the Banning Fault. YVWD, South Mesa, and South Mountain actively extract groundwater from the Calimesa Management Area to supplement municipal supplies in their respective service areas. Yucaipa Creek conveys surface water.

The Calimesa Management Area is bordered to the north and west by the South Mesa Barrier and Chicken Hill Fault, which both influence groundwater flow within the Subbasin. The Banning Fault runs through the southern section of the Calimesa Management Area and separates the Calimesa subarea from the Singleton and Live Oak subareas. The western portion of the Banning Fault predates deposition of the Live Oak formation and only affects the underlying crystalline bedrock (Cromwell et al. 2020a).

Static groundwater levels measured across the Banning Fault within the Calimesa Management Area indicate that the fault does not act as a barrier to groundwater flow. Static groundwater levels are actively measured at South Mesa-05 (1,400 feet south of the Banning Fault), South Mesa-07 (100 feet south of the Banning Fault), South Mesa-09 (1,000 feet north of the Banning Fault), and South Mesa-16 (700 feet north of the Banning Fault). Water level measurements collected at these four wells between 1990 and 2018 show that groundwater elevations differ by approximately 40 feet across the Banning Fault (Figure 2-68, Groundwater Elevations across the Banning Fault in the Calimesa Management Area). These declines are likely attributable to the natural hydraulic gradient within the principal aquifer. Because the Banning Fault does not affect groundwater flow within the Subbasin, the southern boundary of the Calimesa Management Area was extended south to the boundary between the Yucaipa Subbasin and San Timoteo Subbasin.

Simulation results from the YIHM indicate that the average annual recharge to the Calimesa Management Area is 7,481 AFY (Appendix 2-C, Table 2C-20). The largest sources of recharge to the Calimesa Management Area are subsurface inflows from the North Bench Management area and the adjudicated Beaumont basin, precipitation recharge, and return flows (Appendix 2-C, Tables 2C-20, 2C-22). Results from the YIHM indicate that subsurface inflows from the North Bench Management Area and the adjudicated Beaumont basin are not correlated with water year type, while average annual precipitation recharge varies from approximately 1,100 AFY during critically dry water years to approximately 2,800 AFY during wet water years (Appendix 2-C, Table 2C-20).

Simulation results from the YIHM indicate that the average annual outflow from the Calimesa Management Area is 7,802 AFY (Appendix 2-C, Table 2C-20). Outside of groundwater extractions, subsurface outflows are the largest component of outflow from the Calimesa Management Area. Most of the subsurface outflow is to the Western Heights Management Area, the adjudicated Beaumont basin, and the San Timoteo Management Area (Appendix 2-C, Tables 2C-20 and 2C-22). Between 1965 and 2014, groundwater was extracted from the Calimesa Management Area at an average rate of approximately 5,280 AFY (Appendix 2-C, Table 2C-22). **The estimated sustainable yield for the Calimesa Management Area is 4,955 AFY** (subtracting the difference of 7,802 – 5,276 AFY from the average annual inflow of 7,481 AFY). The average annual extraction rate of 5,276 AFY is approximately 320 AFY higher than the estimated sustainable yield for the Management Area, which resulted in an average annual decrease in groundwater in storage of approximately 320 AFY (Appendix 2-C, Table 2C-20).

The water balance for the Calimesa Management Area is not as influenced by climate as the North Bench Management Area. Figure 2-69 shows groundwater elevations observed since 1965. The management area experienced an increasing trend in groundwater levels during the wet period from 1978 to 1983, but then experienced a declining trend from 1987 to 2008. The declining trend in groundwater levels occurred during the wet period from 1993 to 1998 because groundwater extractions exceeded the estimated sustainable yield. The historical low in groundwater elevation was observed at the end of the 2008 WY at approximately 2,000 to 2,050 feet above NAVD88 (Figure 2-69). The historical high in groundwater elevation was observed at the end of the 2007 WY at approximately 2,200 feet above NAVD88 (Figure 2-69). The simulated annual change in storage indicated a historical low in storage in the 2015 WY at 798,800 AF; the historical high in storage was at approximately 850,000 AF at the end of the 1989 WY (Figure 2-70, Historical and Current Volume of Groundwater in Storage in the Calimesa Management Area).

The Calimesa Management Area contains one potential GDE that is located more than 0.5 miles away from active groundwater production wells (Figure 2-57). Because this habitat is not proximal to groundwater extractions within the Management Area, it is not anticipated that future production within the Calimesa Management Area will impact habitat health at this mapped environment. Accordingly, sustainability within the Calimesa Management Area will be assessed by avoiding significant and unreasonable chronic declines in groundwater elevations and reduction of groundwater in storage. Historical and projected water budgets and impacts to these sustainability indicators will be described in Chapter 3 of this GSP.

2.9.3 Western Heights Management Area

The Western Heights Management Area is the Western Heights Subarea (Section 2.5.1.7). The boundary for this management area includes the South Mesa Barrier to the north, the Chicken Hill Fault to the east, the Banning Fault to the south, and the Crafton Hills to the west (Figure 2-63). WHWC is the only water purveyor with municipal water supply wells operating in the management area. No active private wells have been identified in this management area.

The Chicken Hill Fault has a significant influence on groundwater flow across it. Groundwater elevations measured at wells WHWC-11 and WHWC-12, which are located in the Western Heights subarea and approximately 2,500 feet and 4,000 feet, respectively, west of the Chicken Hill Fault, had static groundwater levels consistently measured at 300 to 350 feet lower than static groundwater elevations measured at well YVWD-49 and the South Mountain Chicken Hill and Hog Canyon 2 wells (Figure 2-15). Groundwater Elevation contour maps indicate a steep hydraulic head difference across the Chicken Hill Fault, with a hydraulic depression centered at wells WHWC-02A, WHWC-11, WHWC-12, and WHWC-14 (Figure 2-33). There appears to be no hydraulic influence on groundwater elevations in the Calimesa subarea east of the Chicken Hill Fault.

Simulation results from the YIHM indicate that the Western Heights Management Area receives little recharge from sources of water derived outside of the Subbasin (Appendix 2-C, Table 2C-18). Throughout the 1965–2014 historical period, the YIHM indicates that the Western Heights Management Area was recharged at an average rate of 2,011 AFY. The major component of recharge was subsurface inflow from the Calimesa, North Bench and San Timoteo Management Areas. Recharge from direct precipitation ranged from 183 AFY in normal water year types to 602 AFY in wet water year types (Appendix 2-C, Table 2C-22).

The average annual outflow, which included subsurface flows to the adjacent Calimesa Management Area and the San Timoteo Management Area, was 2,691 AFY (Appendix 2-C, Table 2C-18). The average annual groundwater extraction from the Western Heights Management Area was 2,443 AFY (Appendix 2-C, Table 2C-22). **The estimated sustainable yield for the Western Heights Management Area is 1,760 AFY** (subtracting the difference of 2,691 – 2,443 AFY from the average annual inflow of 2,011 AFY).

Between 1965 and 2014, pumping by private extractors and WHWC municipal water supply wells exceeded the estimated sustainable yield of 1,760 AFY for the Western Heights subarea (Appendix 2-C, Table 2C-18). Consequently, groundwater elevations in the subarea steadily declined by approximately 150 feet in that period (Figure 2-71, Historical Groundwater Elevations in the Western Heights Management Area). Groundwater production in the subarea declined to or below the estimated sustainable yield beginning in 2015 (Appendix 2-C, Table 2C-18), which ended the declining trend in groundwater levels. The historical low in groundwater elevation was observed at approximately 1,749 feet above NAVD88 in 2015 (Figure 2-71). The volume in storage as simulated by the YIHM declined from approximately 441,360 AF in the 1965 WY to approximately 408,800 AF in the 2015 WY, which is the historical low in groundwater in storage (Figure 2-72, Historical and Current Volume of Groundwater in Storage in the Western Heights Management Area). The volume in storage has recovered to approximately 409,300 AF in the 2018 WY.

The Western Heights Management Area does not contain shallow groundwater connected to the principal aquifer that supports overlying habitats. Because of this, sustainability within the Western Heights Management Area will be characterized by assessing operation strategies that avoid significant and unreasonable chronic lowering of groundwater levels, reduction of groundwater in storage and the potential for land subsidence should groundwater levels fall below the historical low.

2.9.4 San Timoteo Management Area

The San Timoteo Management Area is defined by the portion of the Live Oak subarea that extends south from the Western Heights and Calimesa Management Areas (Figure 2-63). The management area is structurally bound to the north by the Banning Fault. The degree to which the Banning Fault affects flow in this region of the Subbasin is not well-constrained by measured groundwater levels. The remaining boundary of the San Timoteo Management Area is the boundary of the Yucaipa Subbasin. Municipal water suppliers do not own or operate groundwater production wells within this management area.

Groundwater levels are actively measured within the management area along San Timoteo Creek (Figure 2-73). Recent water level measurements from these wells indicate that groundwater conditions are locally artesian. Shallow groundwater conditions along San Timoteo Creek also support a community of Willow and Freemont Cotton that rely on shallow groundwater as a source of water supply. These communities compose the largest network of groundwater dependent ecosystems within the Subbasin. The YIHM estimates that groundwater evapotranspiration from these habitats averages approximately 1,450 AFY (Appendix 2-C, Table 2C-21). Evapotranspiration losses along the San Timoteo Creek corridor are largest during critically dry water years; under these conditions, the YIHM estimates that the local groundwater dependent ecosystems consume approximately 1,800 AFY of shallow groundwater. During wet water years, the YIHM estimates that evapotranspiration results in the loss of approximately 1,300 AF of groundwater annually (Appendix 2-C, Table 2C-21).

Throughout the 1965-2014 historical period, the YIHM indicates that the San Timoteo Management Area was recharged at an average rate of 14,895 AFY. The major components of recharge included stream leakage and subsurface inflow from the San Timoteo subbasin (Appendix 2-C, Table 2C-21). Recharge from direct precipitation ranged from 213 AFY in normal water year types to 923 AFY in wet water year types. The average annual outflow from this management area is 14,753 AFY. In addition to ET, the other largest components of outflow include subsurface outflows to the San Timoteo subbasin and the San Bernardino Basin Area (Appendix 2-C, Table 2C-21). The YIHM indicates that an average of approximately 9,000 AFY leaves the Subbasin to the San Timoteo subbasin and approximately 3,500 AF to the San Bernardino Basin Area. The average annual groundwater extraction from the San Timoteo Management Area was 183 AFY (Appendix 2-C, Table 2C-21). **The estimated sustainable yield for the San Timoteo Management Area is 325 AFY** (subtracting the difference of 14,753 – 183 AFY from the average annual inflow of 14,895 AFY). The YIHM indicates that the historical low in the volume in storage in the San Timoteo Management Area was approximately 879,000 AF in the 1966 WY, and the historical high was approximately 889,000 AF in the 1998 WY (Figure 2-74, Historical and Current Volume in Storage in the San Timoteo Management Area).

Groundwater production estimates produced by the YIHM indicate that production within the management area ceased in the 2007 WY. However, there are private well owners that produce groundwater for agricultural or domestic purposes. The Yucaipa GSA will make efforts to contact the private well owners to obtain information on their wells, including construction details, production history and current production, and groundwater level and quality information if made available to ascertain their influences on groundwater conditions in the Subbasin.

Because groundwater is not actively produced for municipal water supply from this management area, sustainability at this time will largely be guided by avoiding undesirable results associated with a depletion of interconnected surface water-groundwater systems that sustain GDEs along San Timoteo Creek. The degree to which production in upgradient management areas impact GDE health within the San Timoteo Management Area will be described in Chapter 3 of this GSP.

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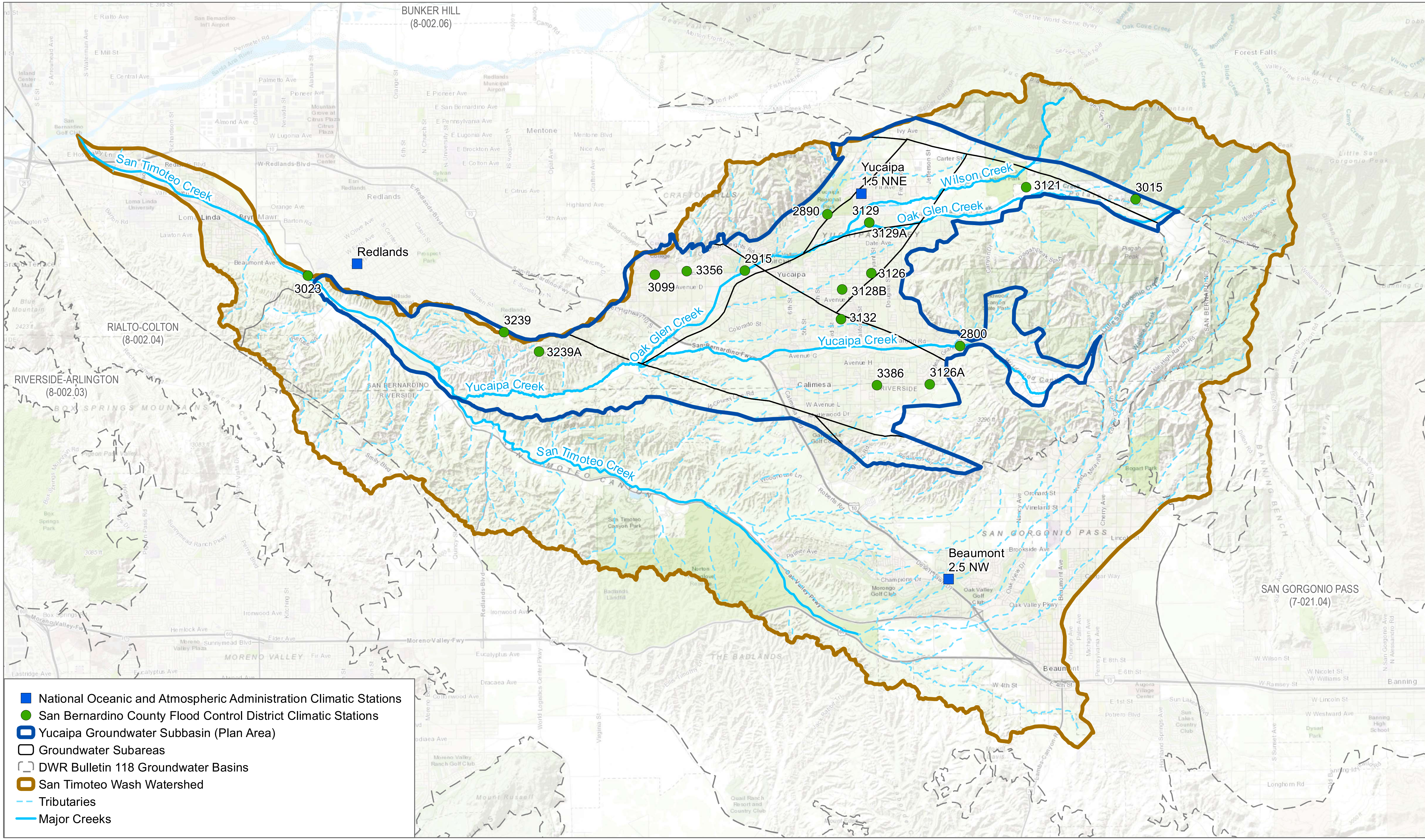

SOURCE: ESRI, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordanance Survey, ESRI Japan, METI, ESRI China (Hong Kong), swisstopo, OpenStreetMap contributors, and the GIS User Community; DWR 2015; USGS NHD 2017; Geoscience 2017

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FIGURE 2-1

Climate Station Locations in the San Timoteo Wash Watershed

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Figure 2-2. Cumulative Departure from Mean Monthly Precipitation at the SBCFCD Oak Glen and Calimesa East Climatic Stations and the NOAA Redlands Climatic Station

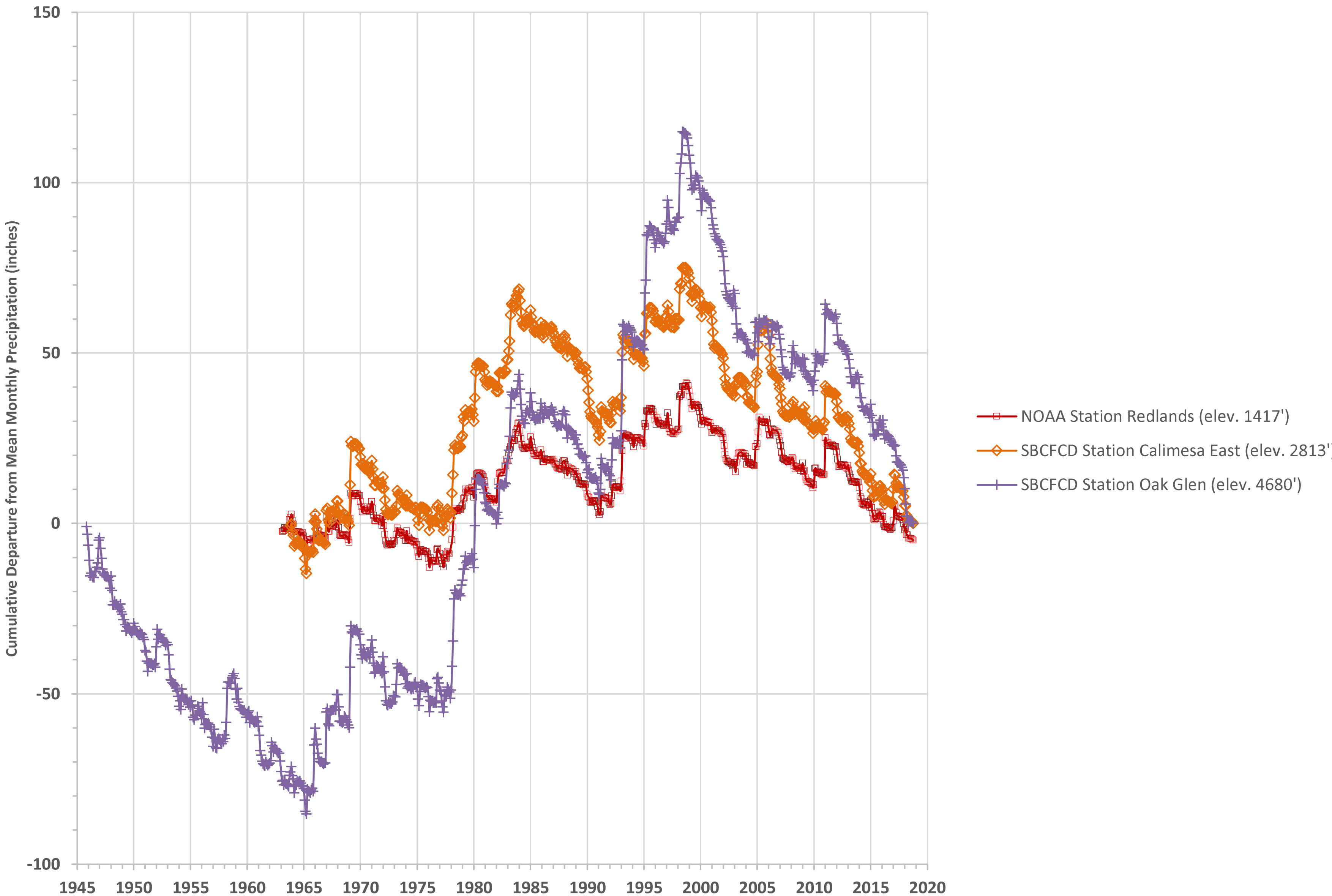

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Figure 2-3. Historical Water Year Types in the Yucaipa Subbasin

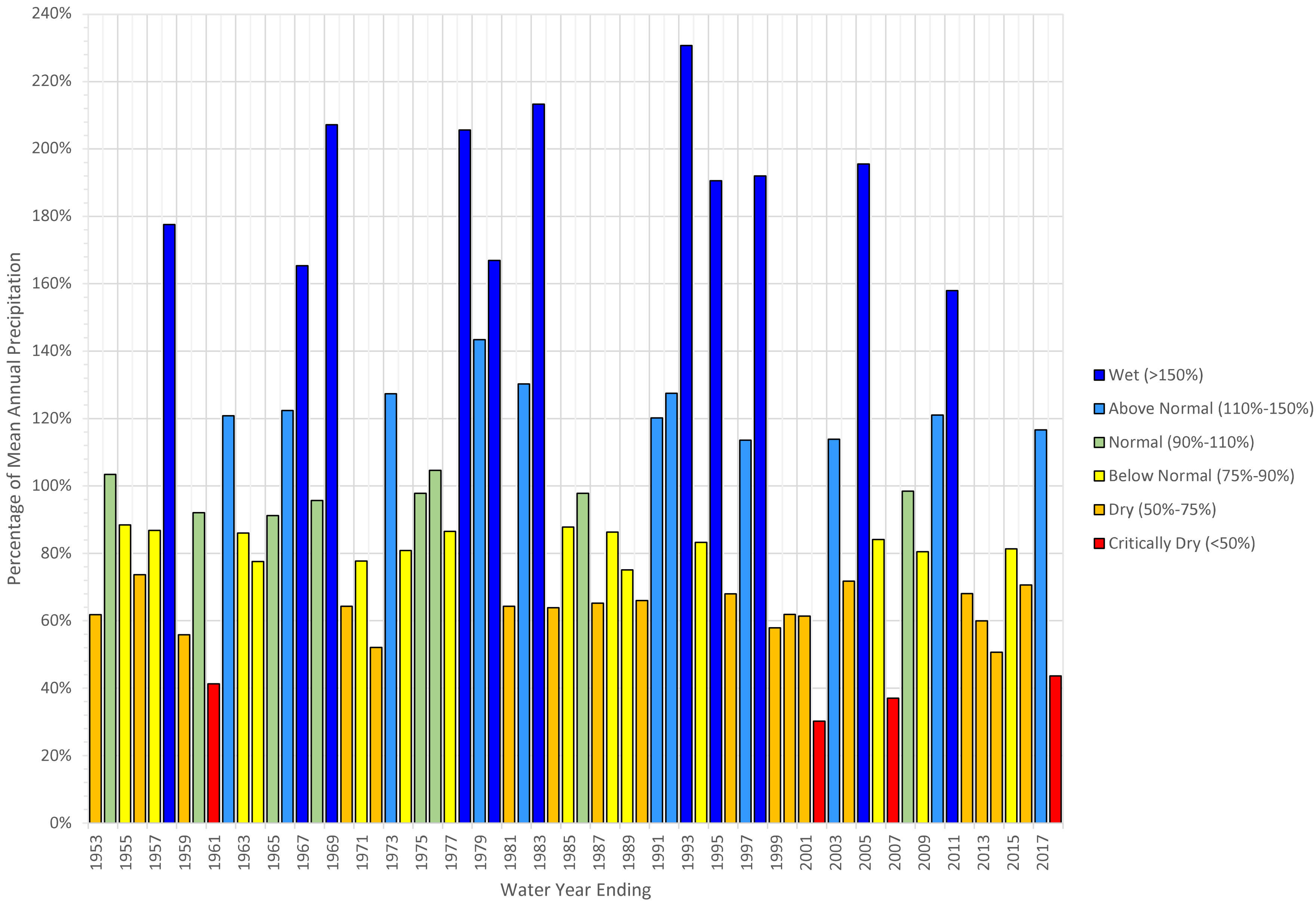

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Figure 2-4. Mean Daily Maximum and Minimum Temperature (Degrees Celsius) at NOAA Redlands Climate Station

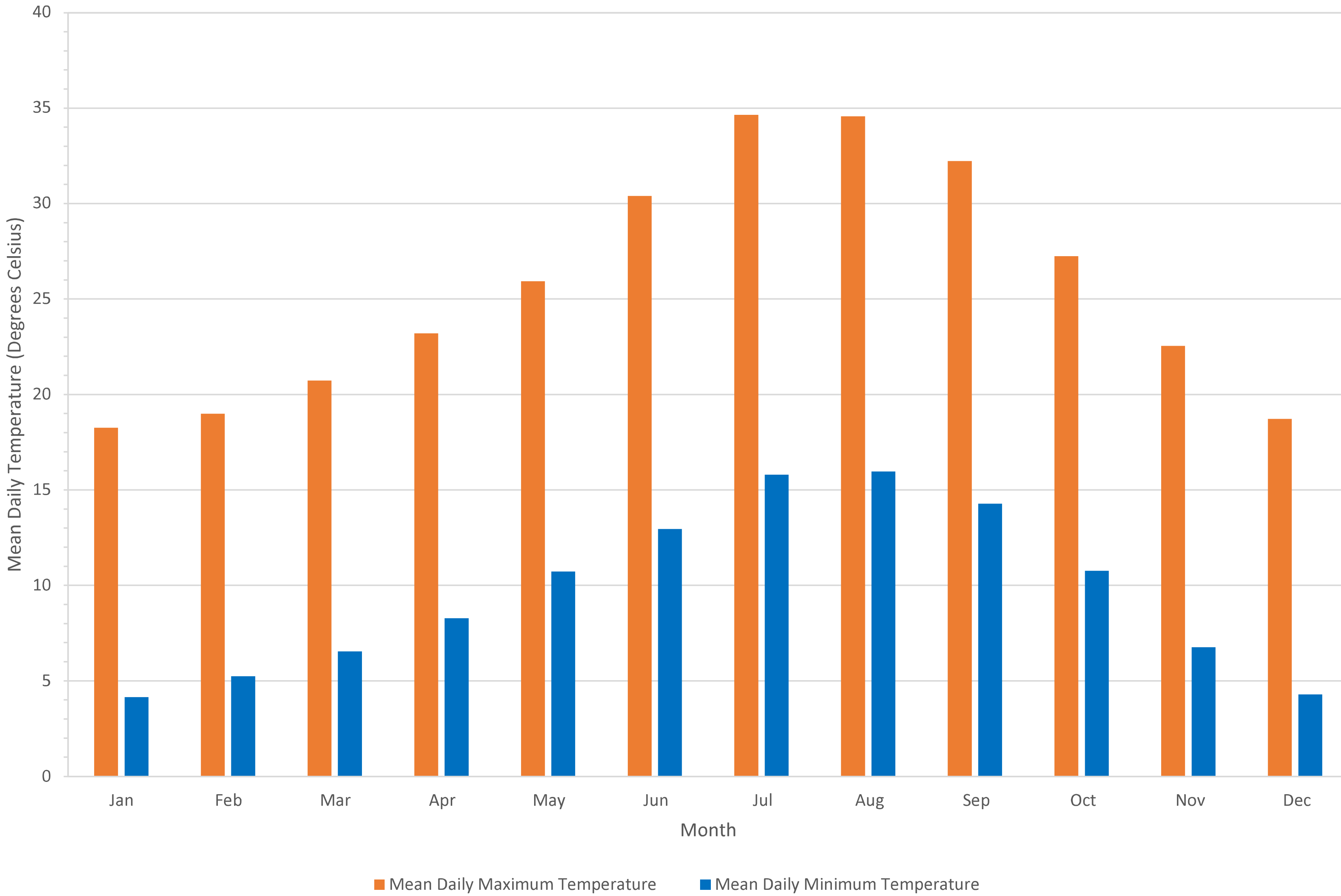

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Figure 2-5. Mean Daily Maximum and Minimum Temperature (Degrees Fahrenheit) at NOAA Redlands Climate Station

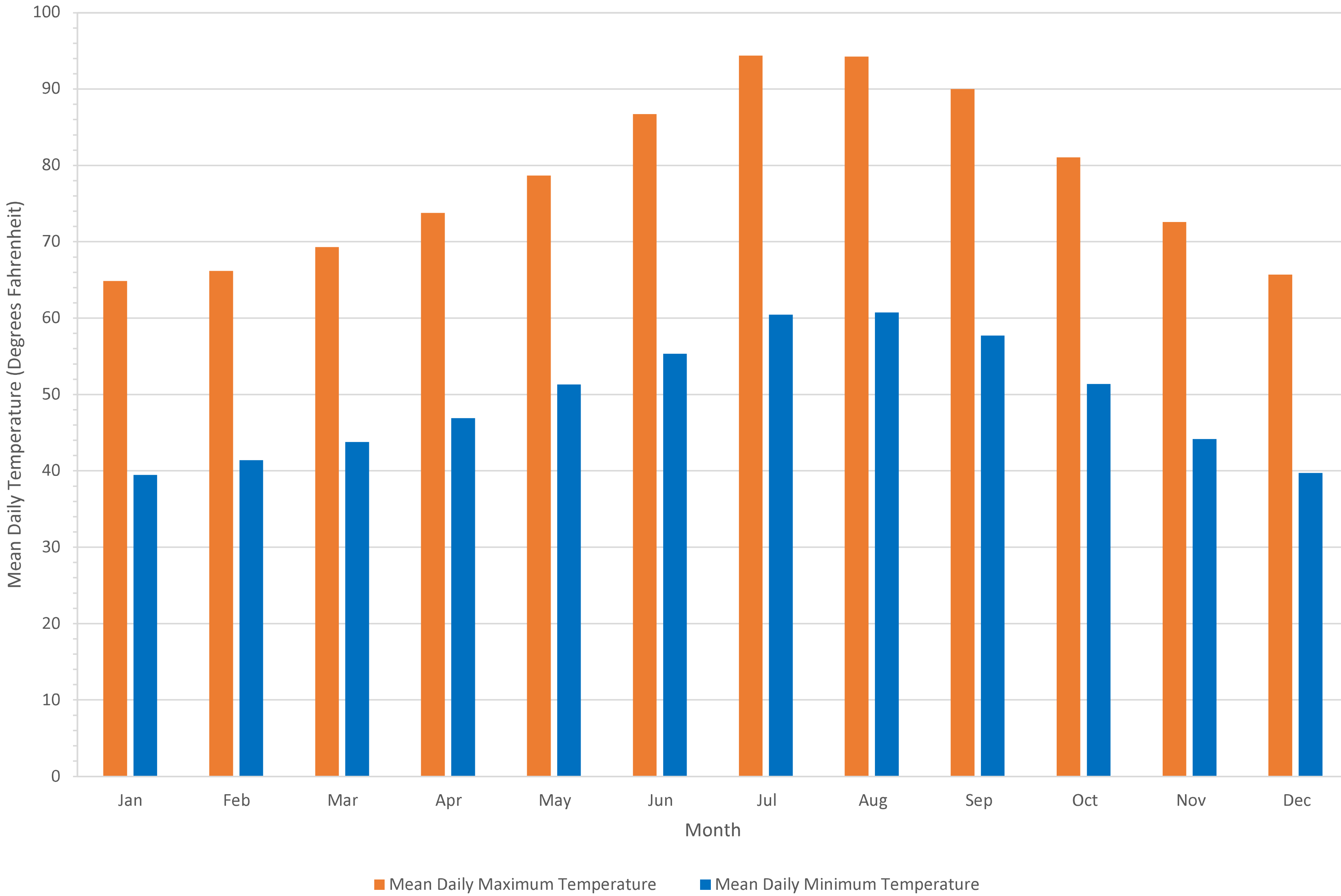

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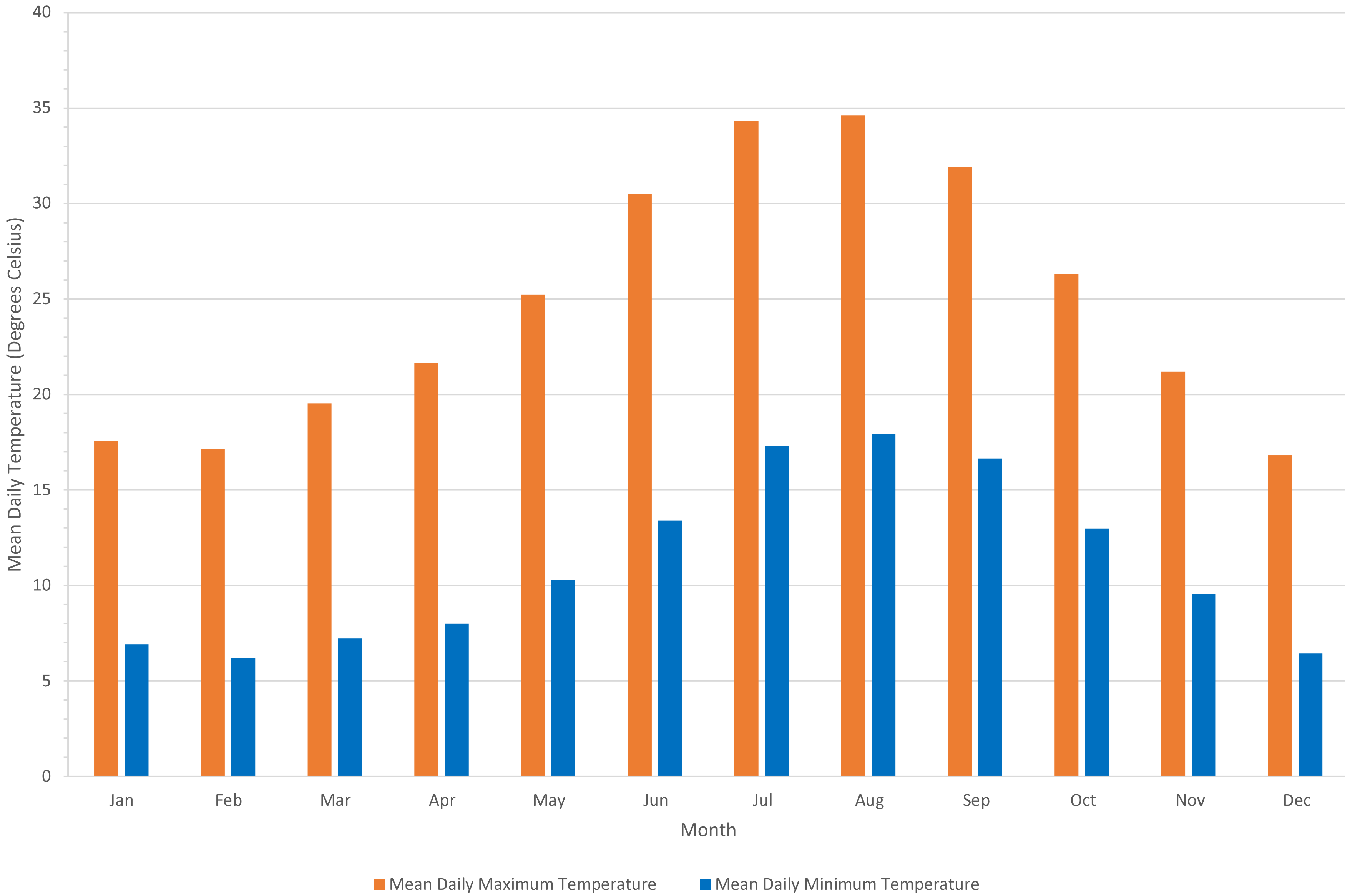
Figure 2-6. Mean Daily Maximum and Minimum Temperature (Degrees Celsius) at NOAA Mill Creek BDF Climate Station



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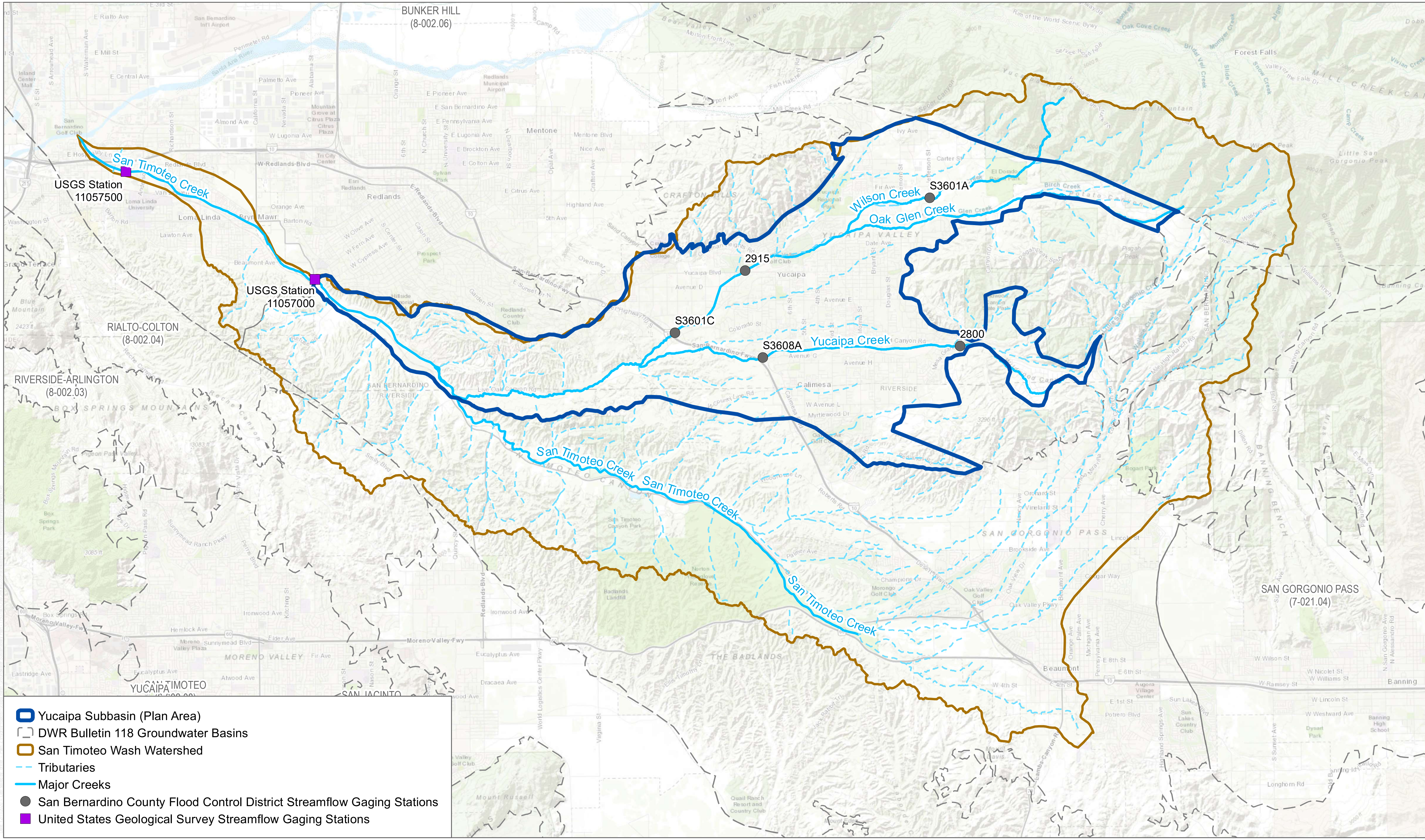

SOURCE: DWR; USGS; San Bernardino County Flood Control District

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0 0.5 1 Miles

FIGURE 2-7

Surface Water Flow in San Timoteo Wash Watershed

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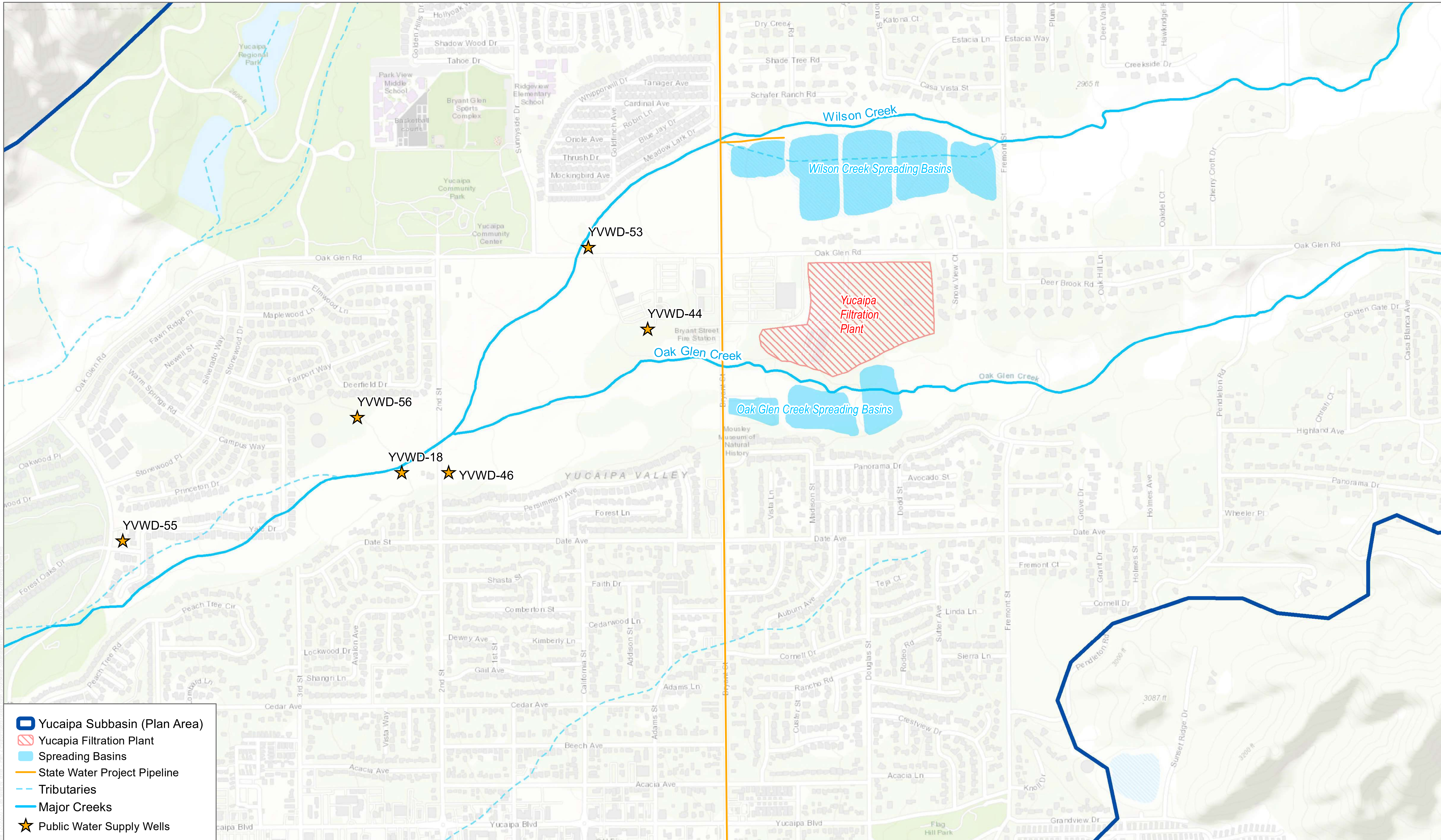

SOURCE: DWR

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0 500 1,000 Feet

FIGURE 2-8

Locations of the Wilson Creek and Oak Glen Creek Spreading Basins in the Yucaipa Subbasin

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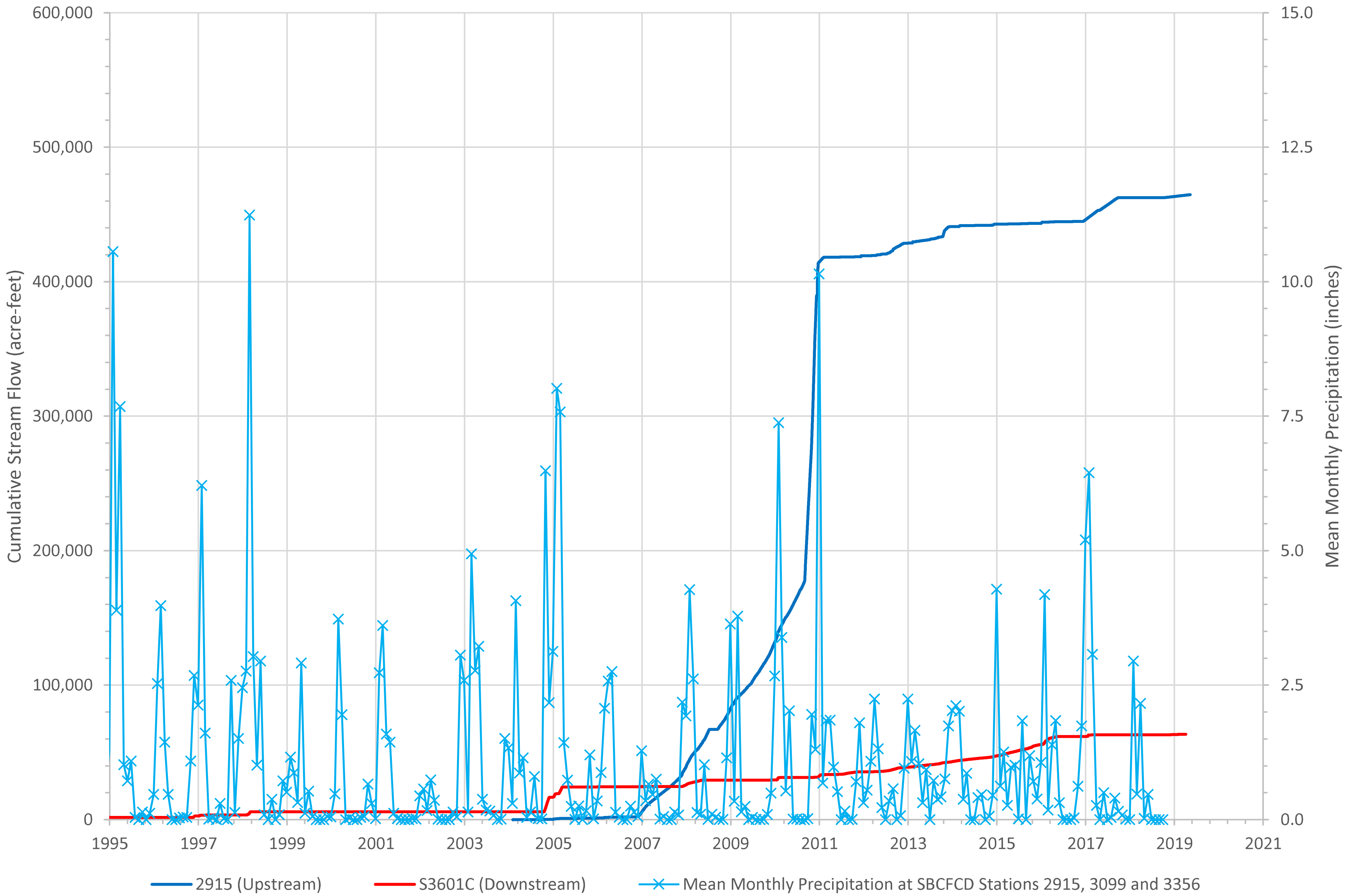
Figure 2-9. Cumulative Stream Flow at
SBCFCD Stations 2915 and S3601C on Oak Glen Creek



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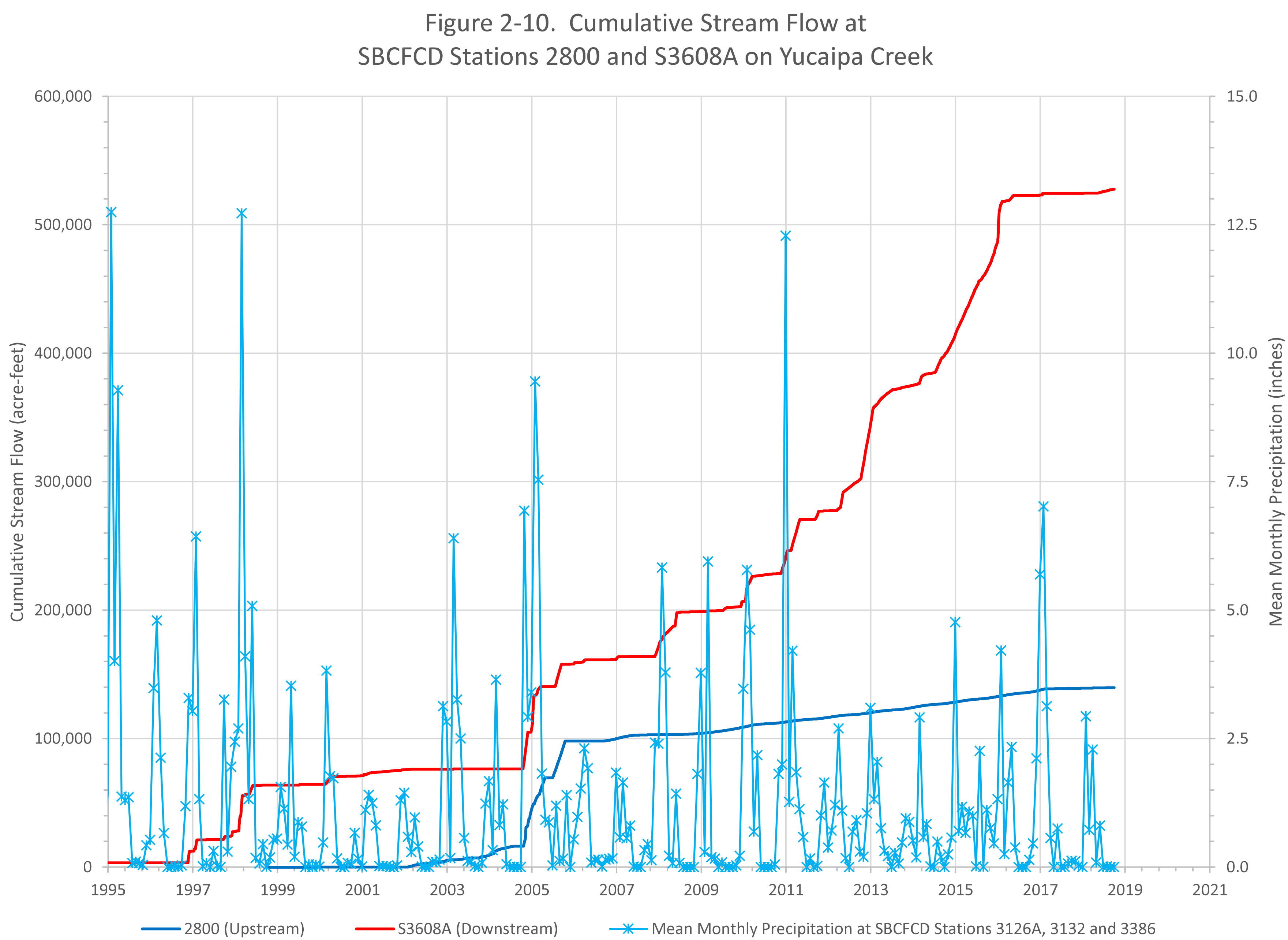

Figure 2-10. Cumulative Stream Flow at
SBCFCD Stations 2800 and S3608A on Yucaipa Creek
Cumulative Stream Flow (acre-feet)
Mean Monthly Precipitation (inches)
600,000
500,000
400,000
300,000
200,000
100,000
0
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2800 (Upstream)
S3608A (Downstream)
Mean Monthly Precipitation at SBCFCD Stations 3126A, 3132 and 3386

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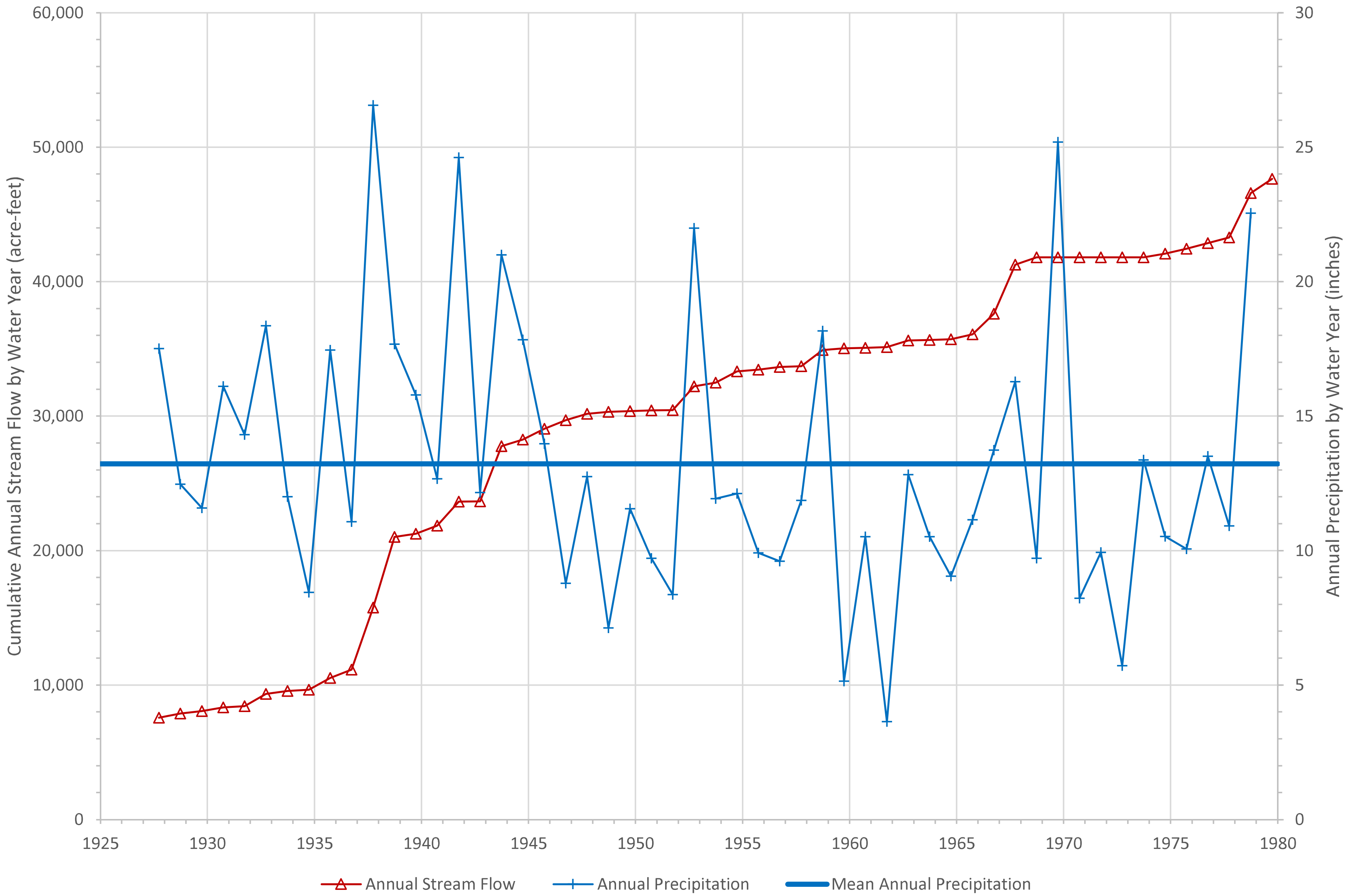
Figure 2-11. Stream Flow Measured at USGS Station 11057000 and Precipitation at NOAA Redlands



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Yucaipa Groundwater Subbasin

Groundwater Subareas

Geologic Units (CGS 2012)

Quaternary

Qa, Young

Qsdloc, Sedimentary Deposits of Live Oak Formation

Tertiary

QTst, San Timoteo Formation (Middle Member)

Tsh, Mill Creek Formation

Tv, Dacite Dikes

Mesozoic and Older

pKm, Cretaceous and Pre-Cretaceous Metamorphic Formations of Sedimentary and Volcanic Origin

Trb, Granitic and Other Intrusive Crystalline Rocks, San Gabriel Mountains-type

Faults and Geologic Contacts

contact, identity and existence certain, location accurate

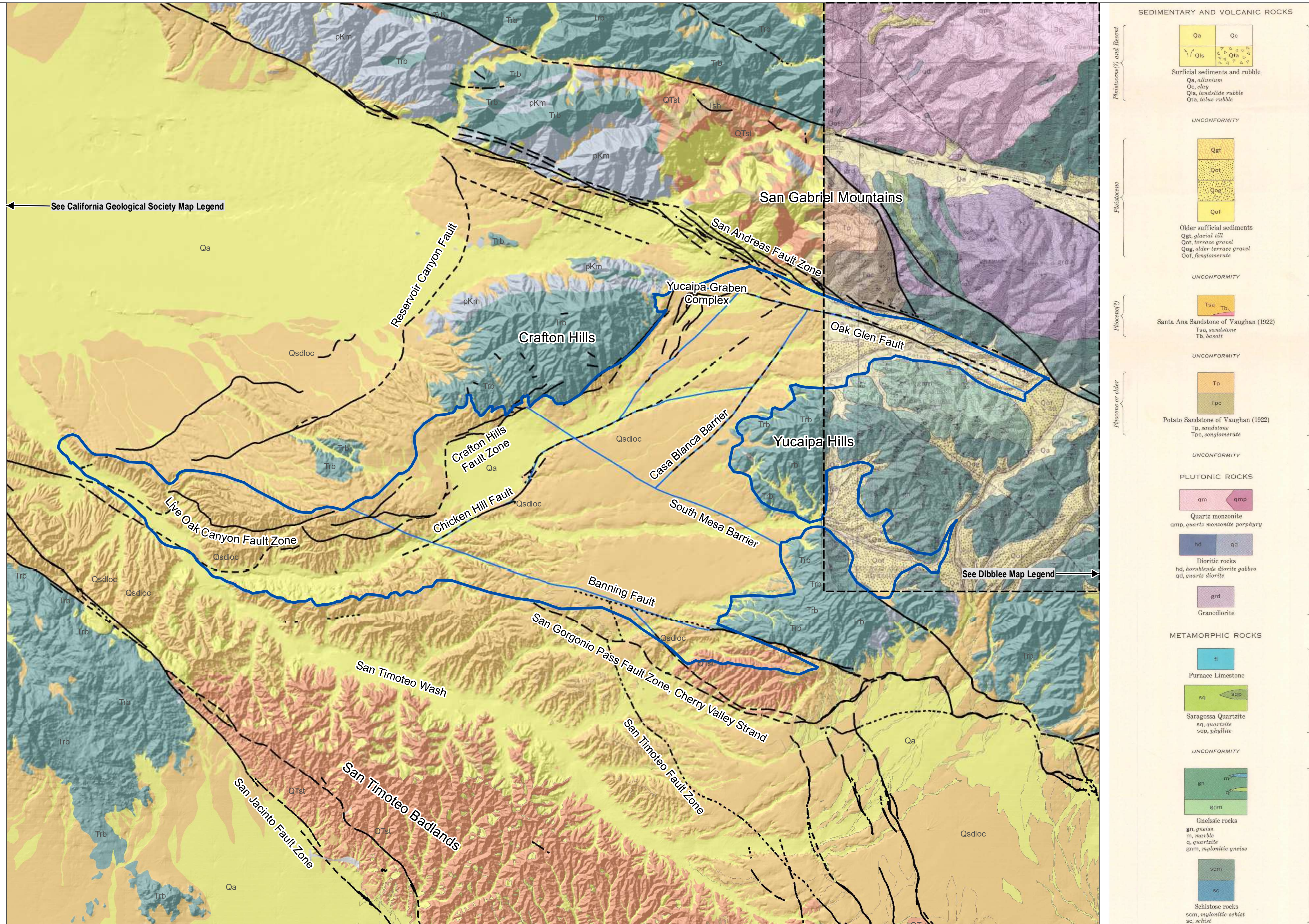
contact, identity and existence certain, location approximate

fault, identity and existence certain, location accurate

fault, identity and existence certain, location approximate

fault, identity and existence certain, location concealed

fault, identity and existence certain, location inferred



SOURCE: CGS 2012, USGS 1999

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DUDEK

0 0.5 1 2 Miles

FIGURE 2-12

Geologic Map of the Yucaipa Subbasin

Yucaipa Subbasin Groundwater Sustainability Plan

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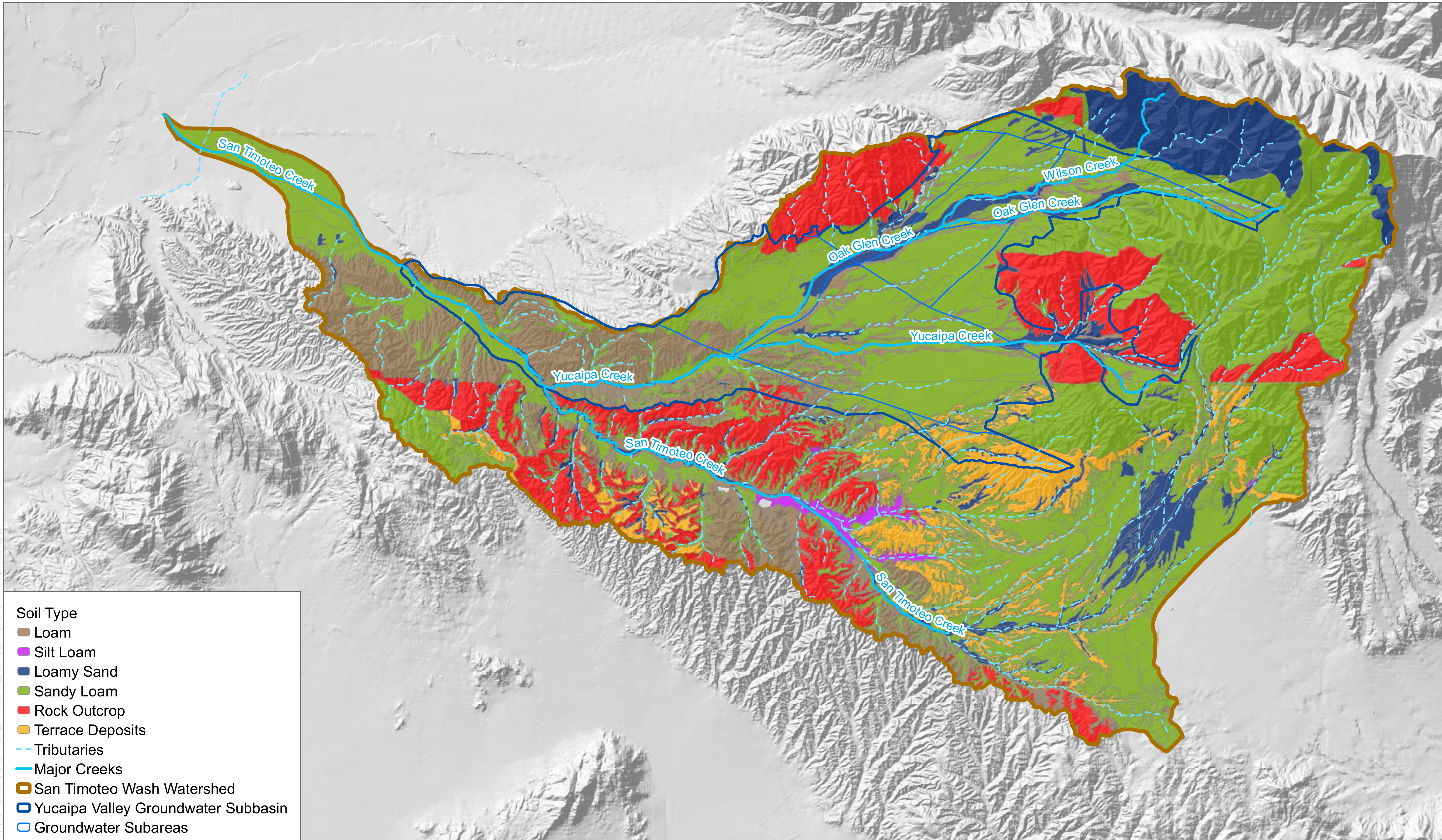

SOURCE: Source: USDA 2020

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0 4,200 8,400 Feet

FIGURE 2-13

Soils within the San Timoteo Wash Watershed

Groundwater Sustainability Plan for the Yucaipa Valley Subbasin

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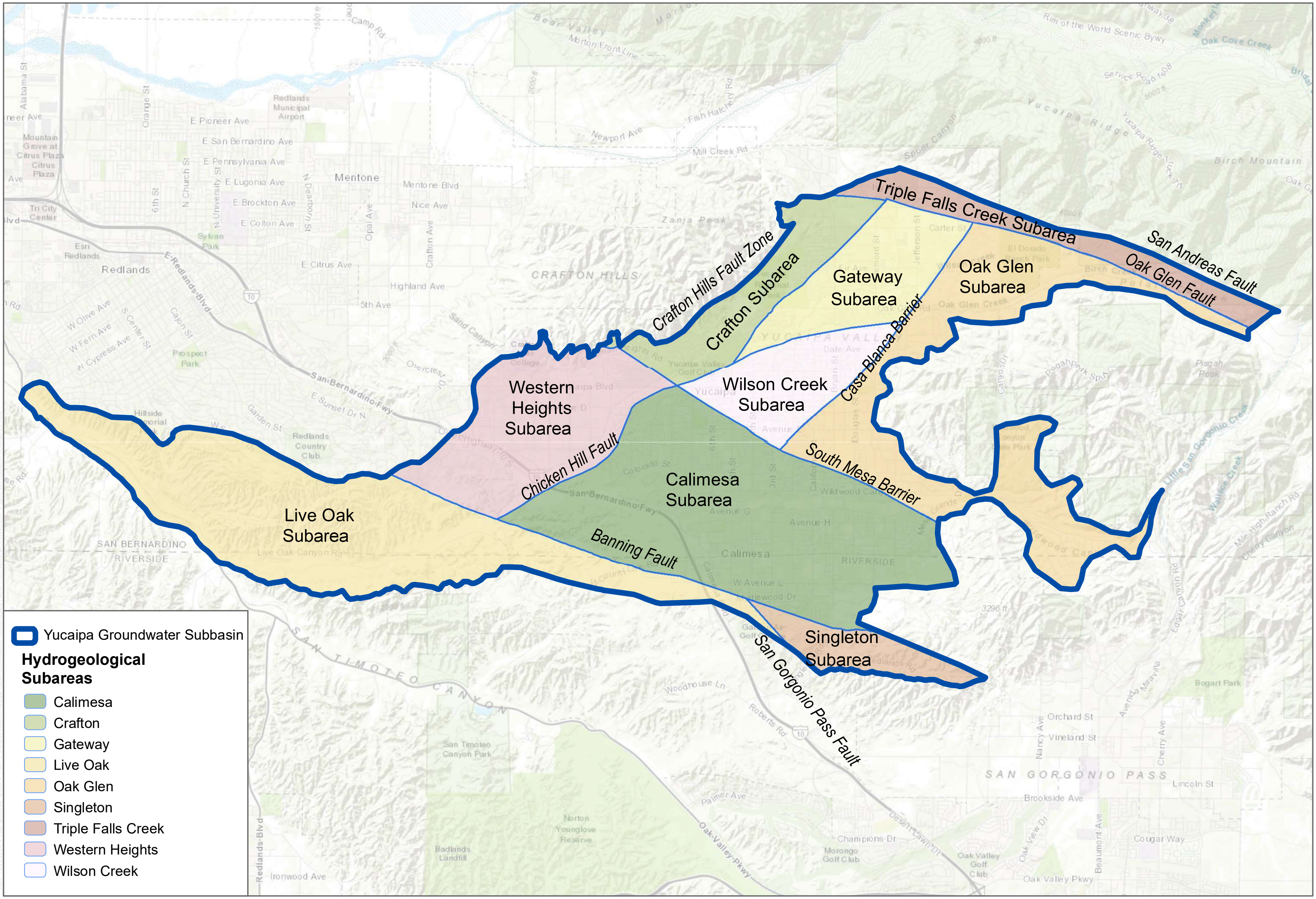

SOURCE: ESRI; Geoscience 2018

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DUDEK

0 0.5 1 Miles

FIGURE 2-14

Hydrogeological Subareas in the Yucaipa Subbasin

Groundwater Sustainability Plan - Yucaipa Groundwater Basin

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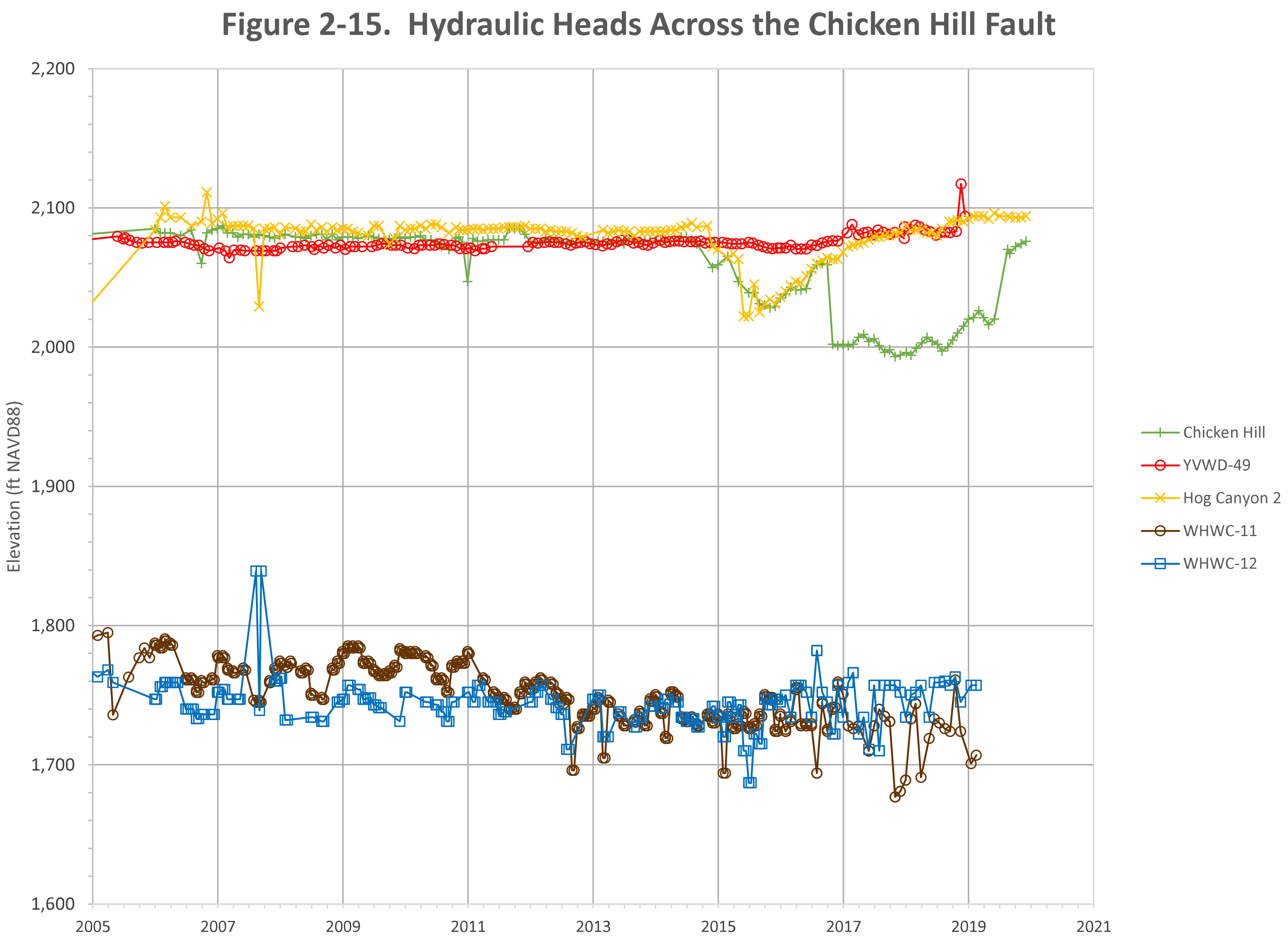

Figure 2-15. Hydraulic Heads Across the Chicken Hill Fault
Elevation (ft NAVD88)
2,200
2,100
2,000
1,900
1,800
1,700
1,600
2005
2007
2009
2011
2013
2015
2017
2019
2021
Chicken Hill
YVWD-49
Hog Canyon 2
WHWC-11
WHWC-12

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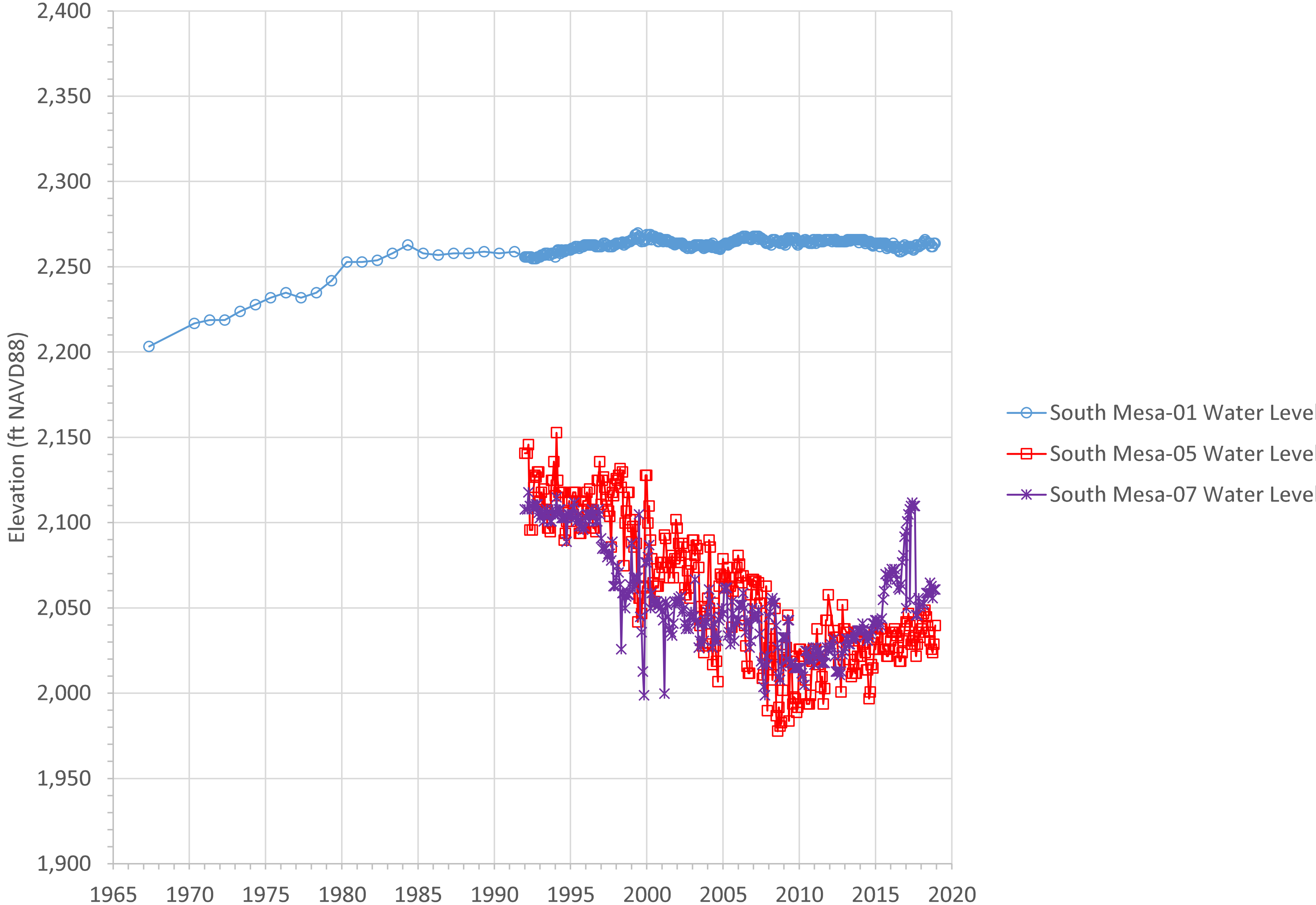
Figure 2-16. Hydraulic Heads at South Mesa Wells 1, 5, and 7



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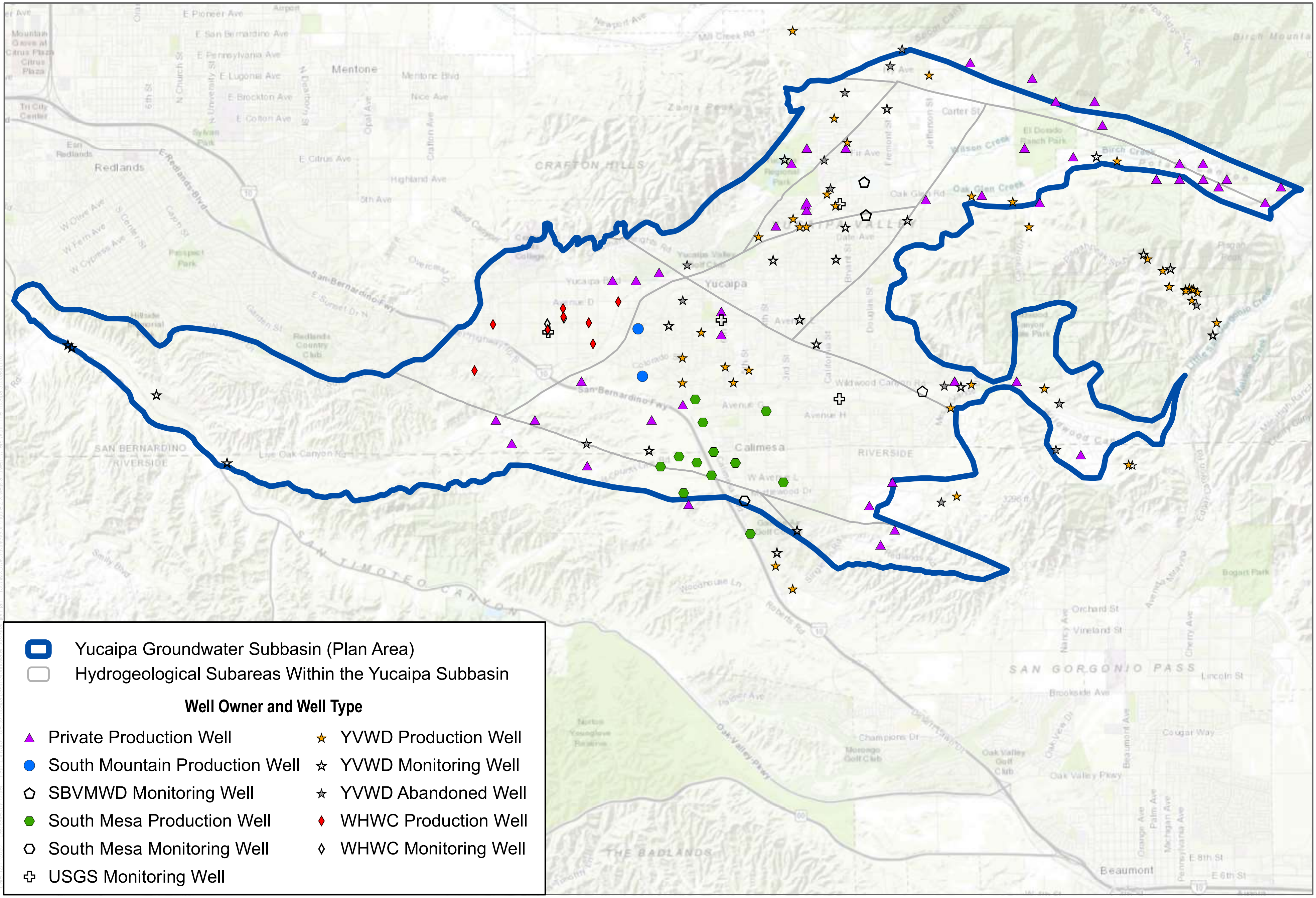

SOURCE:

DUDEK

0 0.5 1 Miles

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FIGURE 2-17

Well Locations and Well Owners within the Yucaipa Subbasin

Yucaipa Subbasin Groundwater Sustainability Plan

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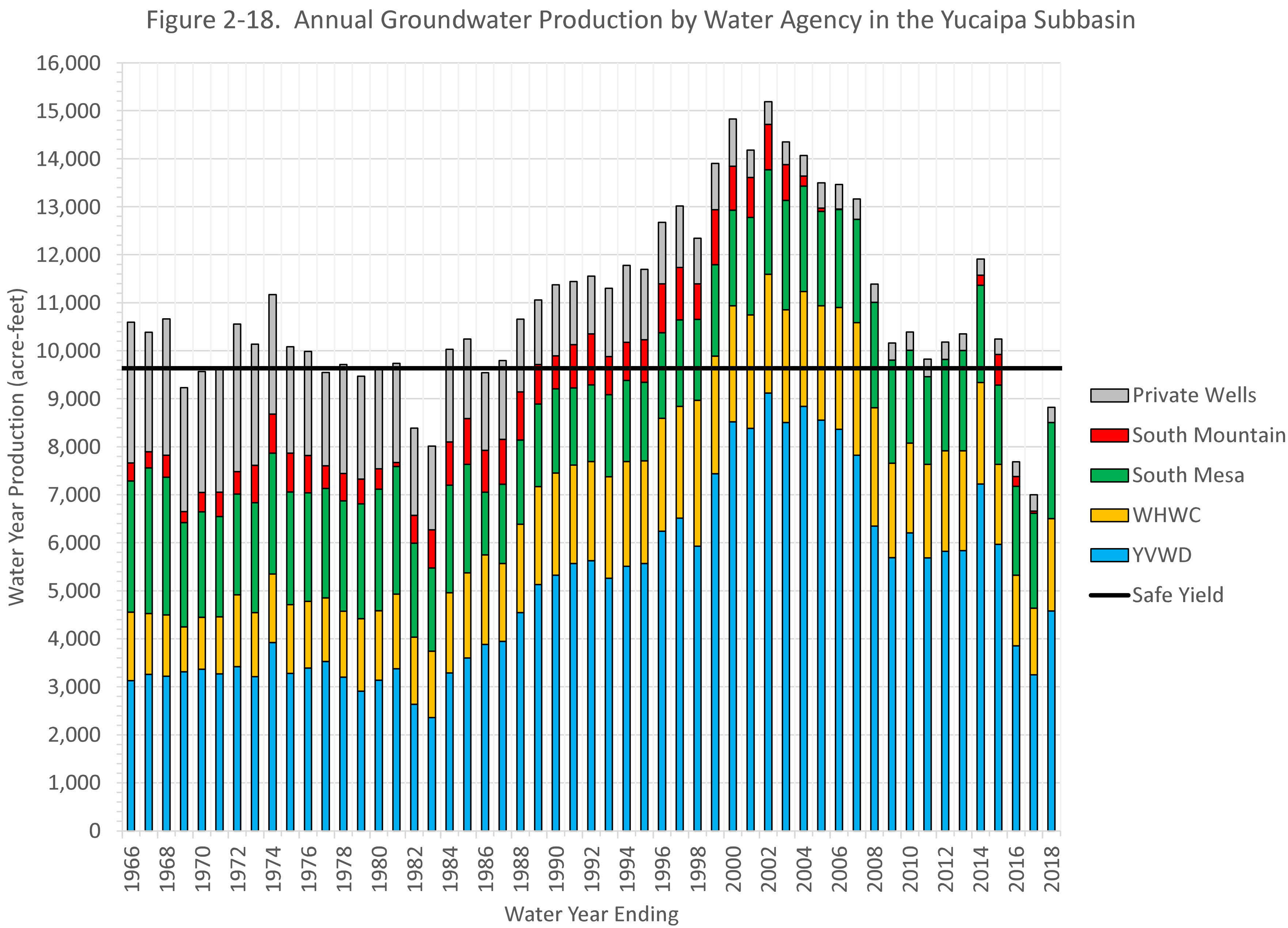

Figure 2-18. Annual Groundwater Production by Water Agency in the Yucaipa Subbasin
Water Year Production (acre-feet)
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Water Year Ending
Private Wells
South Mountain
South Mesa
WHWC
YVWD
Safe Yield

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Figure 2-19. Annual Groundwater Production by Hydrogeologic Subarea in the Yucaipa Subbasin

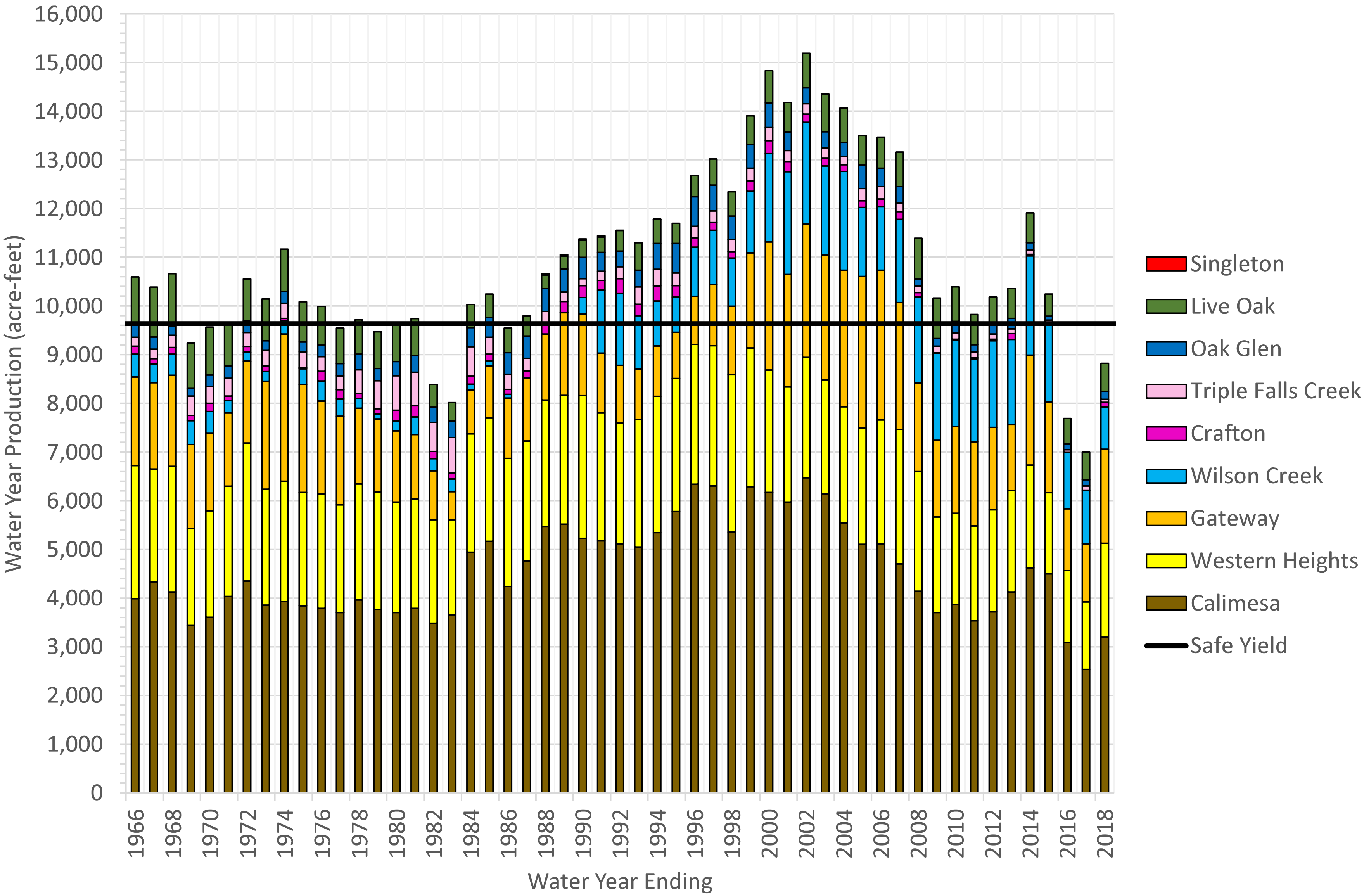

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Figure 2-20. Groundwater under the Influence of Surface Water

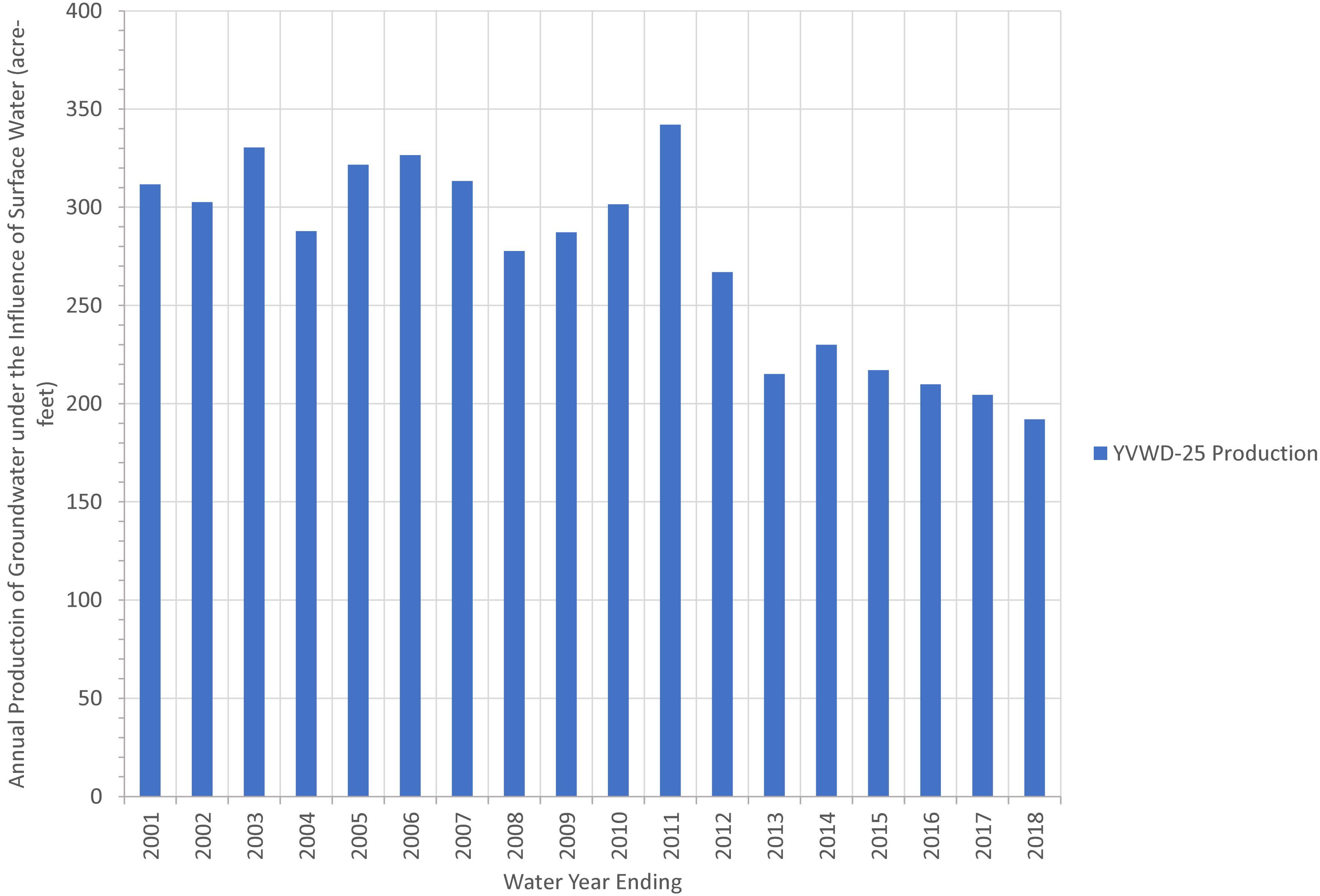

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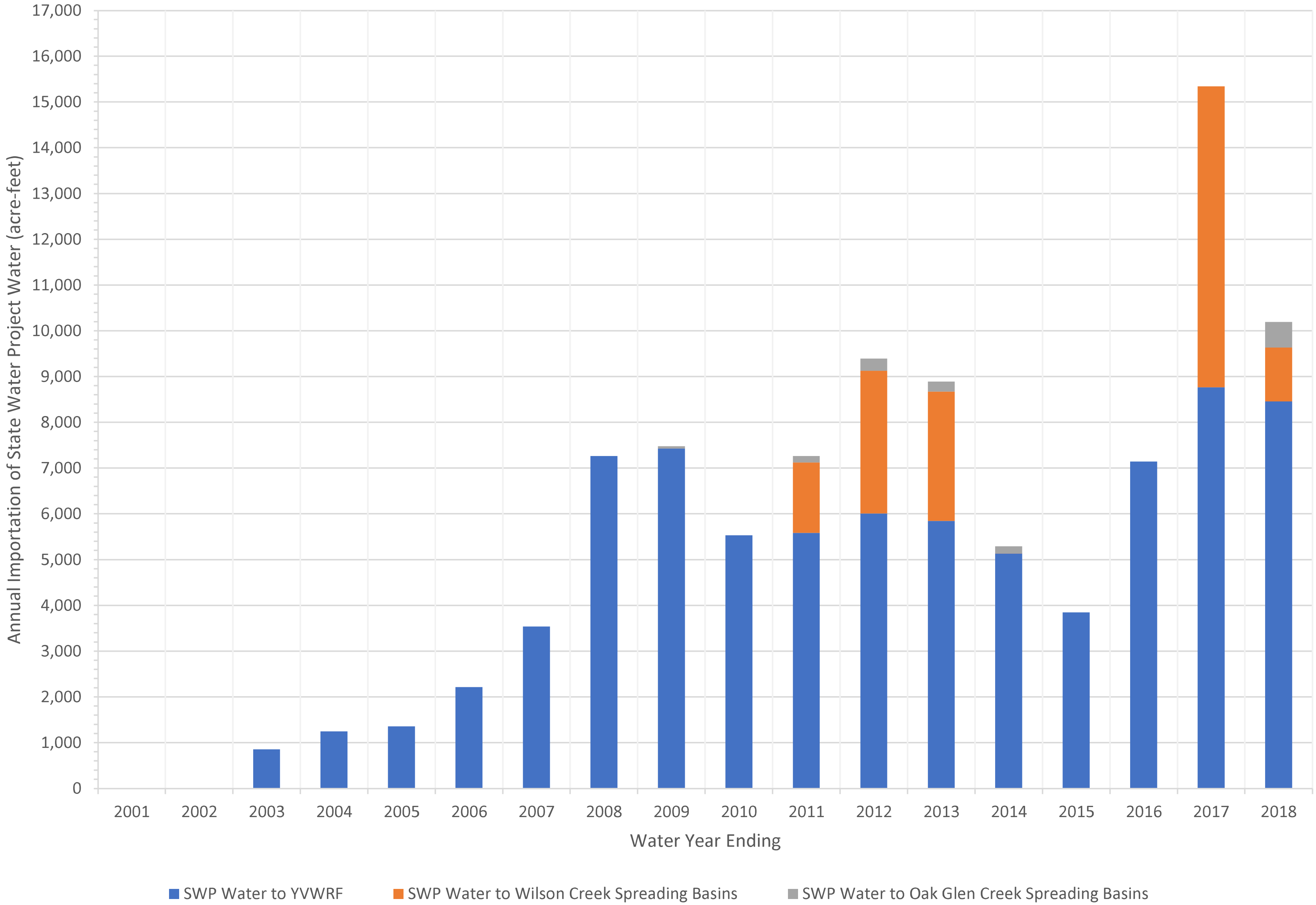
Figure 2-21. Annual Distribution of State Water Project Water in the Yucaipa Subbasin



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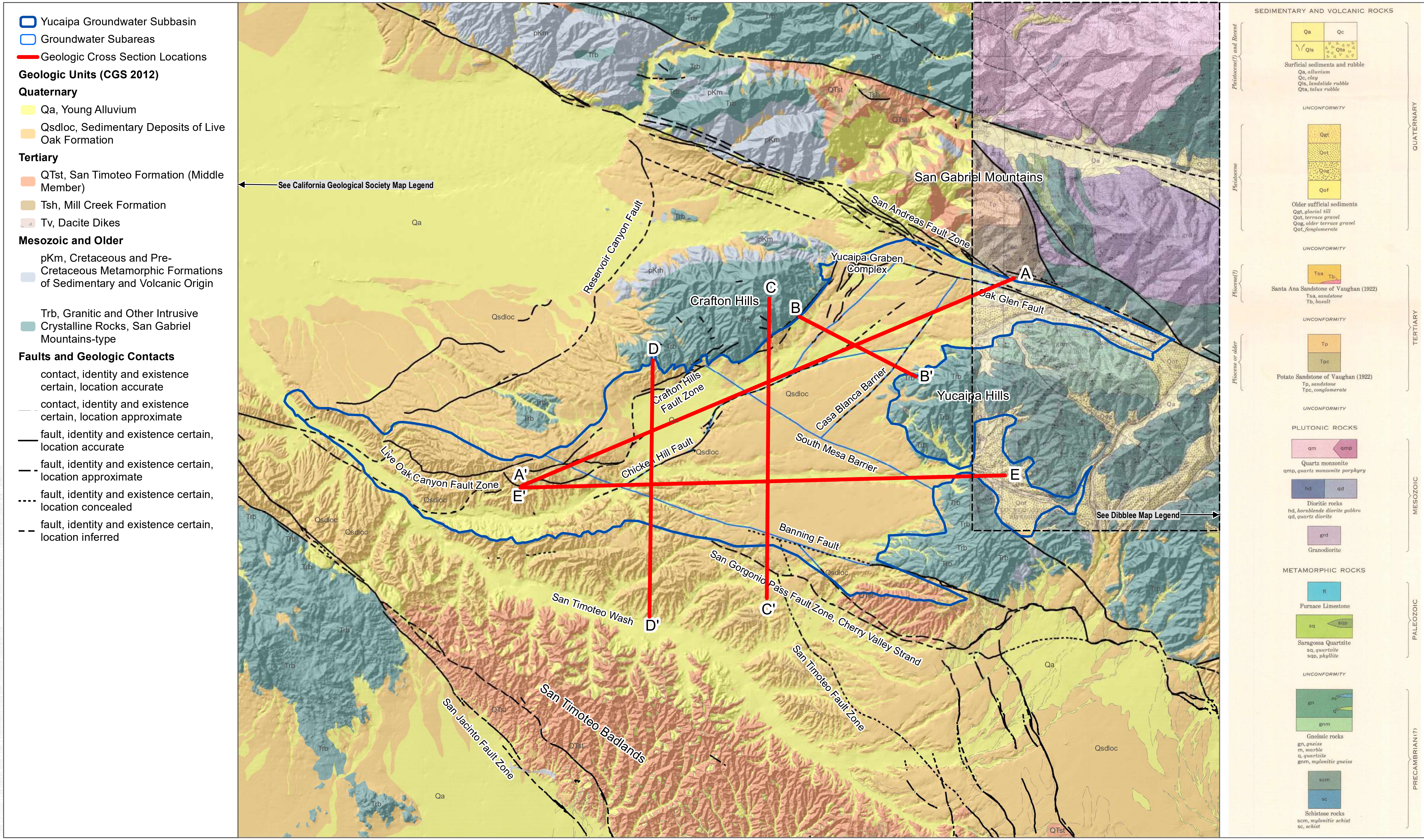

SOURCE: CGS 2012, USGS 1999

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DUDEK

0 0.5 1 2 Miles

FIGURE 2-22

Geologic Map with Delineations of Geologic Cross-Sections

Yucaipa Subbasin Groundwater Sustainability Plan

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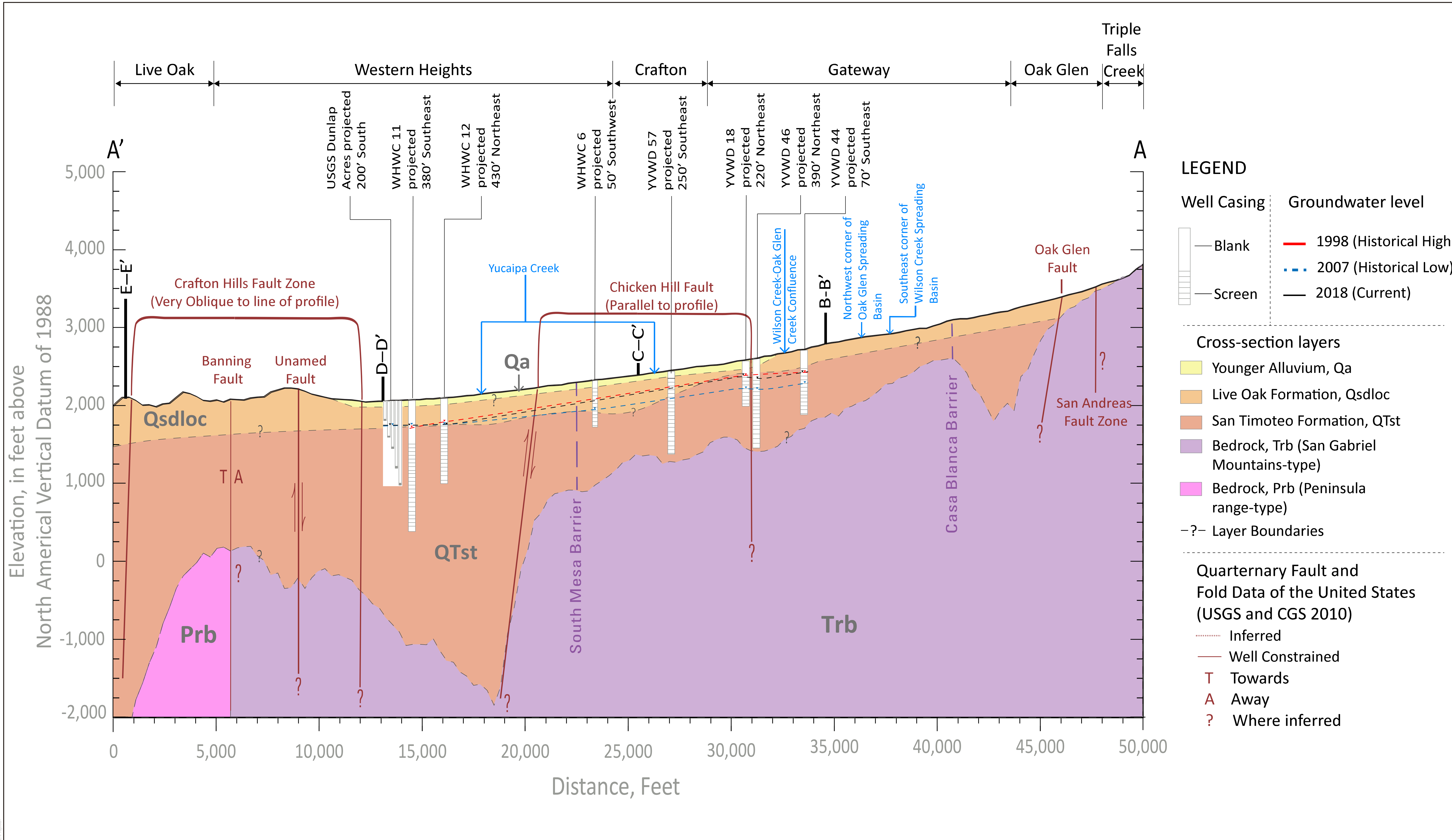

SOURCE: Geophysical Logs and Preliminary Data from Mendez (2013), Geoscience (2014), Motron and Miller (2006), Jennings, Strand, and Rogers (1977)

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FIGURE 2-23

Geologic Cross-Section A-A'

Yucaipa Subbasin Groundwater Sustainability Plan

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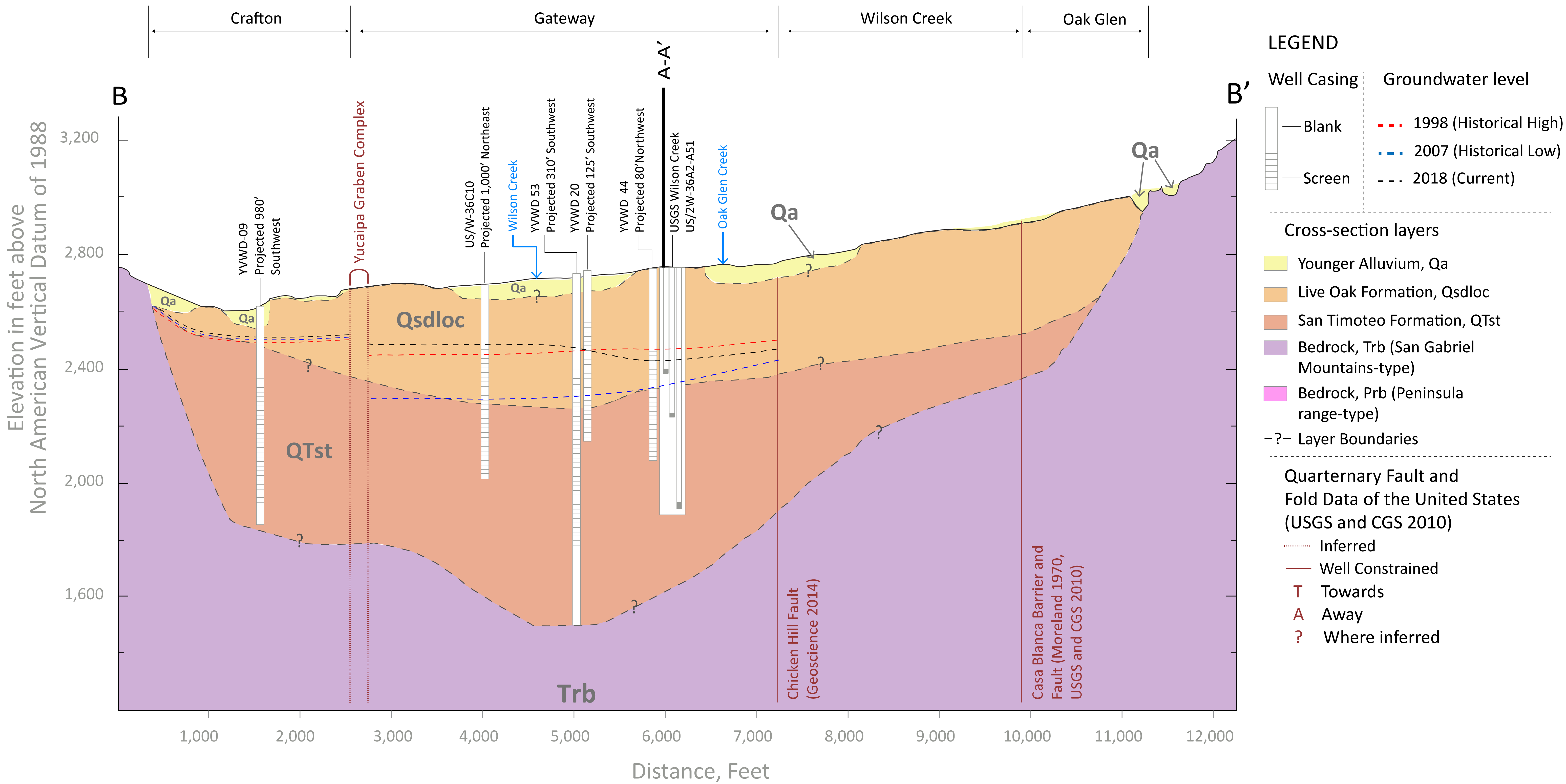

SOURCE: Geophysical Logs and Preliminary Data from Mendez (2013), Motron and Miller (2006), Jennings, Strand, and Rogers (1977)

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DUDEK

Figure 2-24
Geologic Cross-Section B-B'
Yucaipa Subbasin Groundwater Sustainability Plan

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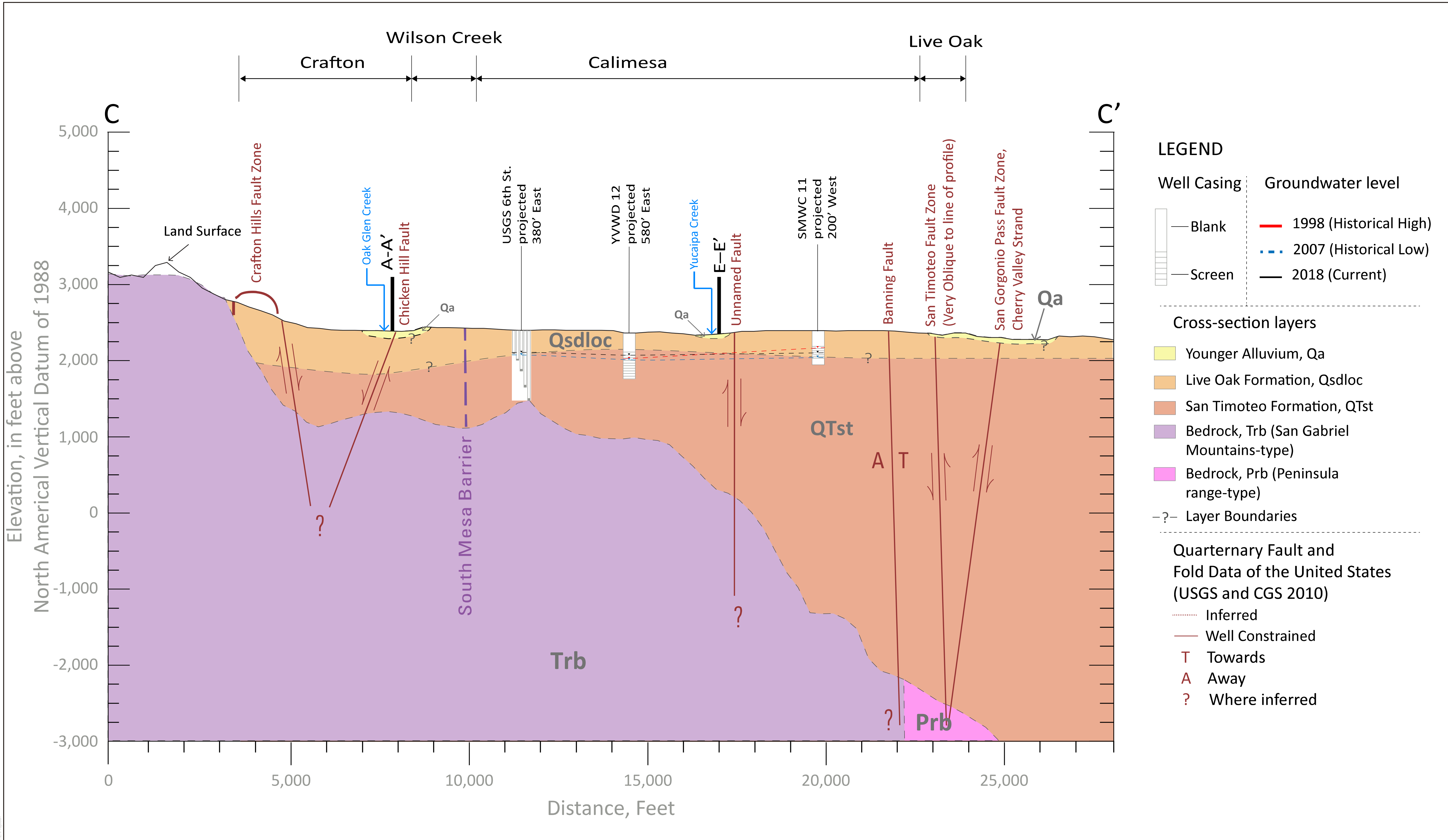

SOURCE: Geophysical Logs and Preliminary Data from Mendez (2013), Geoscience (2014), Motron and Miller (2006), Jennings, Strand, and Rogers (1977)

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FIGURE 2-25

Geologic Cross-Section C-C'

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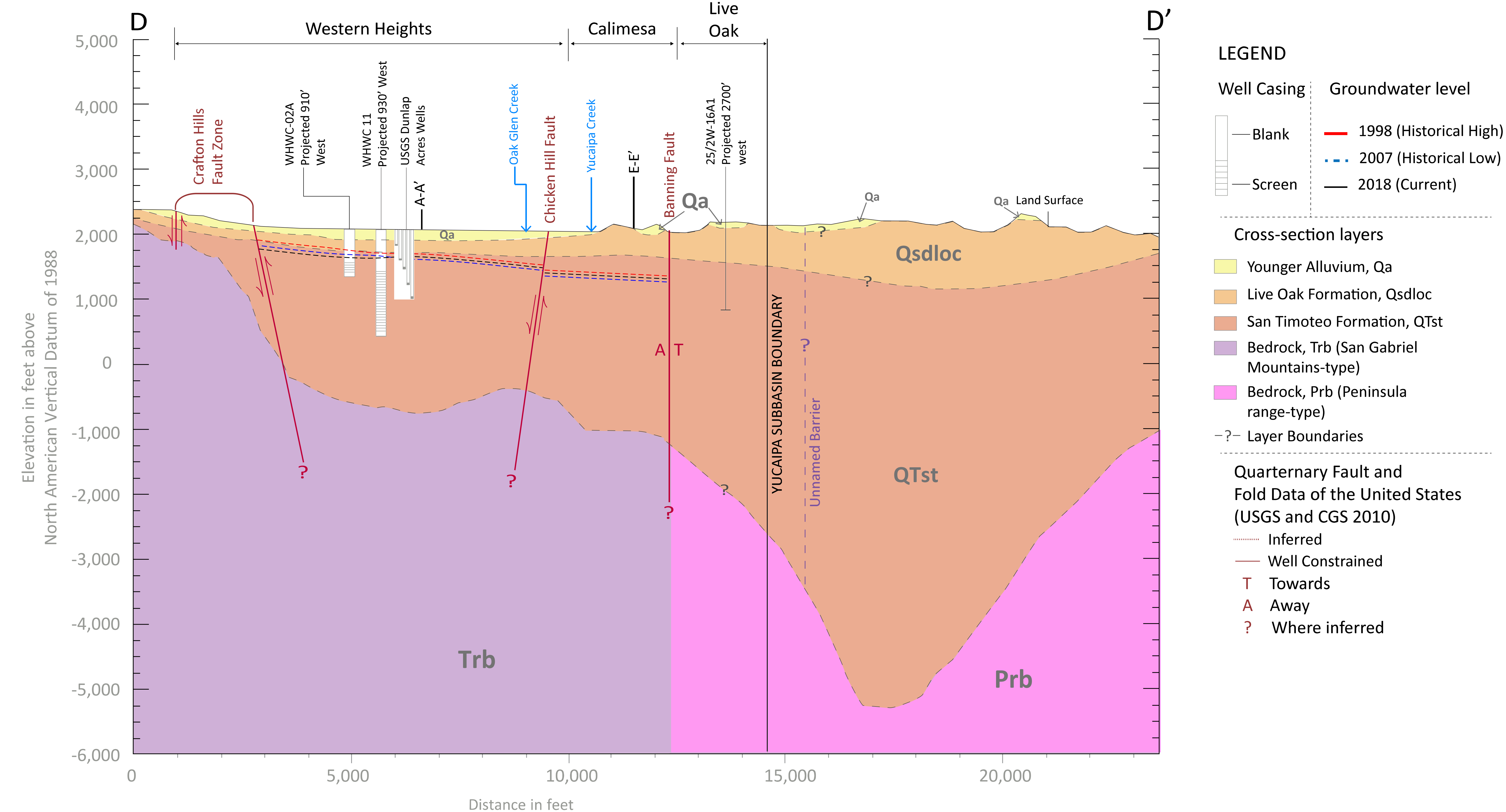

SOURCE: Geophysical Logs and Preliminary Data from Mendez (2013), Geoscience (2014), Motron and Miller (2006), Jennings, Strand, and Rogers (1977)

DUDEK

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FIGURE 2-26
Geologic Cross Section D-D'
Yucaipa Subbasin Groundwater Sustainability Plan

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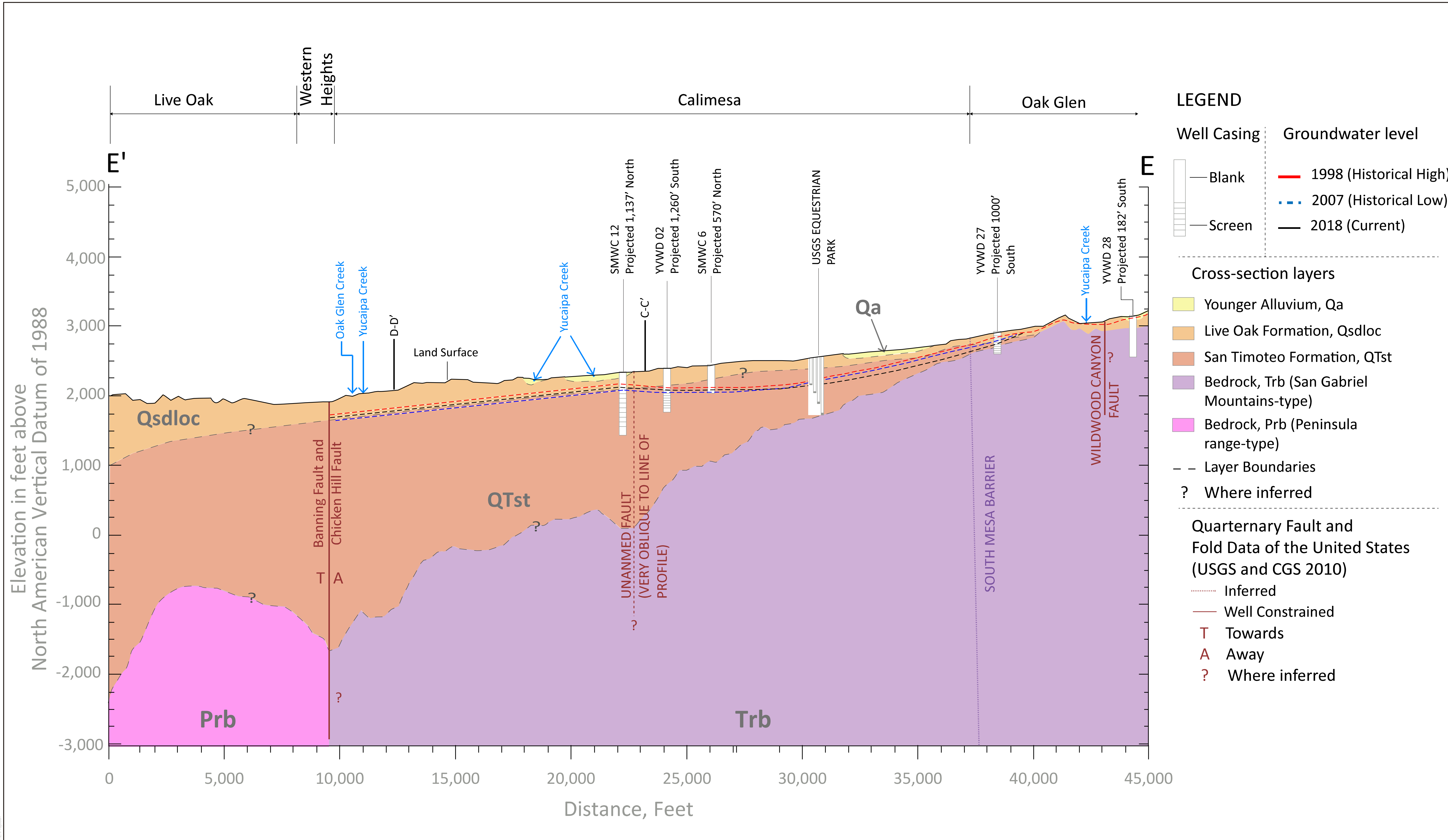

SOURCE: Geophysical Logs and Preliminary Data from Mendez (2013), Geoscience (2014), Motron and Miller (2006), Jennings, Strand, and Rogers (1977)

DUDEK

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FIGURE 2-27
Geologic Cross Section E-E'
Yucaipa Subbasin Groundwater Sustainability Plan

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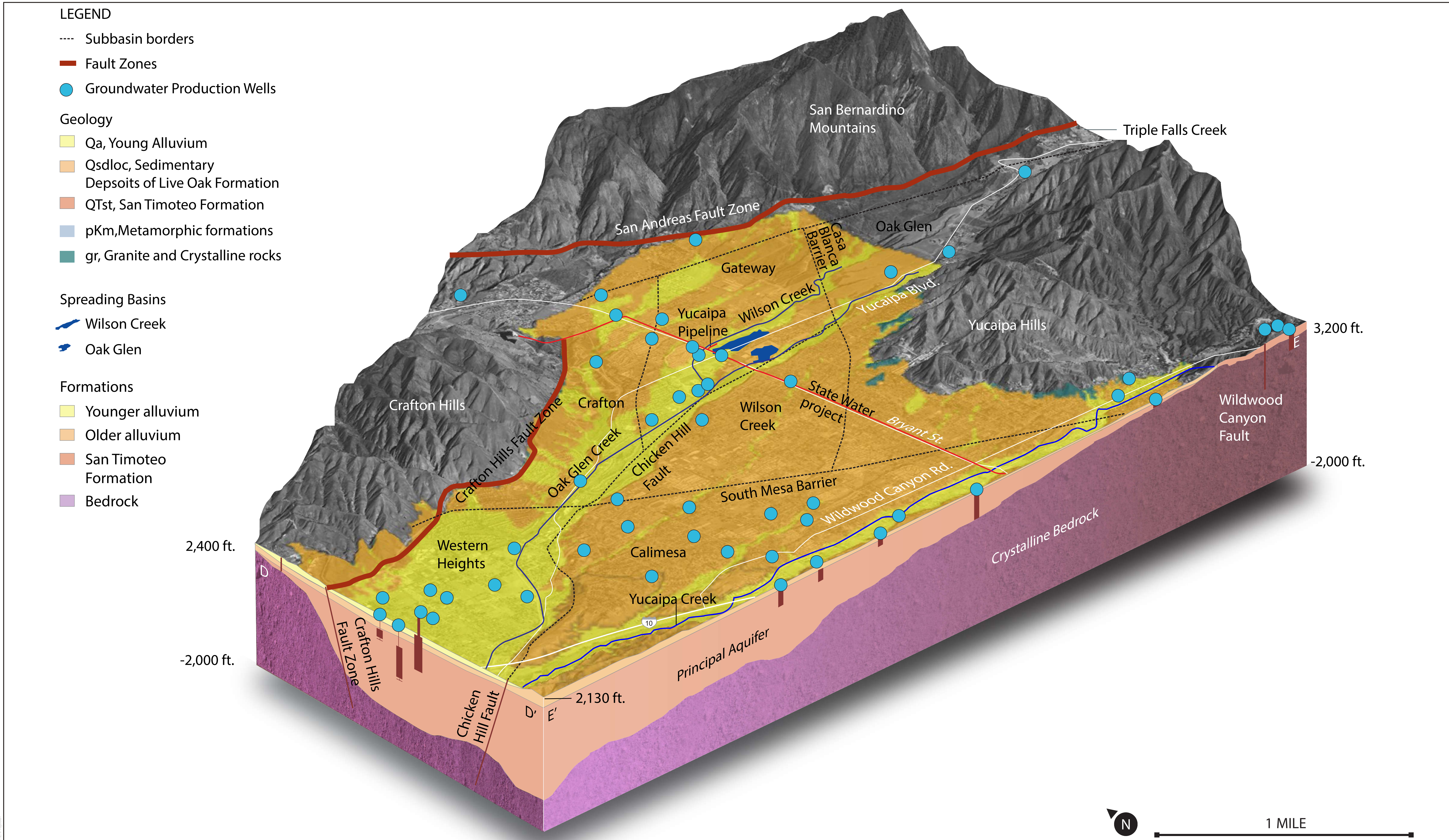

SOURCE: USGS, DWR, Google Earth

DUDEK

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FIGURE 2-28

Hydrogeologic Conceptual Model of the Yucaipa Subbasin

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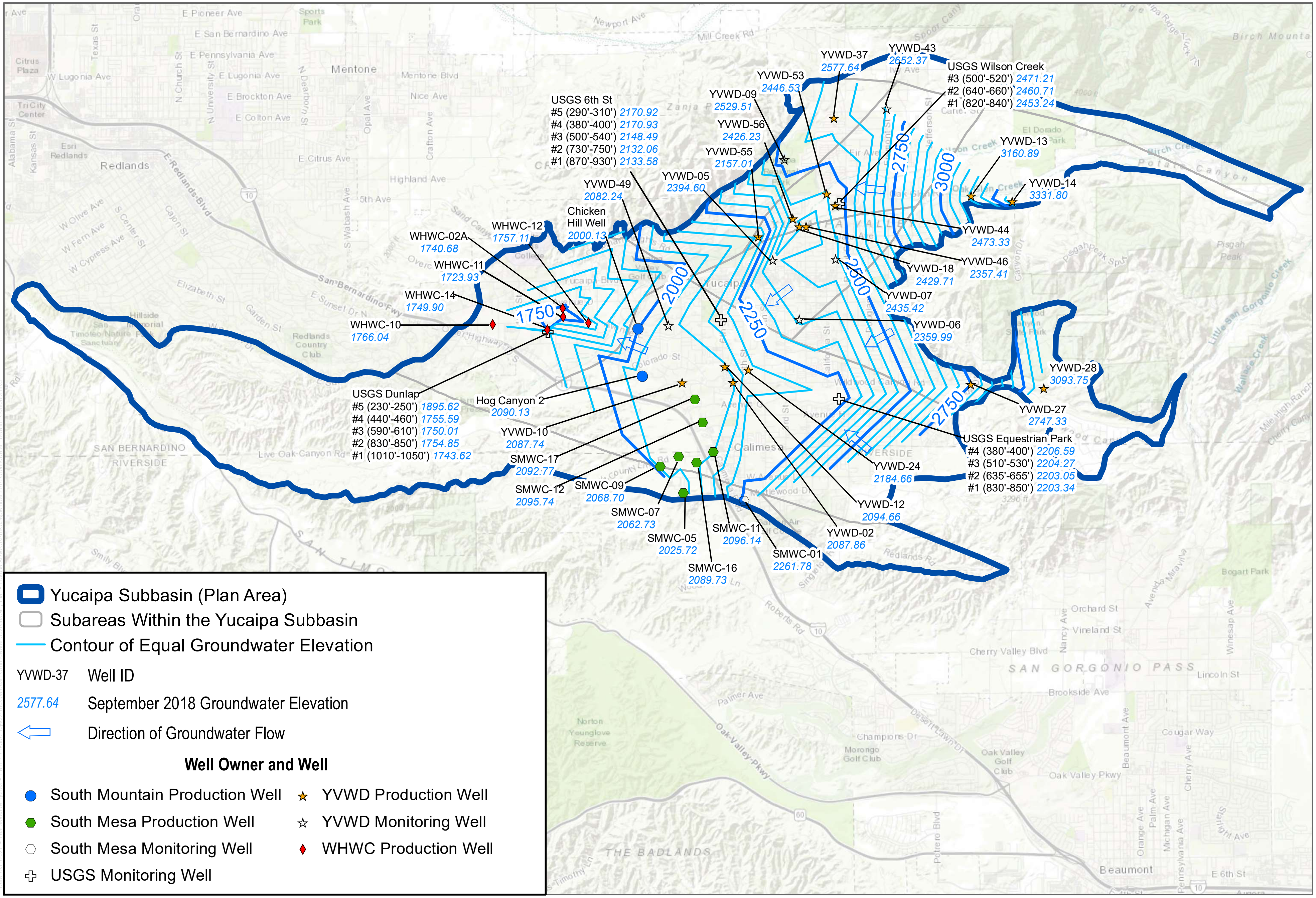

SOURCE: YVWD, WHWC, South Mesa, City of Redlands, USGS

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FIGURE 2-29

September 2018 Groundwater Elevations within the Yucaipa Subbasin

Yucaipa Subbasin Groundwater Sustainability Plan

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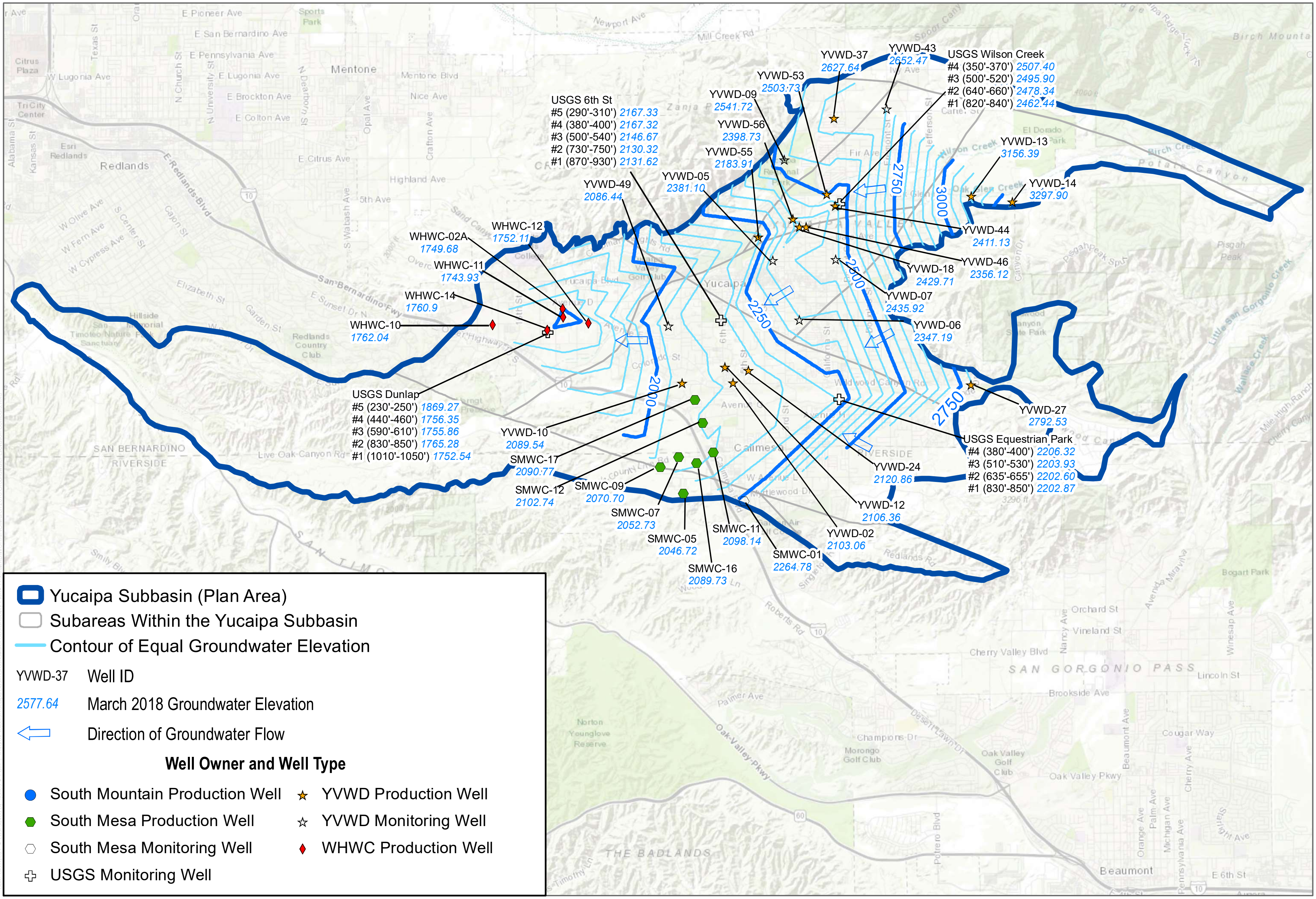

SOURCE: YVWD, WHWC, South Mesa, City of Redlands, USGS

FIGURE 2-30

March 2018 Groundwater Elevations within the Yucaipa Subbasin

Yucaipa Subbasin Groundwater Sustainability Plan

DUDEK

0 0.5 1 Miles

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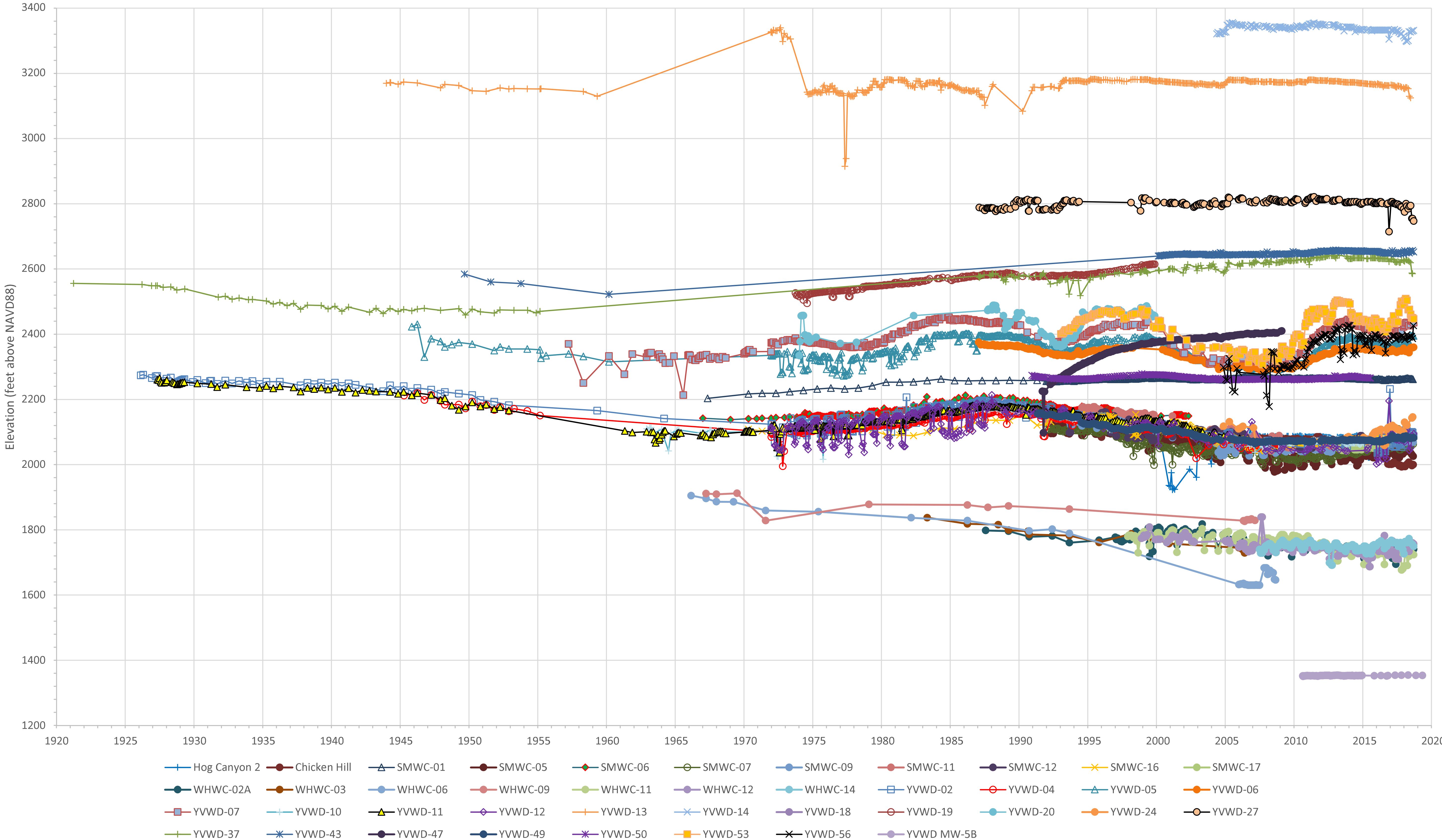
Figure 2-31. Historical Groundwater Elevations in the Yucaipa Subbasin



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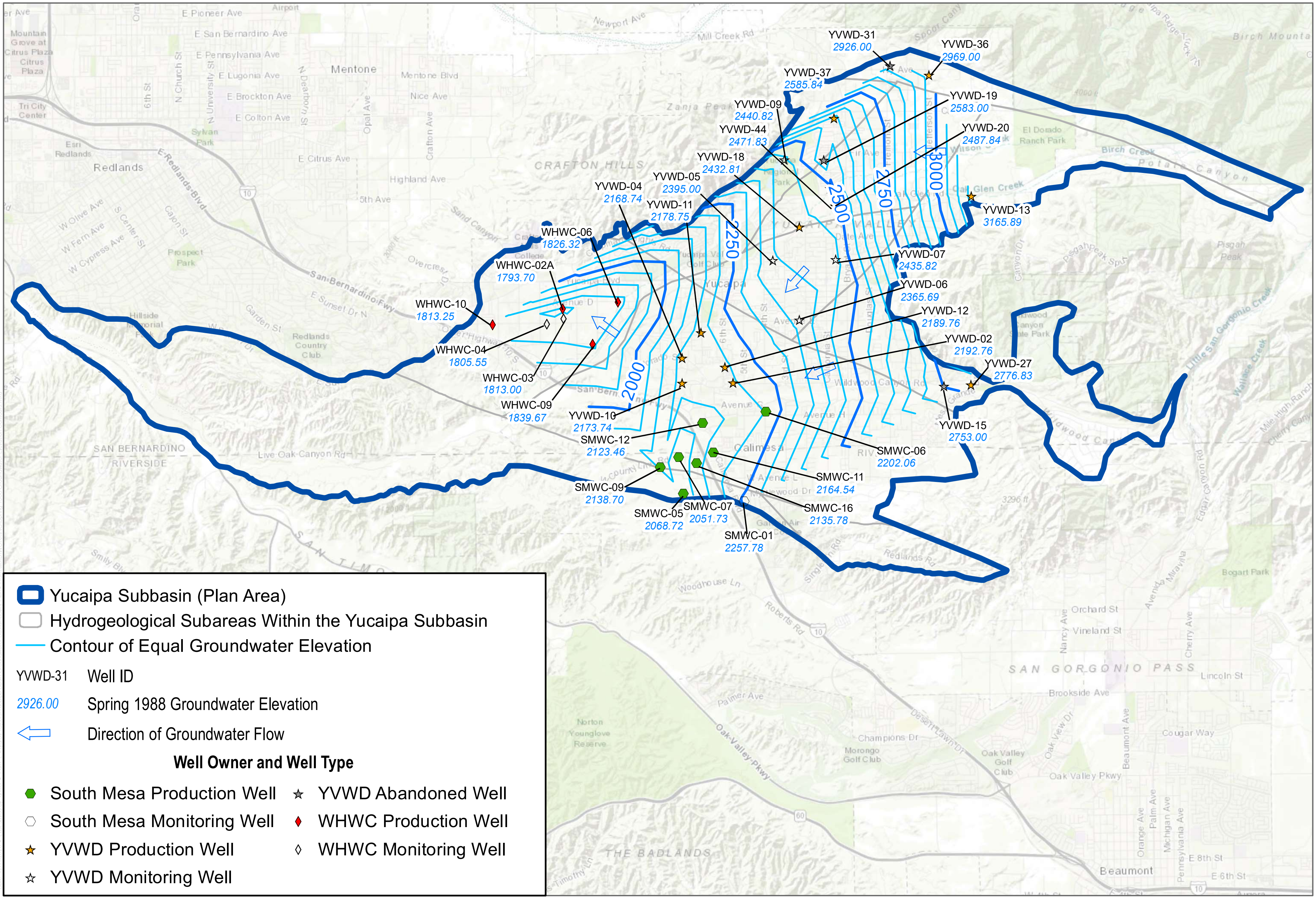

SOURCE: YVWD, WHWC, South Mesa

FIGURE 2-32

Historical High (Spring 1998) Groundwater Elevations in the Yucaipa Subbasin

Yucaipa Subbasin Groundwater Sustainability Plan

DUDEK

0 0.5 1 Miles

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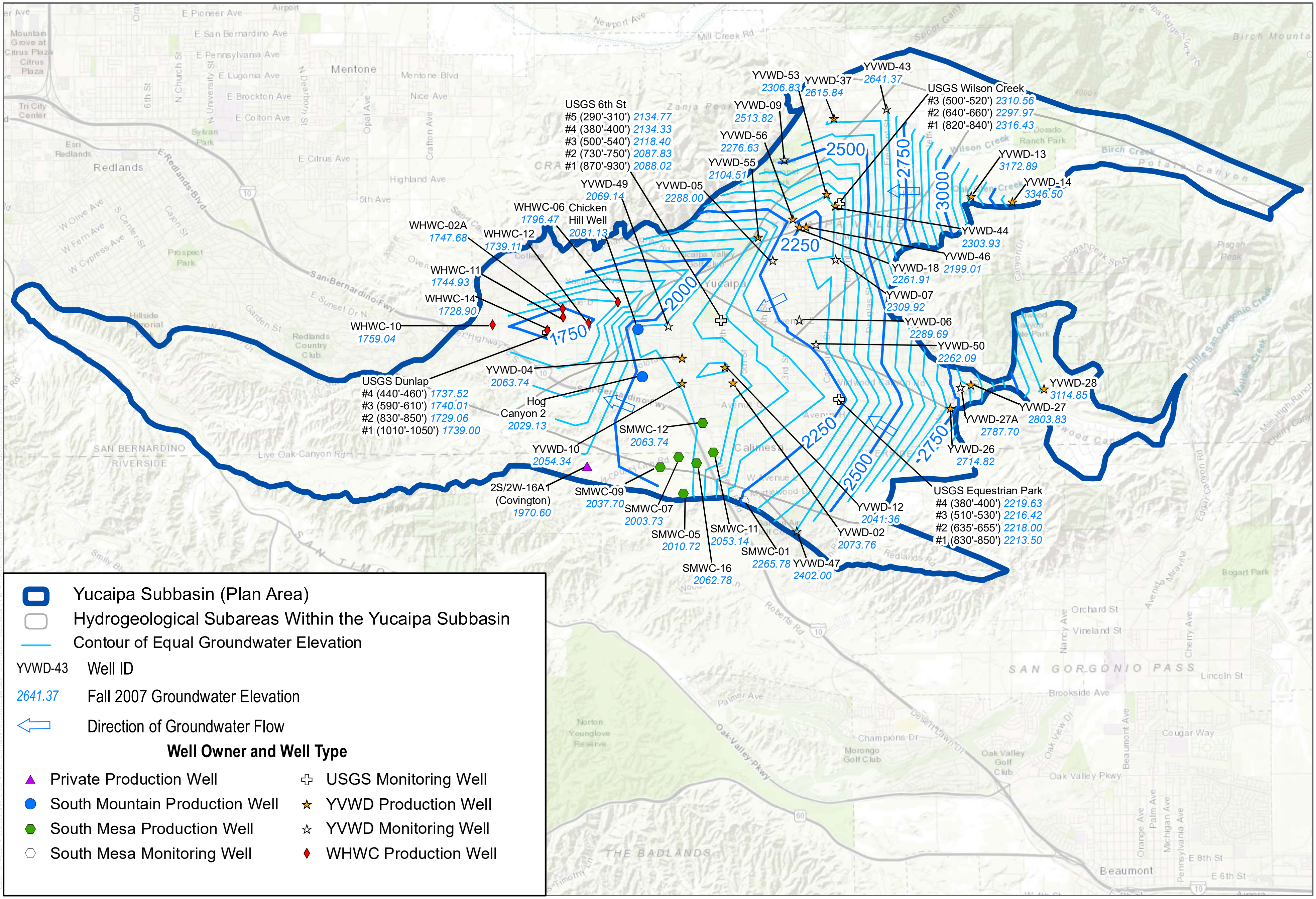

SOURCE: YVWD, WHWC, South Mesa, City of Redlands

DUDEK

0 0.5 1 Miles

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FIGURE 2-33

Historical Low (Fall 2007) Groundwater Elevations in the Yucaipa Subbasin

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Figure 2-34. Annual Groundwater Production by Water Year and Groundwater Elevations in the Calimesa Subarea

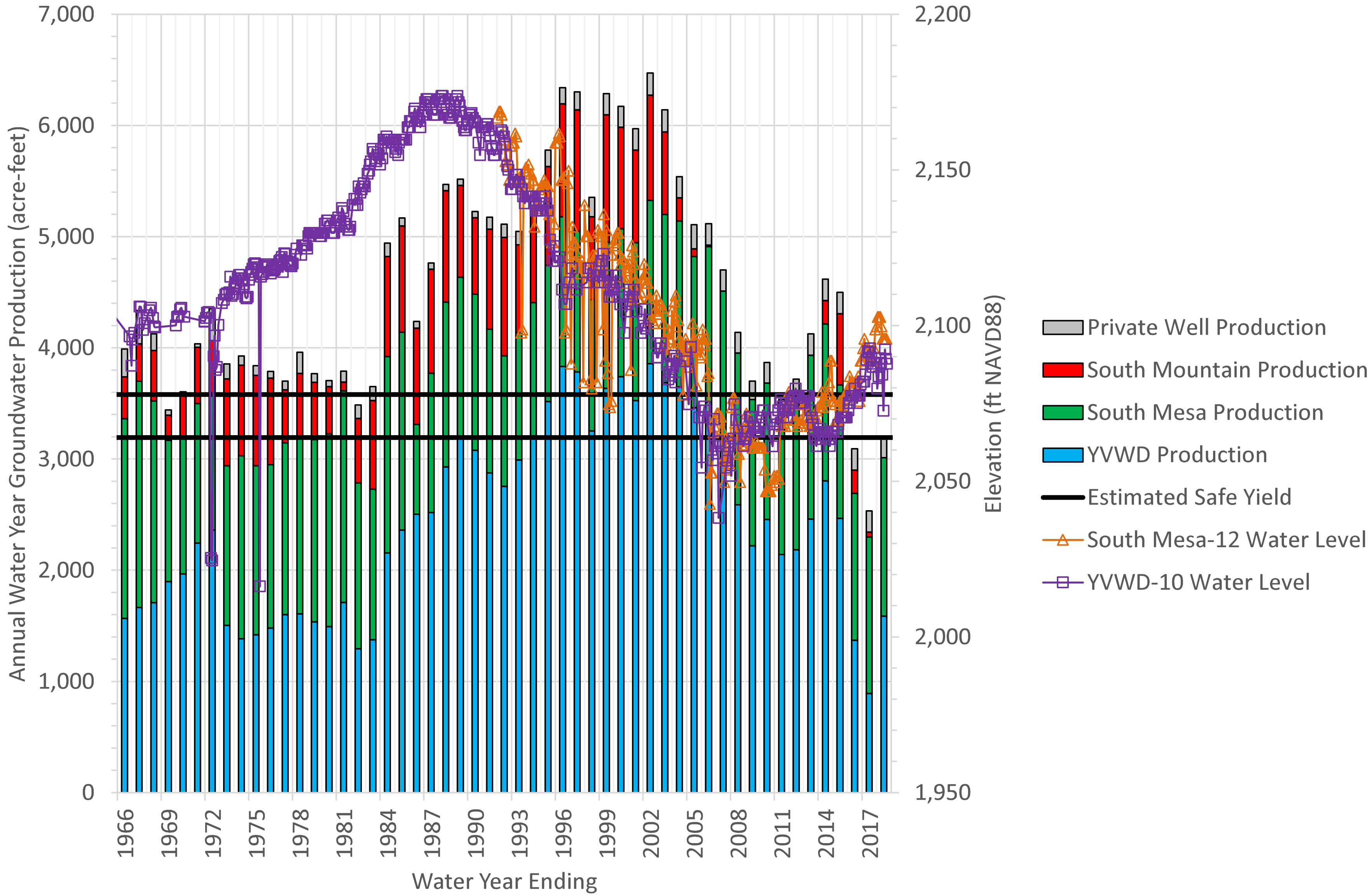

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Figure 2-35. Historical Groundwater Elevations vs. Water Year-Type in the Yucaipa Subbasin

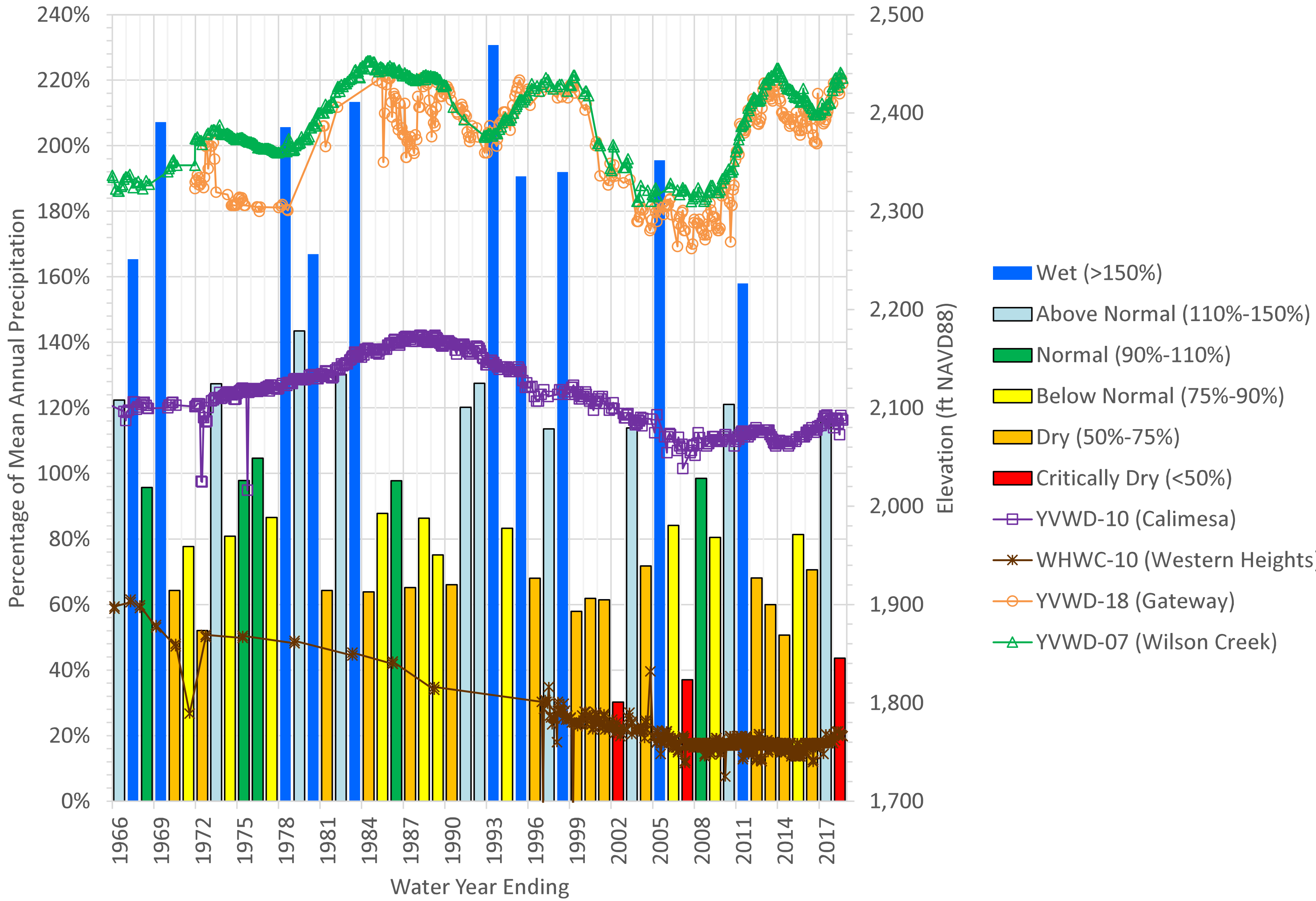

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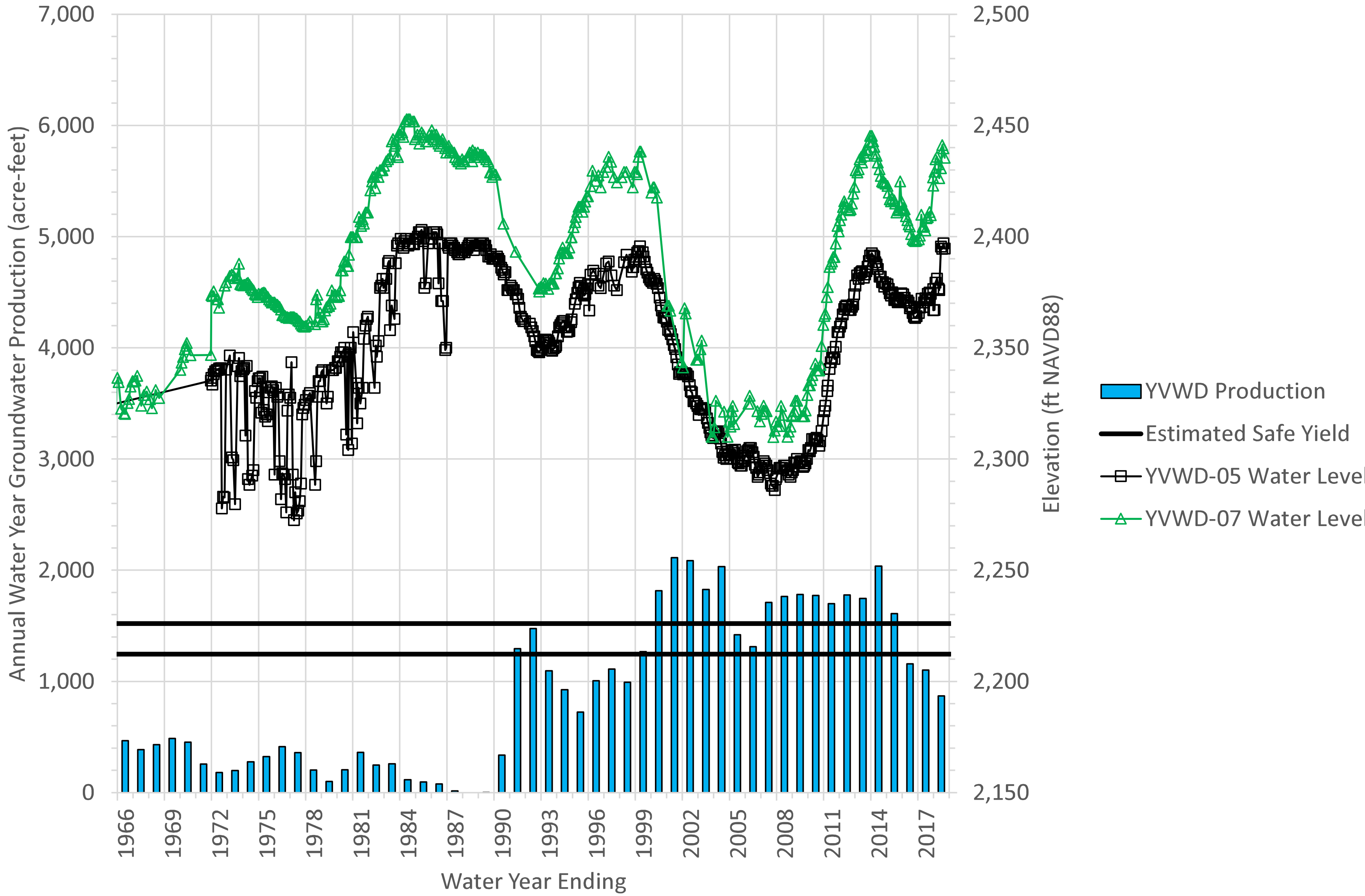
Figure 2-36. Annual Groundwater Production by Water Year and Groundwater Elevations in the Wilson Creek Subarea



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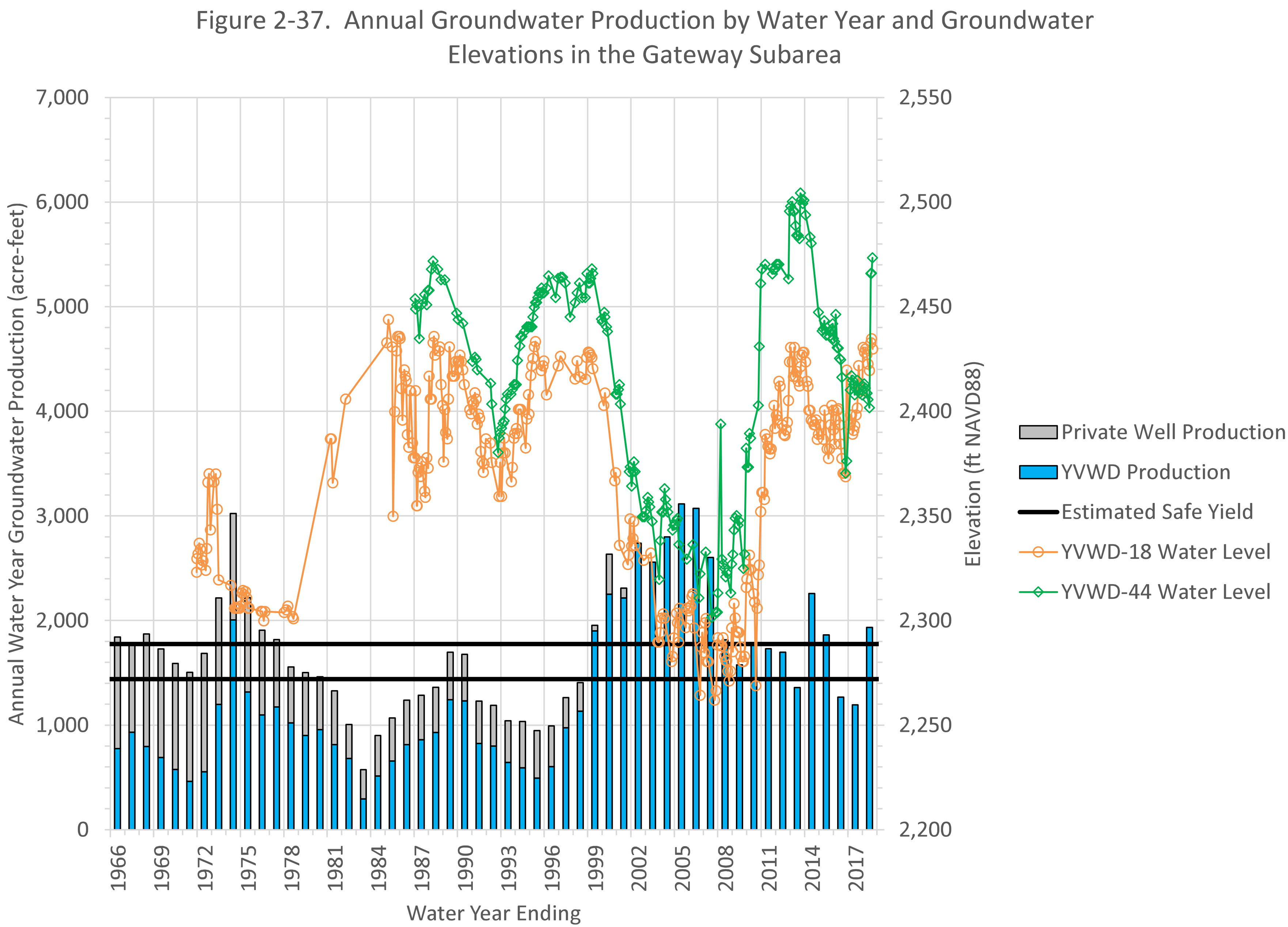

Figure 2-37. Annual Groundwater Production by Water Year and Groundwater Elevations in the Gateway Subarea
Annual Water Year Groundwater Production (acre-feet)
Elevation (ft NAVD88)
Water Year Ending
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
Private Well Production
YVWD Production
Estimated Safe Yield
YVWD-18 Water Level
YVWD-44 Water Level

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Figure 2-38. Annual Groundwater Production by Water Year and Groundwater Elevations in the Western Heights Subarea

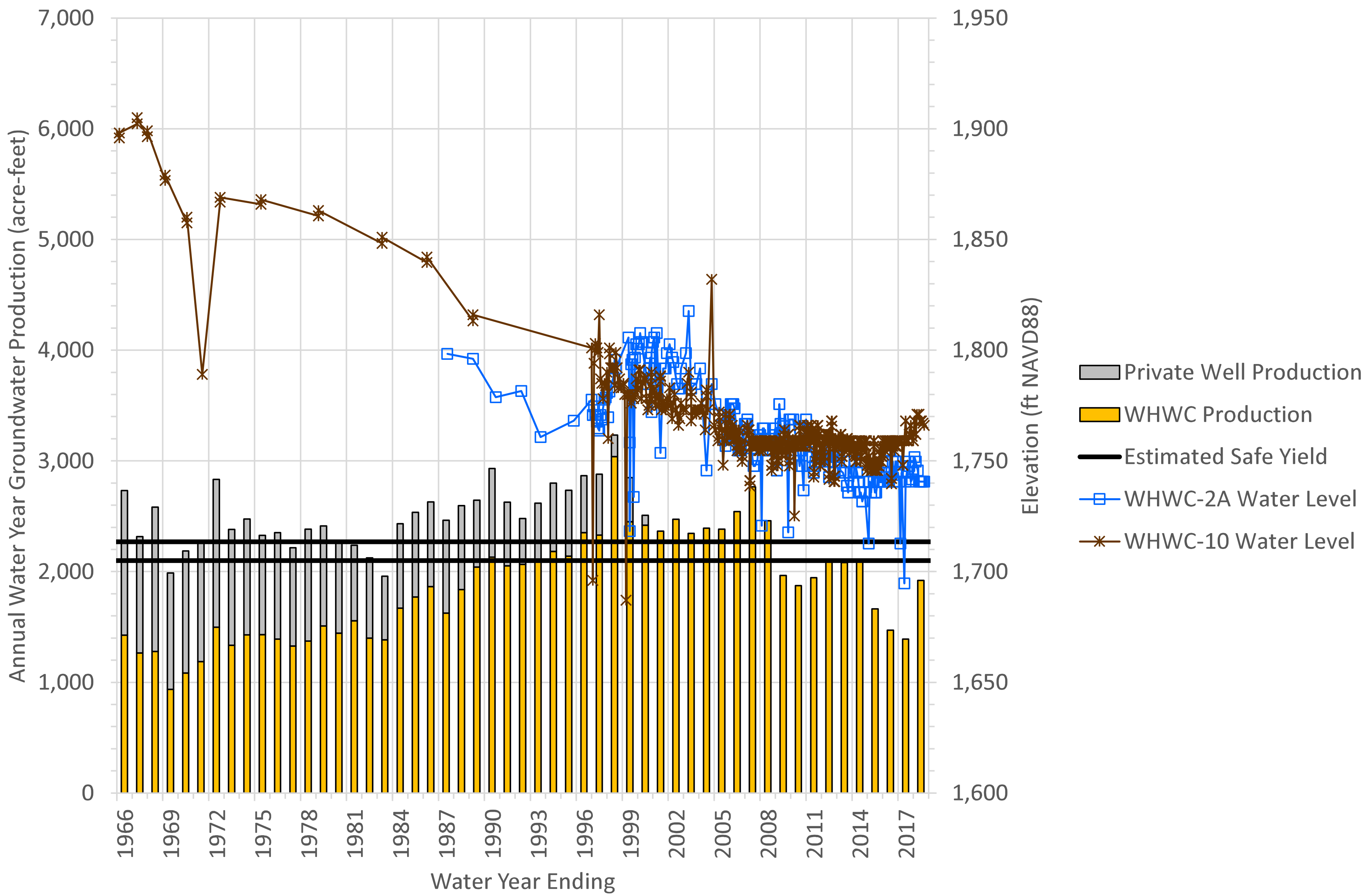

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Figure 2-39. Concentrations of Total Dissolved Solids at the Former Yucaipa Landfill in the Yucaipa Subbasin

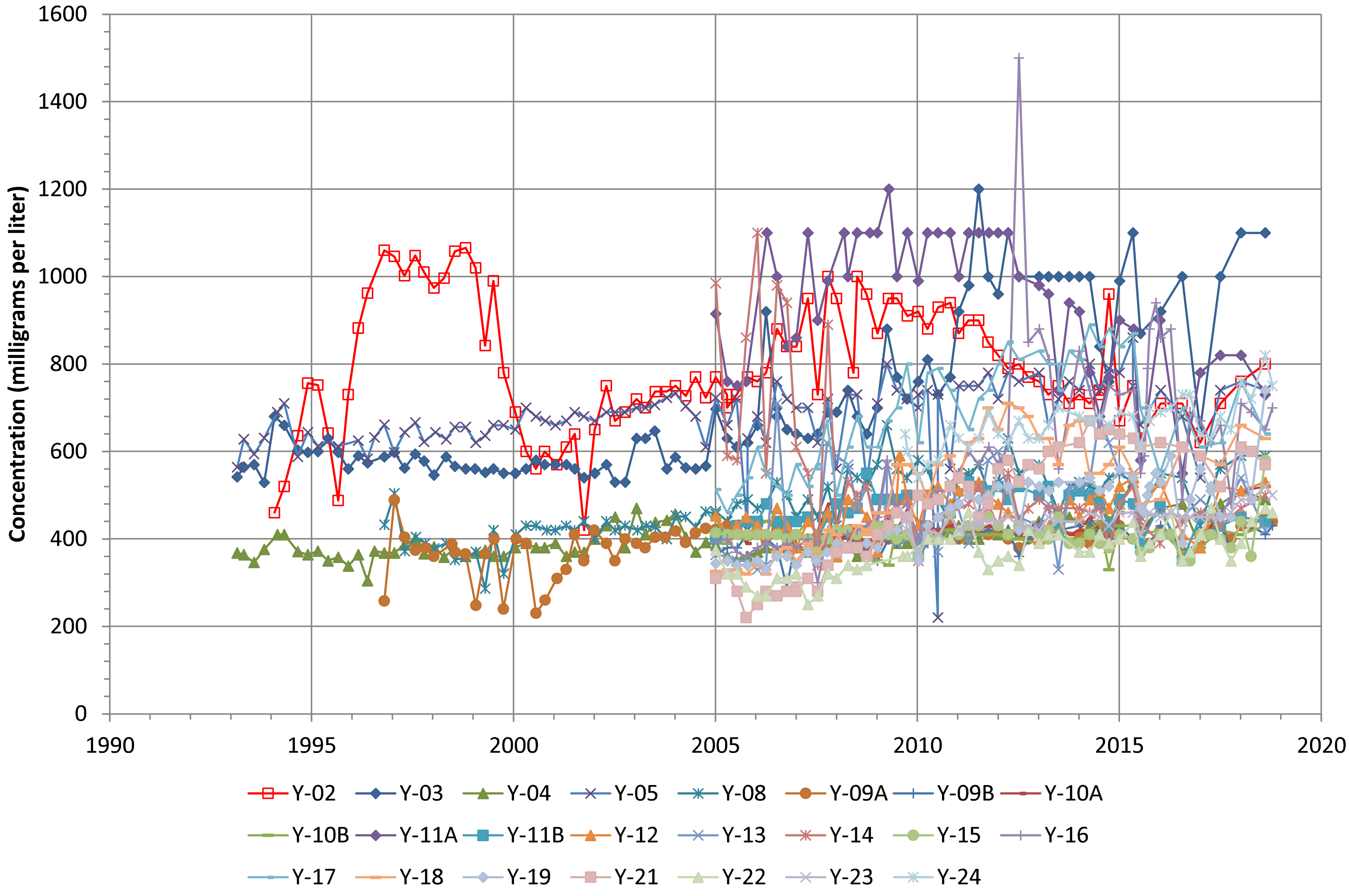

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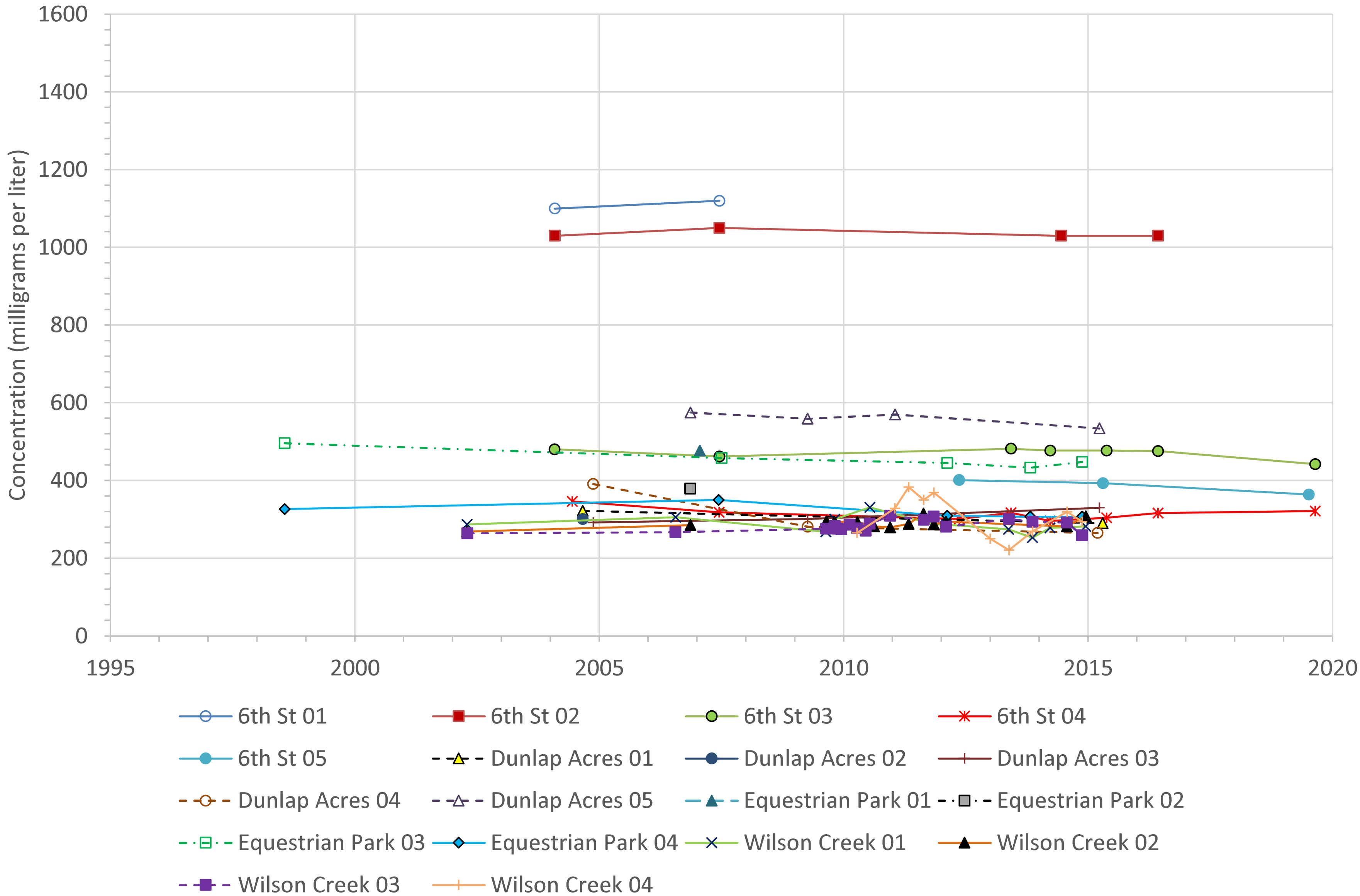
Figure 2-40. Concentrations of Total Dissolved Solids at United States Geological Survey Observation Wells in the Yucaipa Subbasin



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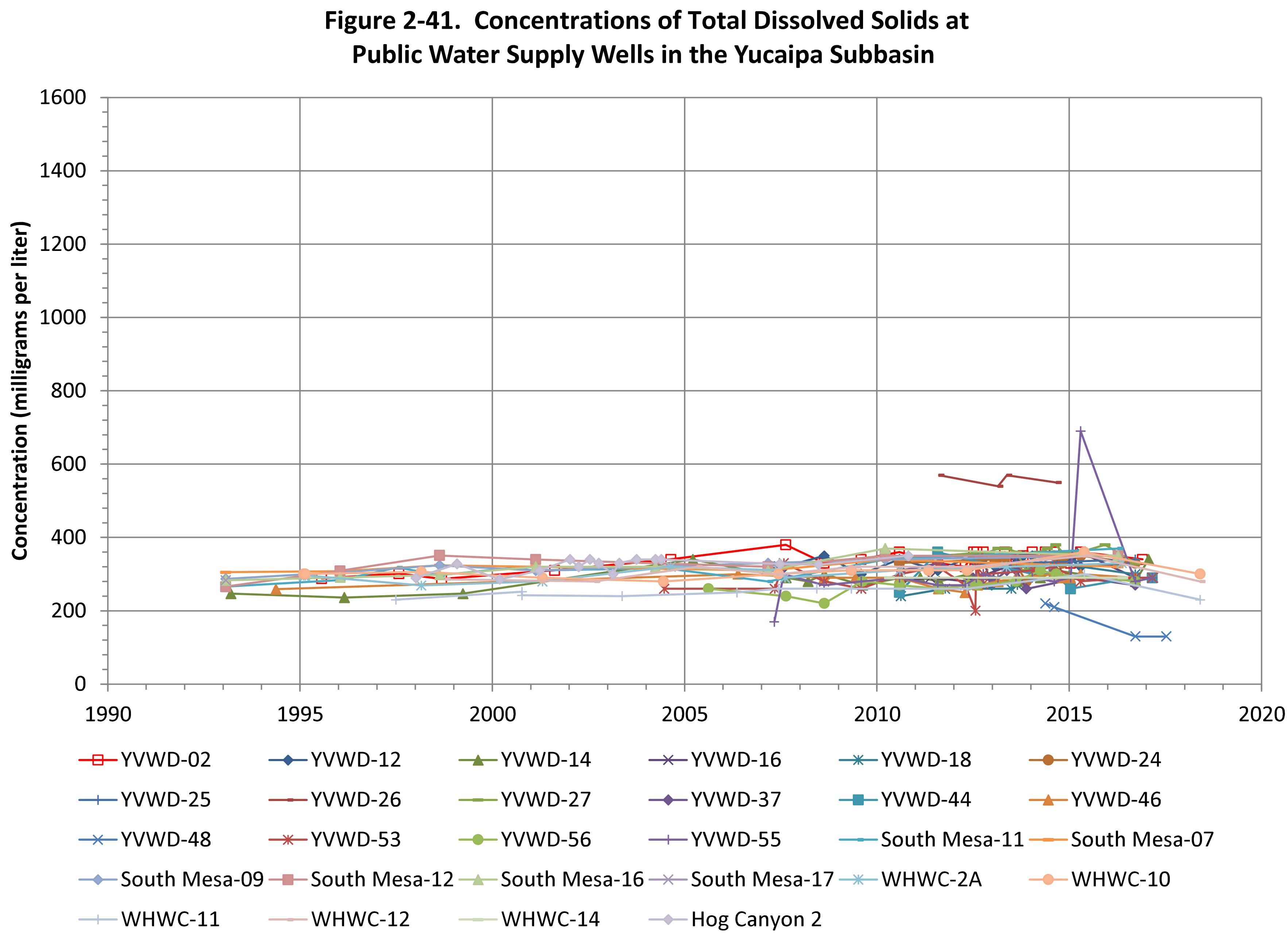
Figure 2-41. Concentrations of Total Dissolved Solids at Public Water Supply Wells in the Yucaipa Subbasin
Concentration (milligrams per liter)
1600
1400
1200
1000
800
600
400
200
0
1990
1995
2000
2005
2010
2015
2020
YVWD-02
YVWD-12
YVWD-14
YVWD-16
YVWD-18
YVWD-24
YVWD-25
YVWD-26
YVWD-27
YVWD-37
YVWD-44
YVWD-46
YVWD-48
YVWD-53
YVWD-56
YVWD-55
South Mesa-11
South Mesa-07
South Mesa-09
South Mesa-12
South Mesa-16
South Mesa-17
WHWC-2A
WHWC-10
WHWC-11
WHWC-12
WHWC-14
Hog Canyon 2

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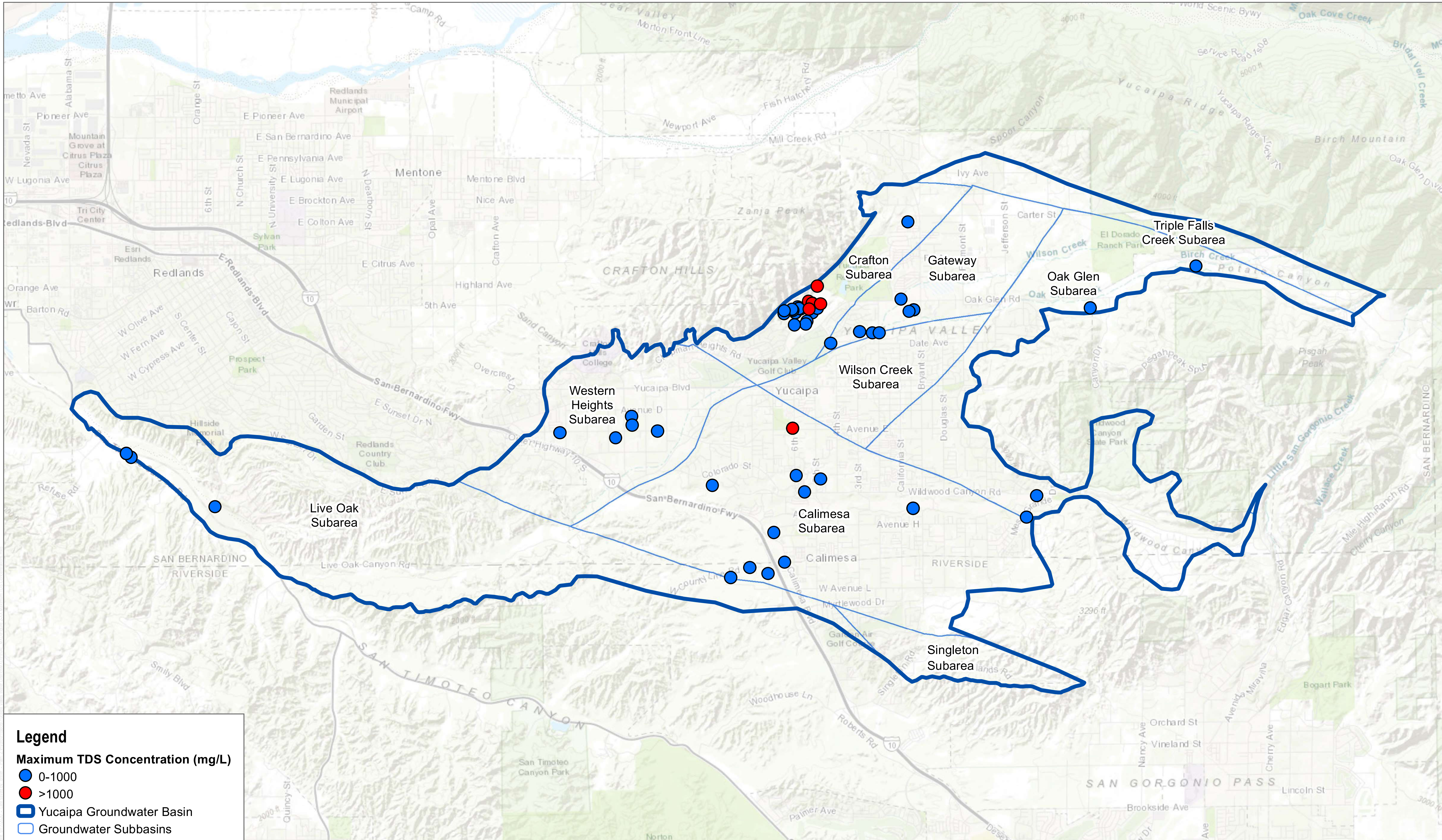

SOURCE: ESRI

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DUDEK

0 0.5 1 Miles

FIGURE 2-42

Maximum Total Dissolved Solids Concentrations Detected in Groundwater Wells

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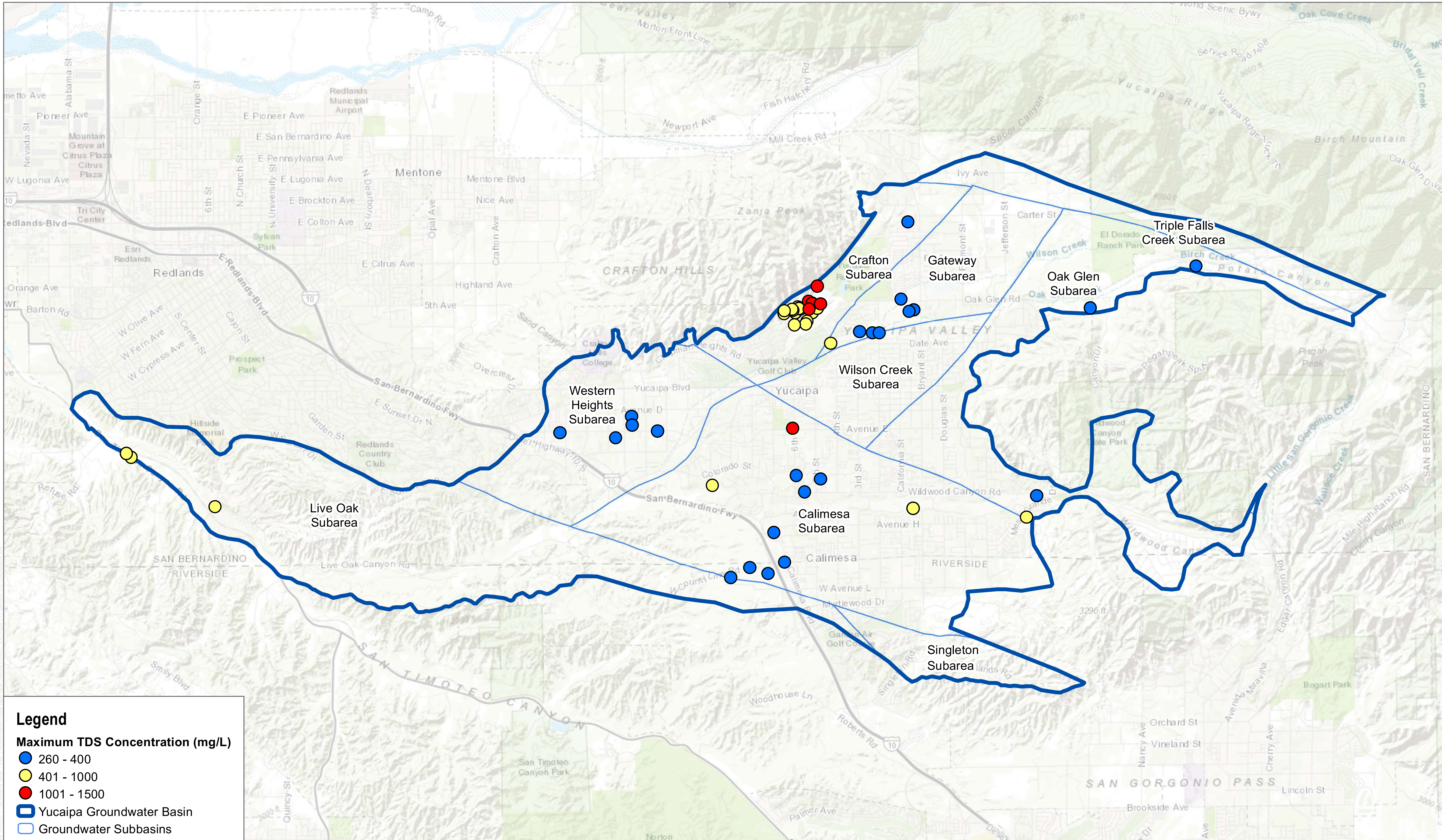

SOURCE: ESRI

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DUDEK

0 0.5 1 Miles

FIGURE 2-43

Maximum Total Dissolved Solids Concentrations Detected in Groundwater Wells

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Figure 2-44. Total Dissolved Solids and Monthly Discharges of Recycled Water at WRWRF OutFall

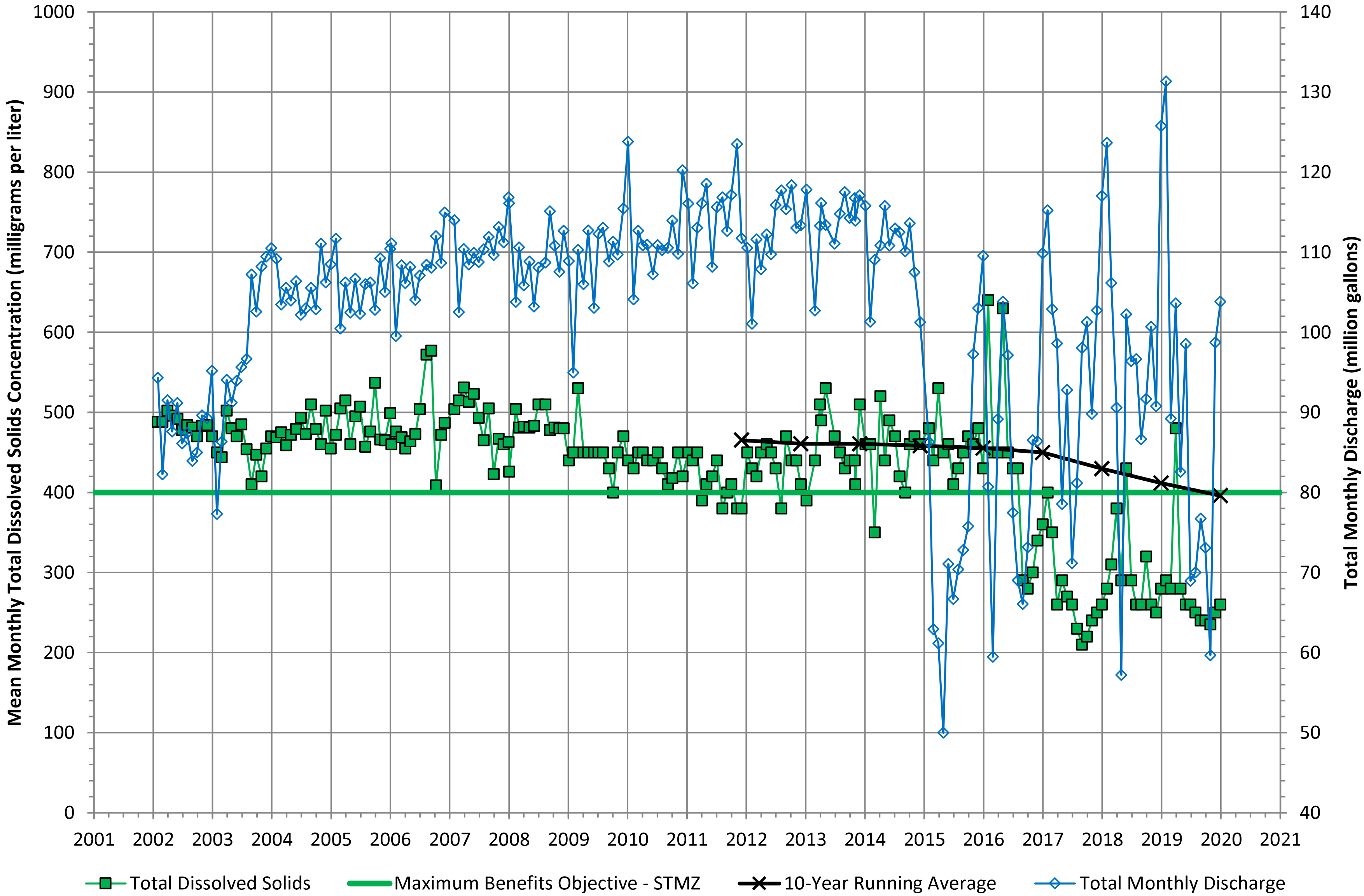

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Figure 2-45. Concentrations of Nitrate (as Nitrogen) at the Former Yucaipa Landfill in the Yucaipa Subbasin

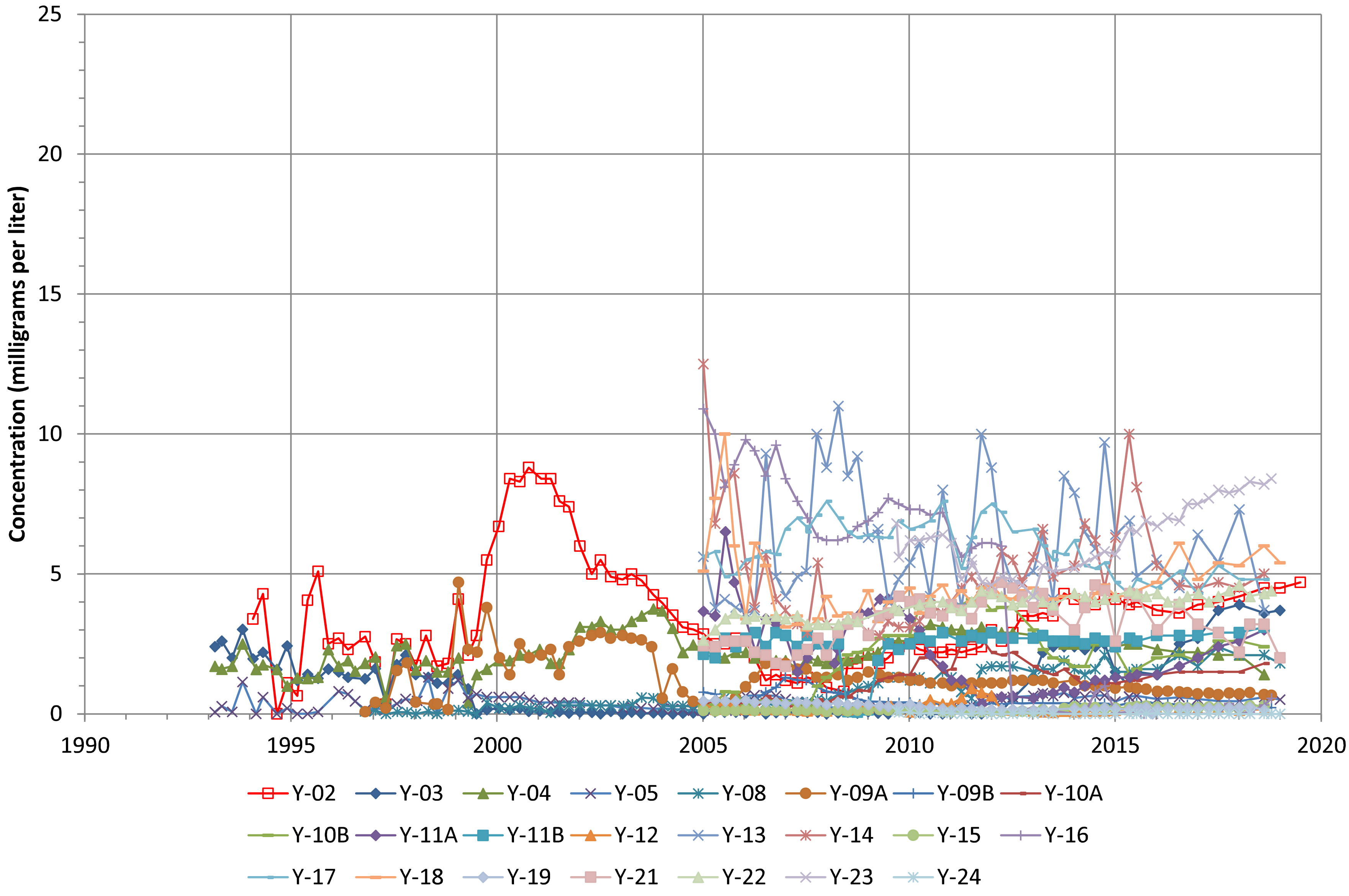

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Figure 2-46. Concentrations of Nitrate (as Nitrogen) at United States Geological Survey Observation Wells in the Yucaipa Subbasin

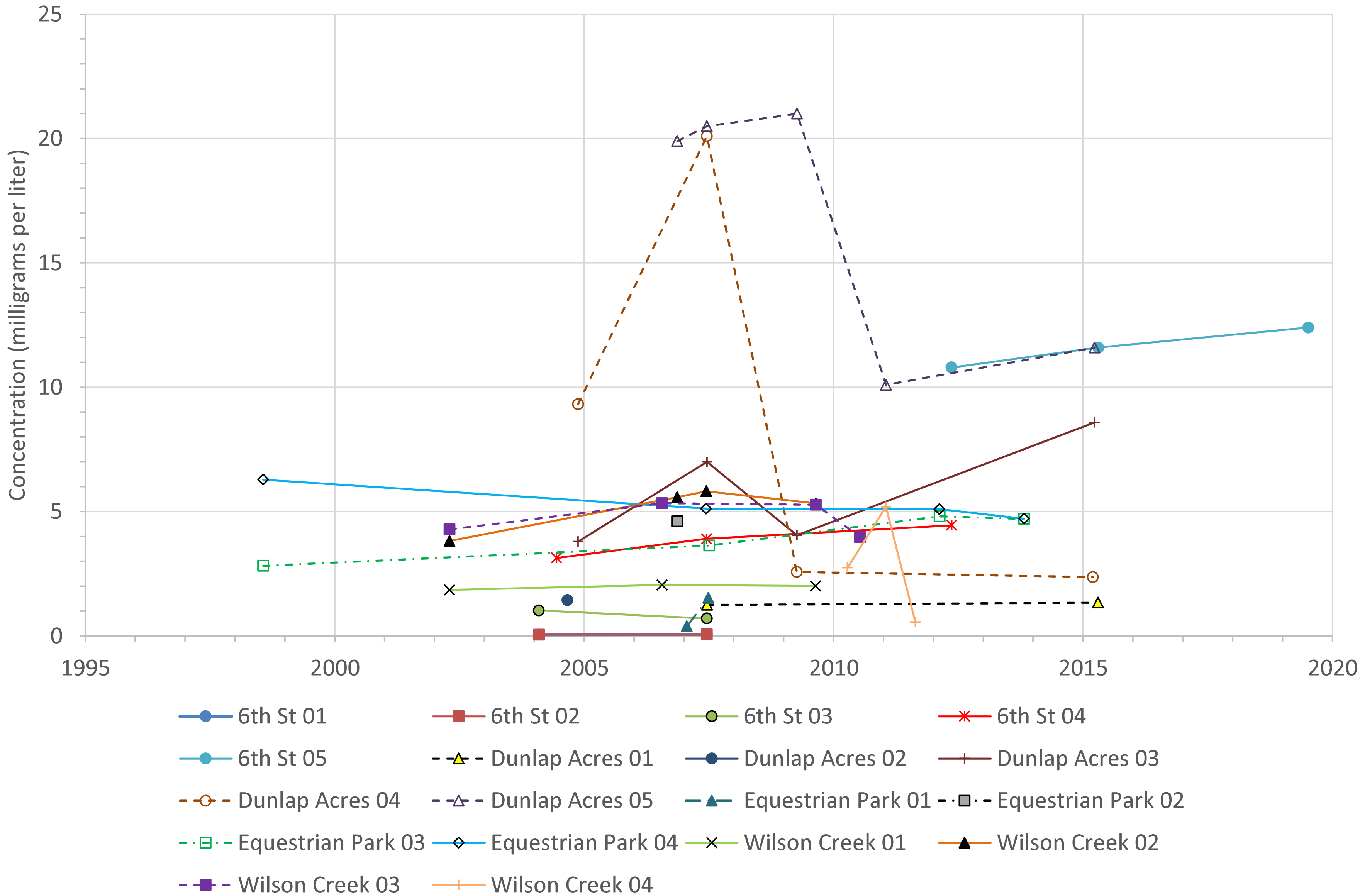

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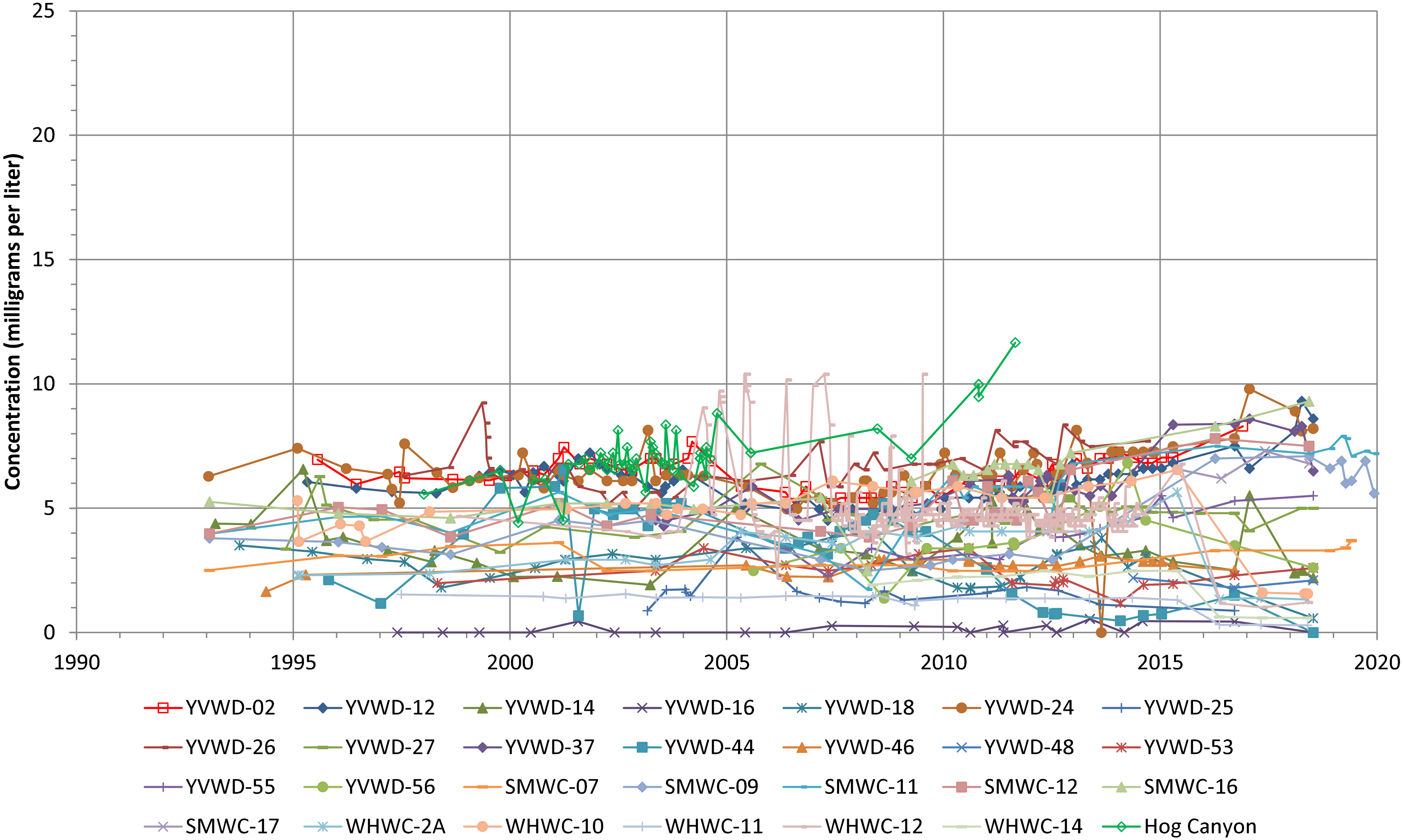
Figure 2-47. Concentrations of Nitrate (as Nitrogen) at Public Water Supply Wells in the Yucaipa Subbasin



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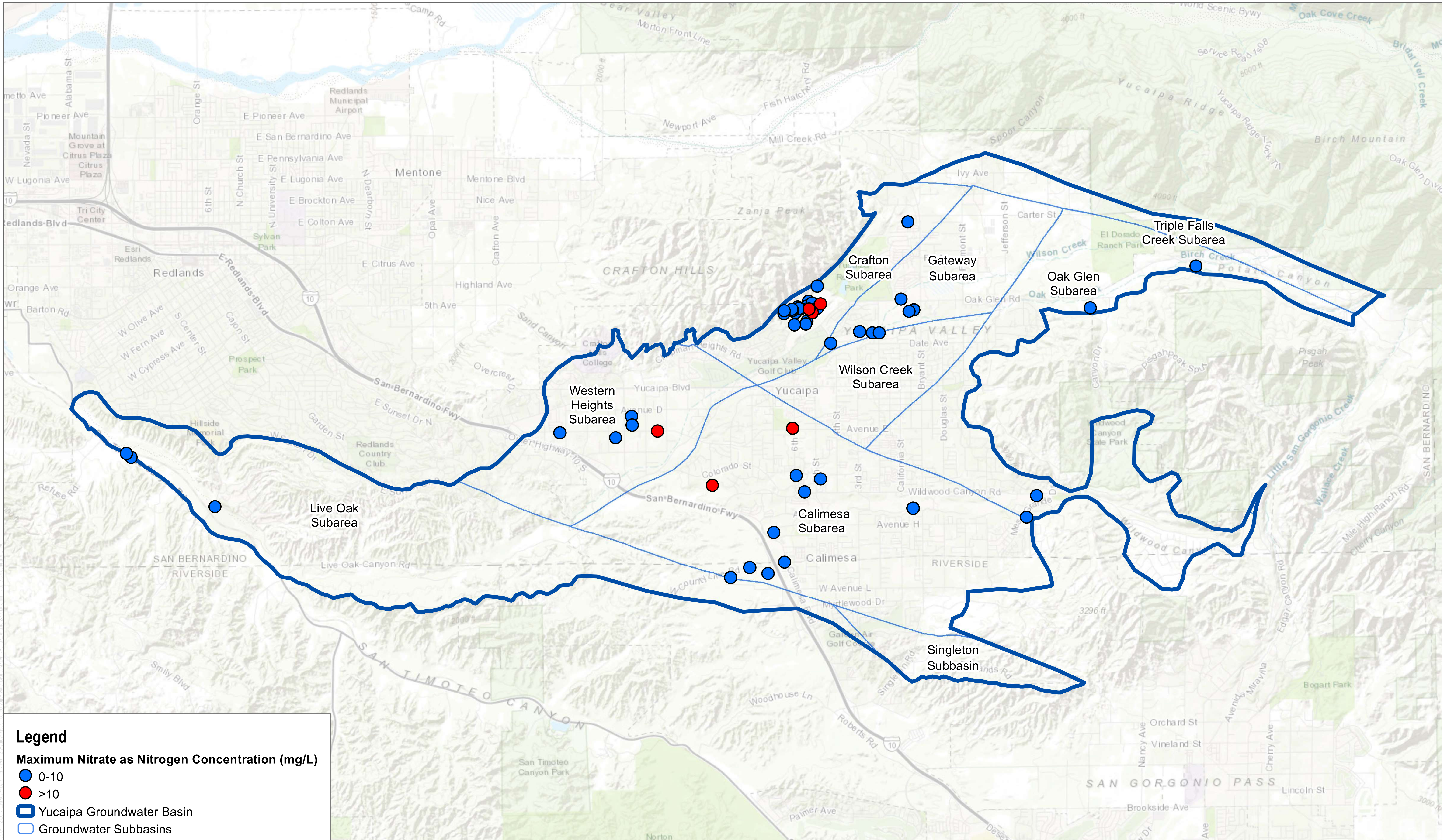

SOURCE: ESRI

DUDEK

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FIGURE 2-48

Maximum Nitrate Concentrations Detected in Groundwater Wells

Groundwater Sustainability Plan - Yucaipa Valley Groundwater Basin

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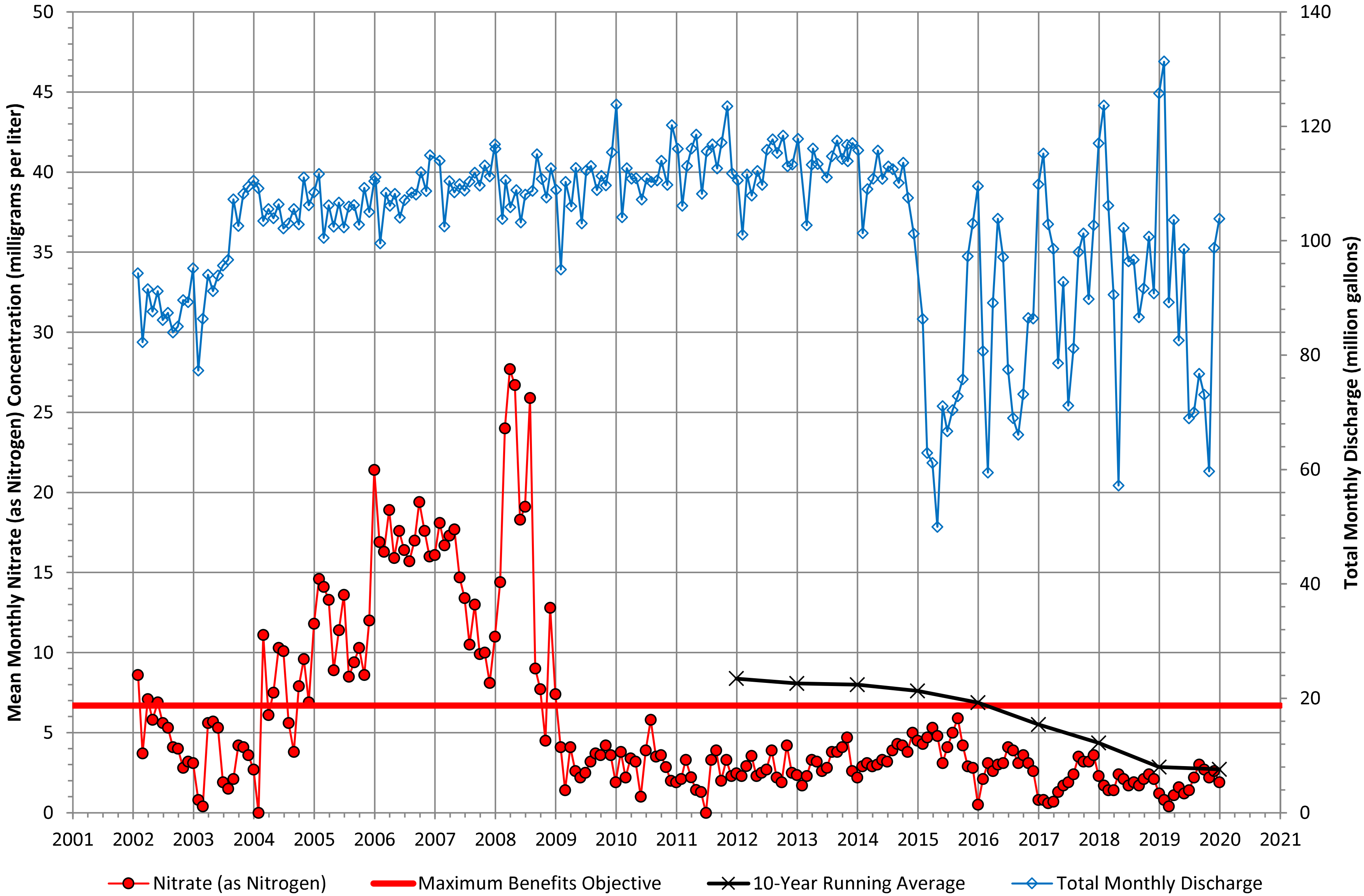
Figure 2-49. Nitrate (as N) and Monthly Discharges of Recycled Water from WRWRF to San Timoteo Creek



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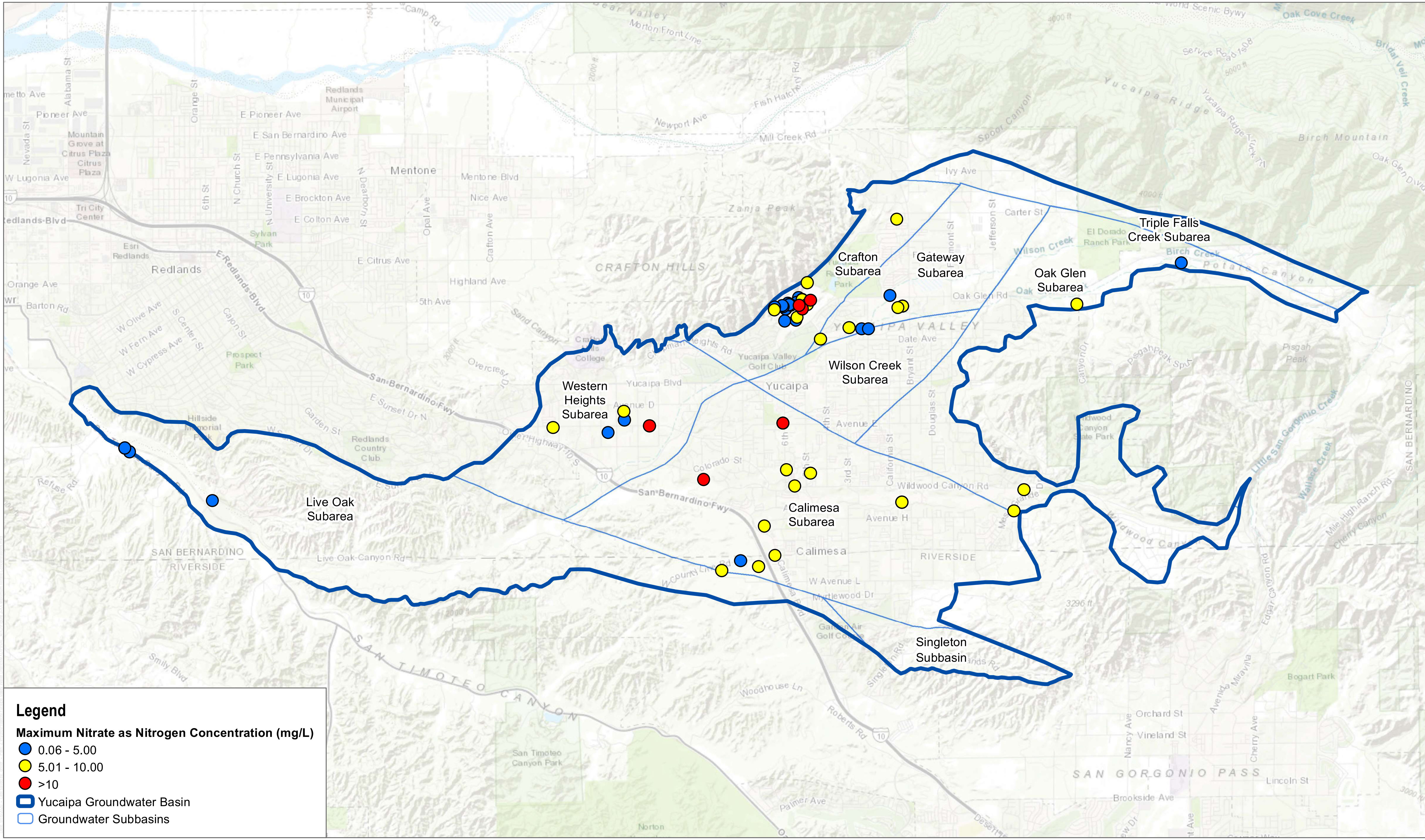

SOURCE: ESRI

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FIGURE 2-50

Maximum Nitrate Concentrations Detected in Groundwater Wells

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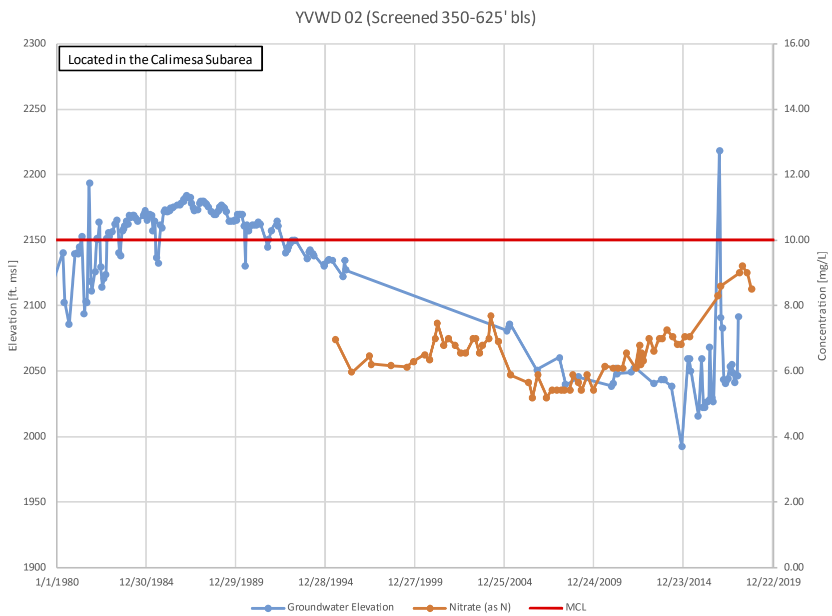

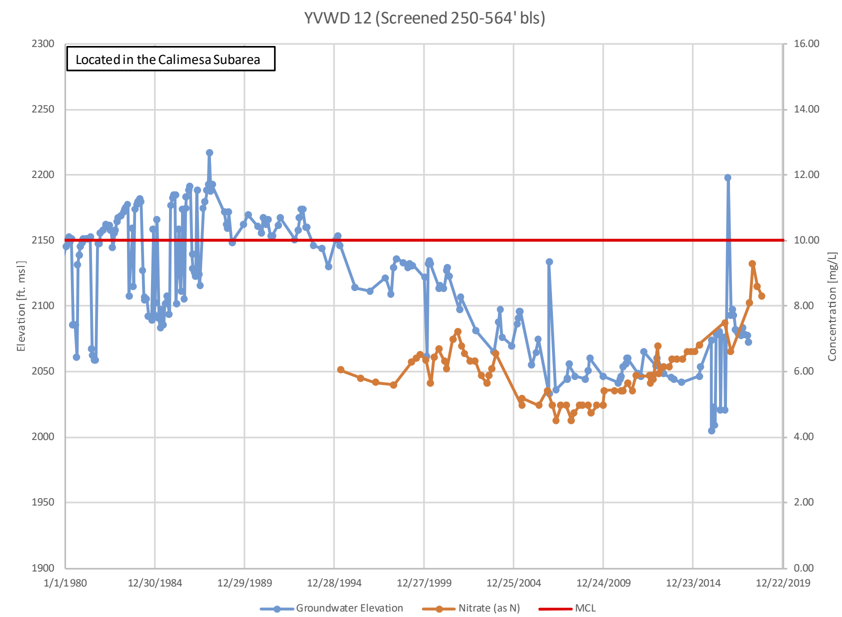

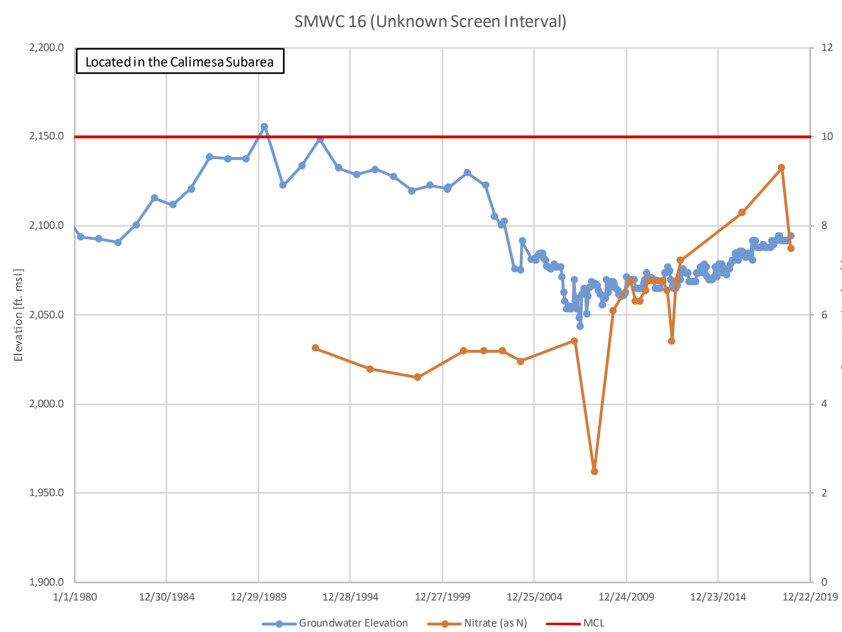

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FIGURE 2-51

Water Quality Hydrographs - Calimesa Subarea

Groundwater Sustainability Plan - Yucaipa Valley Groundwater Basin

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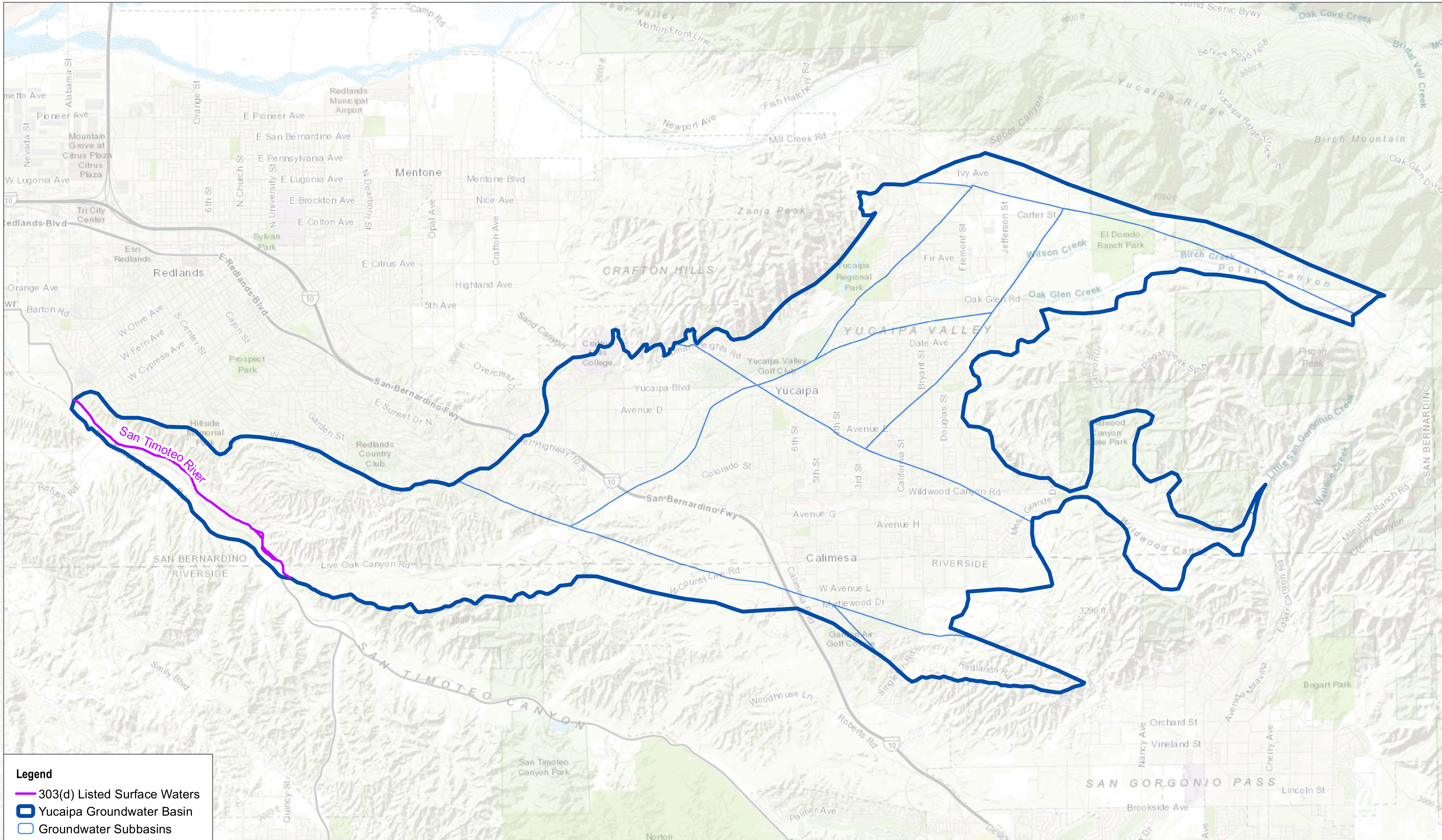

SOURCE: ESRI, RWQCB 2016

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DUDEK

0 0.5 1 Miles

FIGURE 2-52

303(d) Listed Waters

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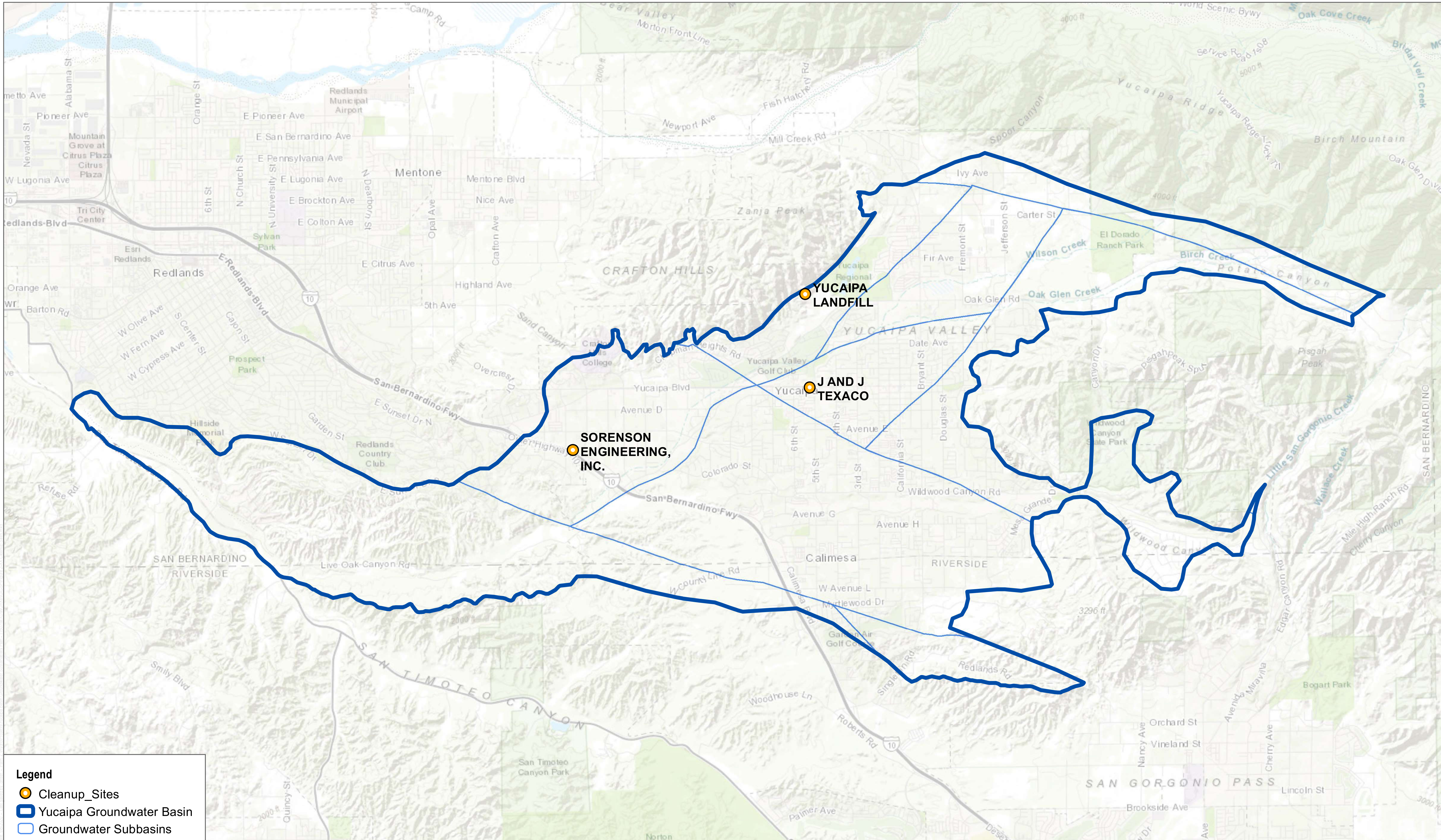

SOURCE: ESRI,

DRAFT

DUDEK

0 0.5 1 Miles

FIGURE 2-53

Cleanup Sites

Groundwater Sustainability Plan - Yucaipa Valley Groundwater Basin

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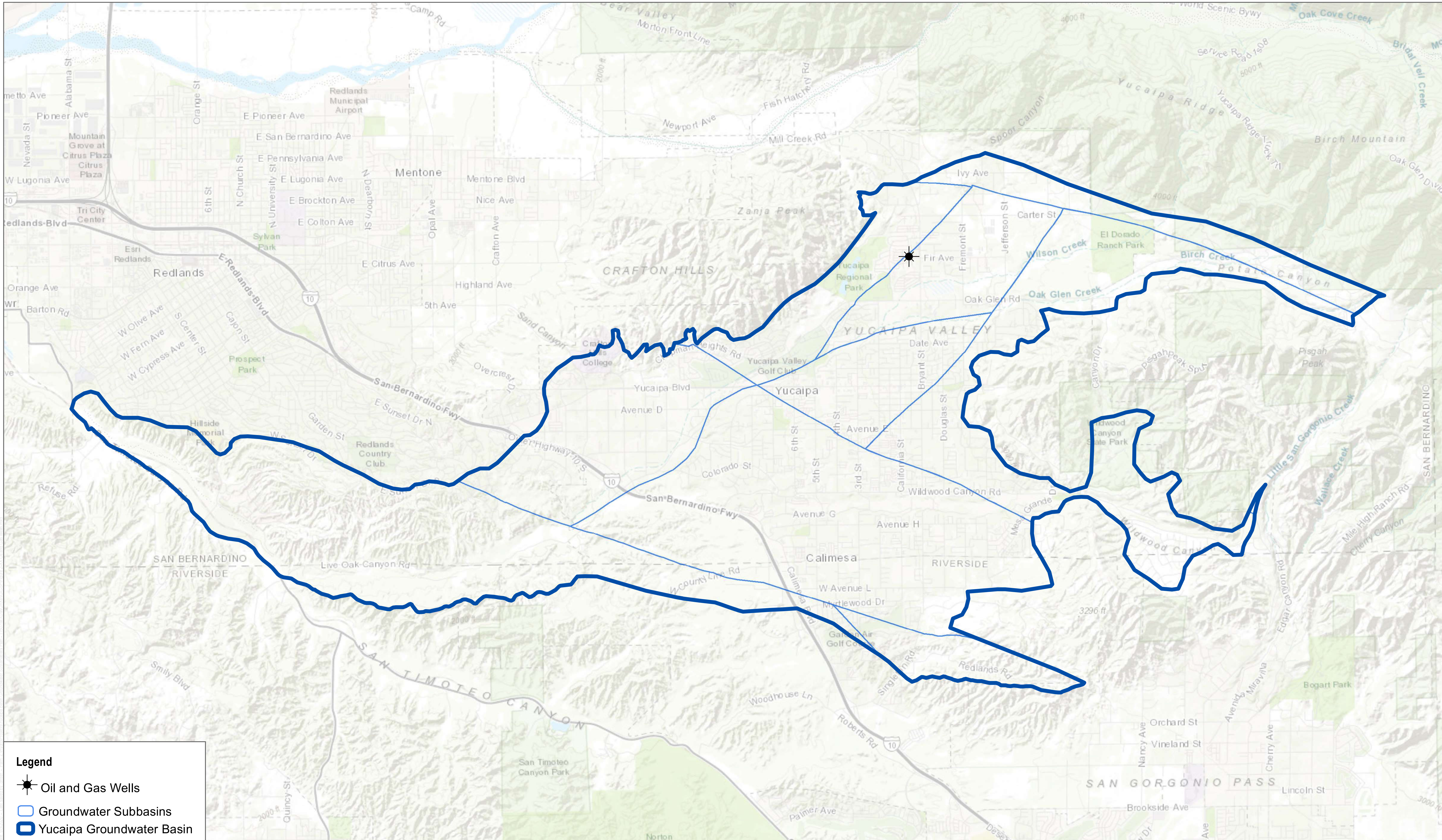

SOURCE: ESRI, DOGGR 2020

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FIGURE 2-54

Oil and Gas Wells

Groundwater Sustainability Plan - Yucaipa Valley Groundwater Basin

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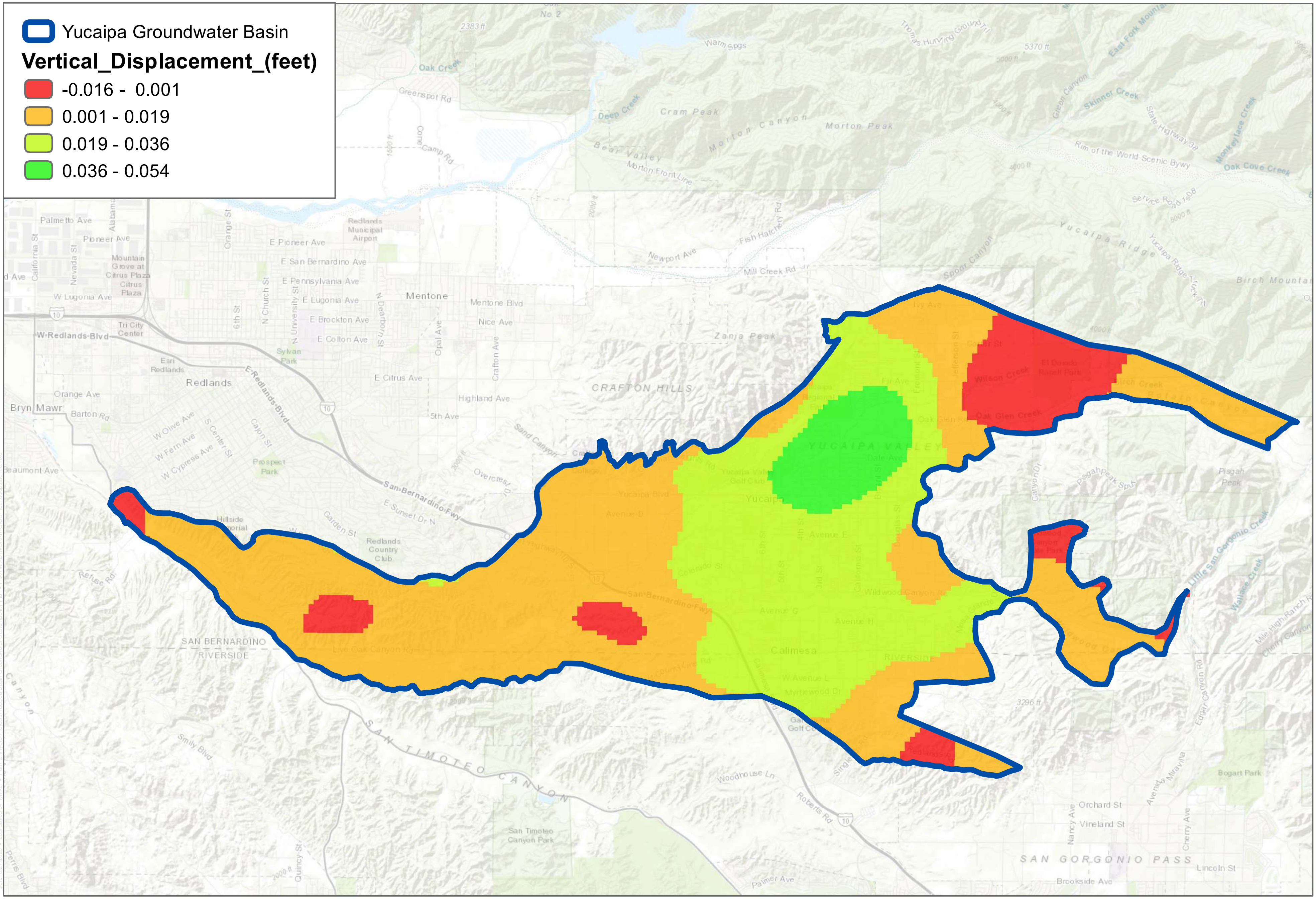

SOURCE: ESRI; SGMA TRE ALTAMIRA InSAR

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0 0.75 1.5 Miles

FIGURE 2-55

Land Subsidence

Groundwater Sustainability Plan - Yucaipa Groundwater Basin

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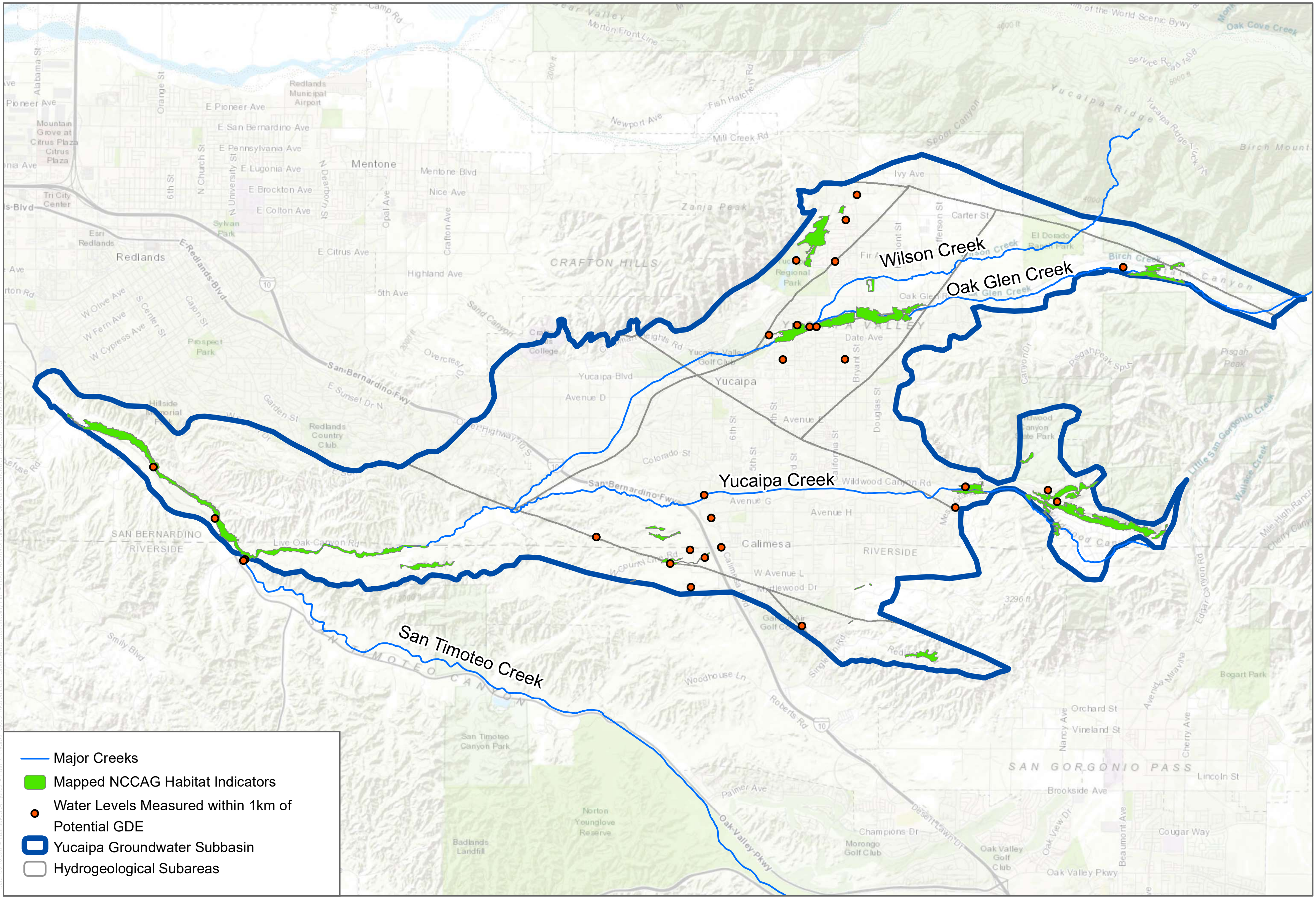

SOURCE: ESRI; DWR 2018; TNC 2019

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0 0.5 1 Miles

FIGURE 2-56

Groundwater Dependent Ecosystems Mapped by DWR in the Plan Area

Groundwater Sustainability Plan - Yucaipa Groundwater Basin

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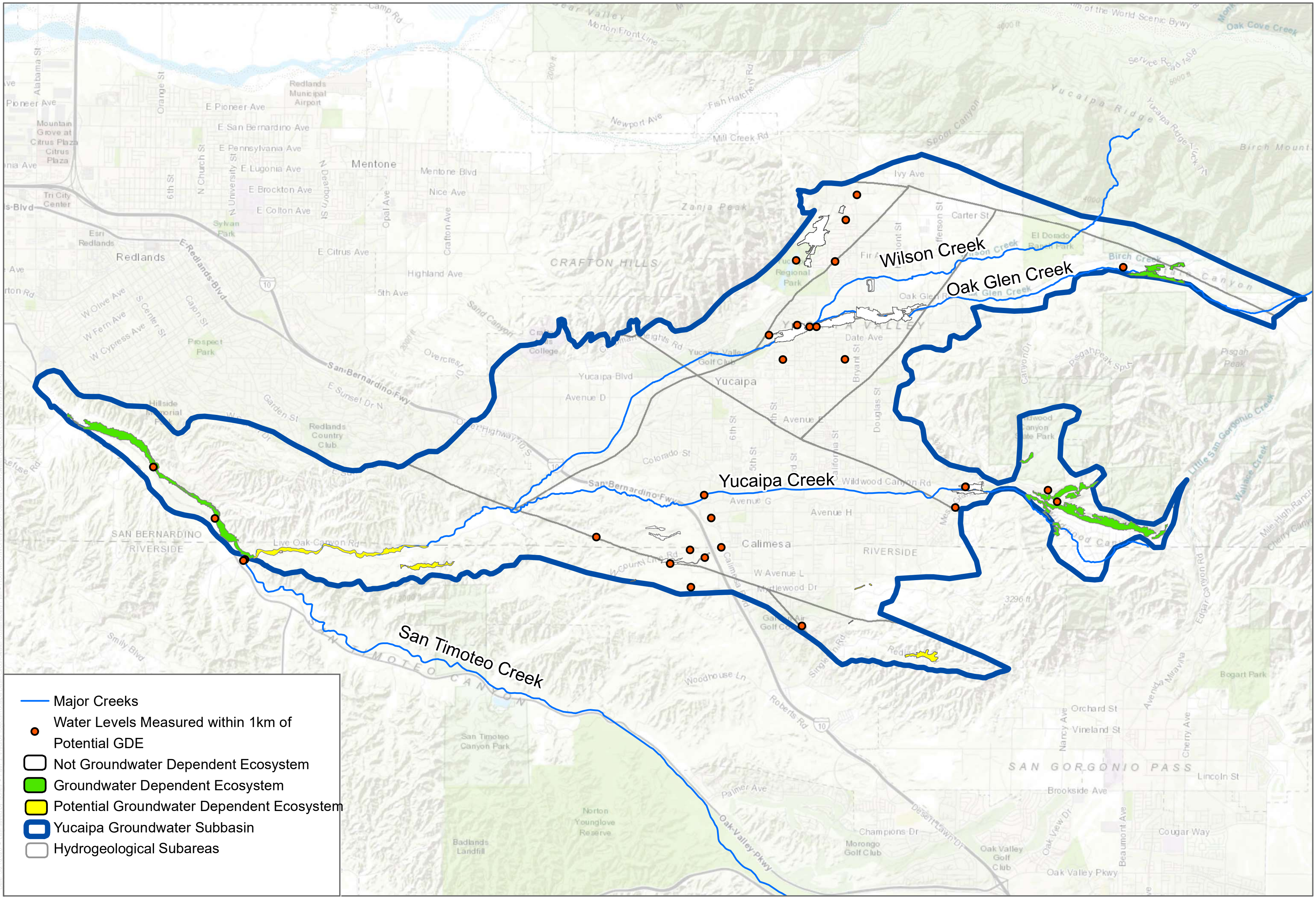

SOURCE: ESRI; DWR 2018; TNC 2019

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FIGURE 2-57

Characterization of Groundwater Dependent Ecosystems in the Plan Area

Groundwater Sustainability Plan - Yucaipa Groundwater Basin

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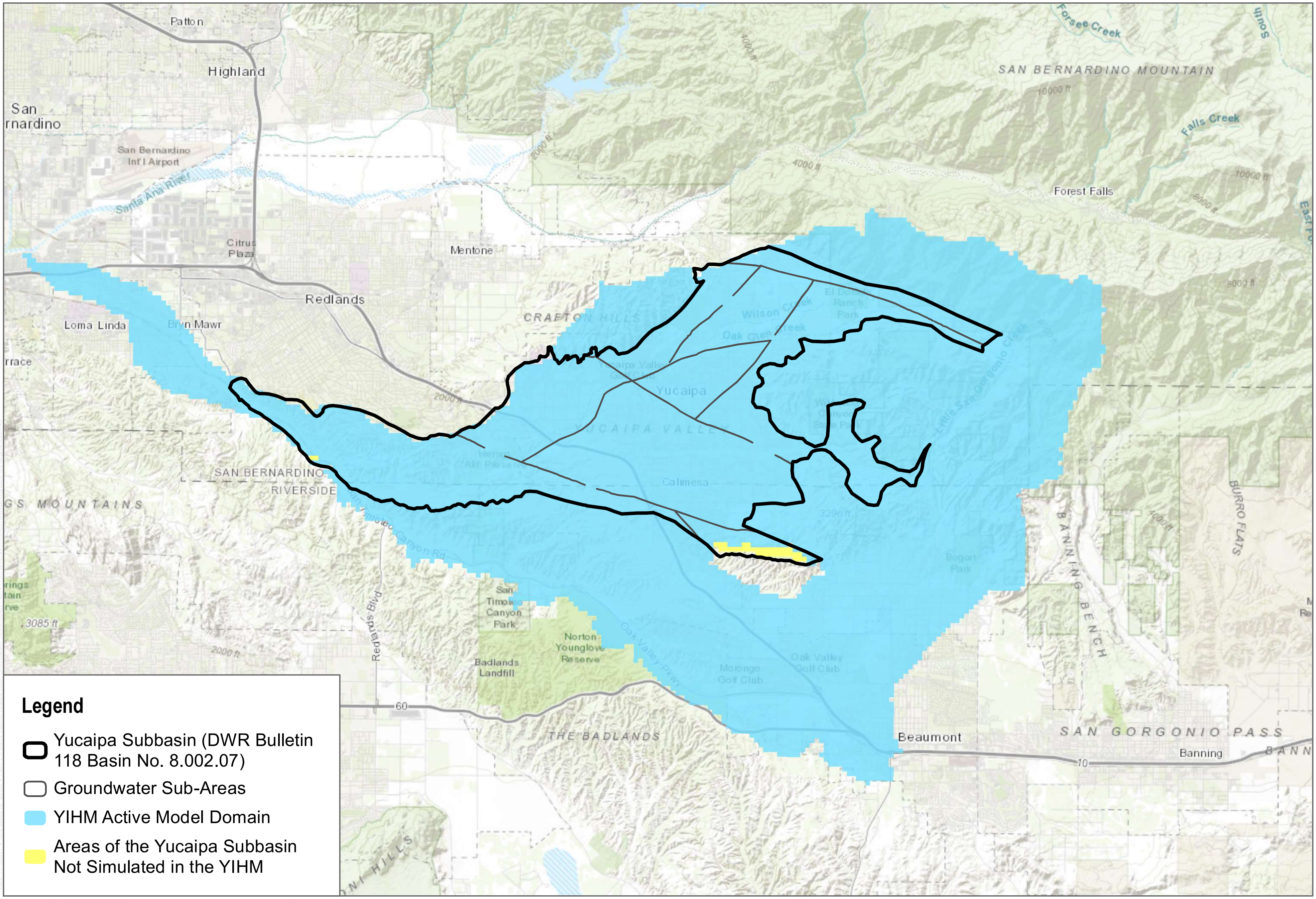

SOURCE: DWR, USGS

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0 1 2 Miles

FIGURE 2-58

Yucaipa Integrated Hydrologic Model Active Model Domain

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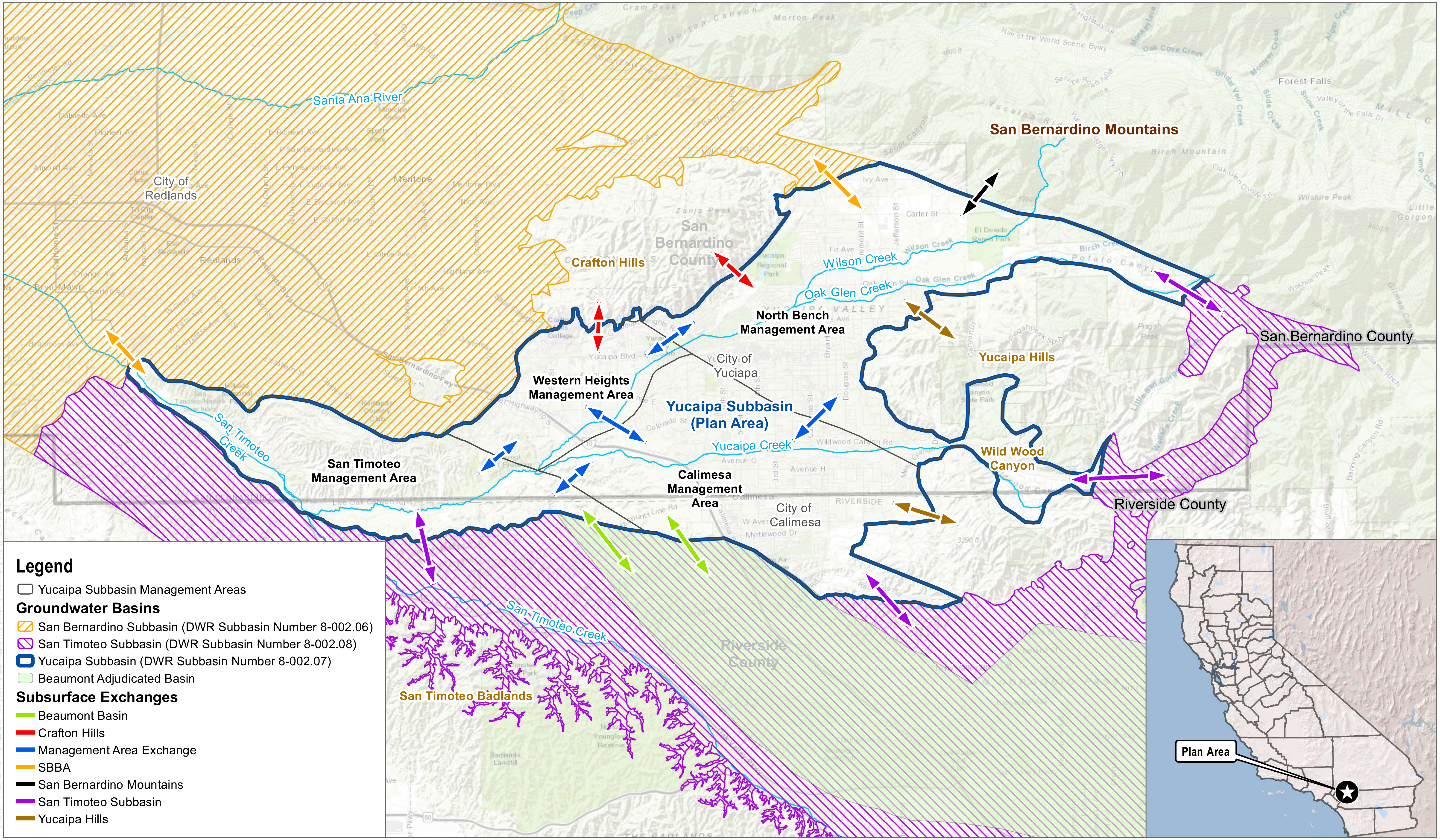

SOURCE: ESRI, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordanance Survey, ESRI Japan, METI, ESRI China (Hong Kong), swisstopo, OpenStreetMap contributors, and the GIS User Community; DWR 2015; USGS NHD 2017

DUDEK

0 0.5 1 Miles

FIGURE 2-59

Subsurface Inflows and Outflows simulated by the YIHM

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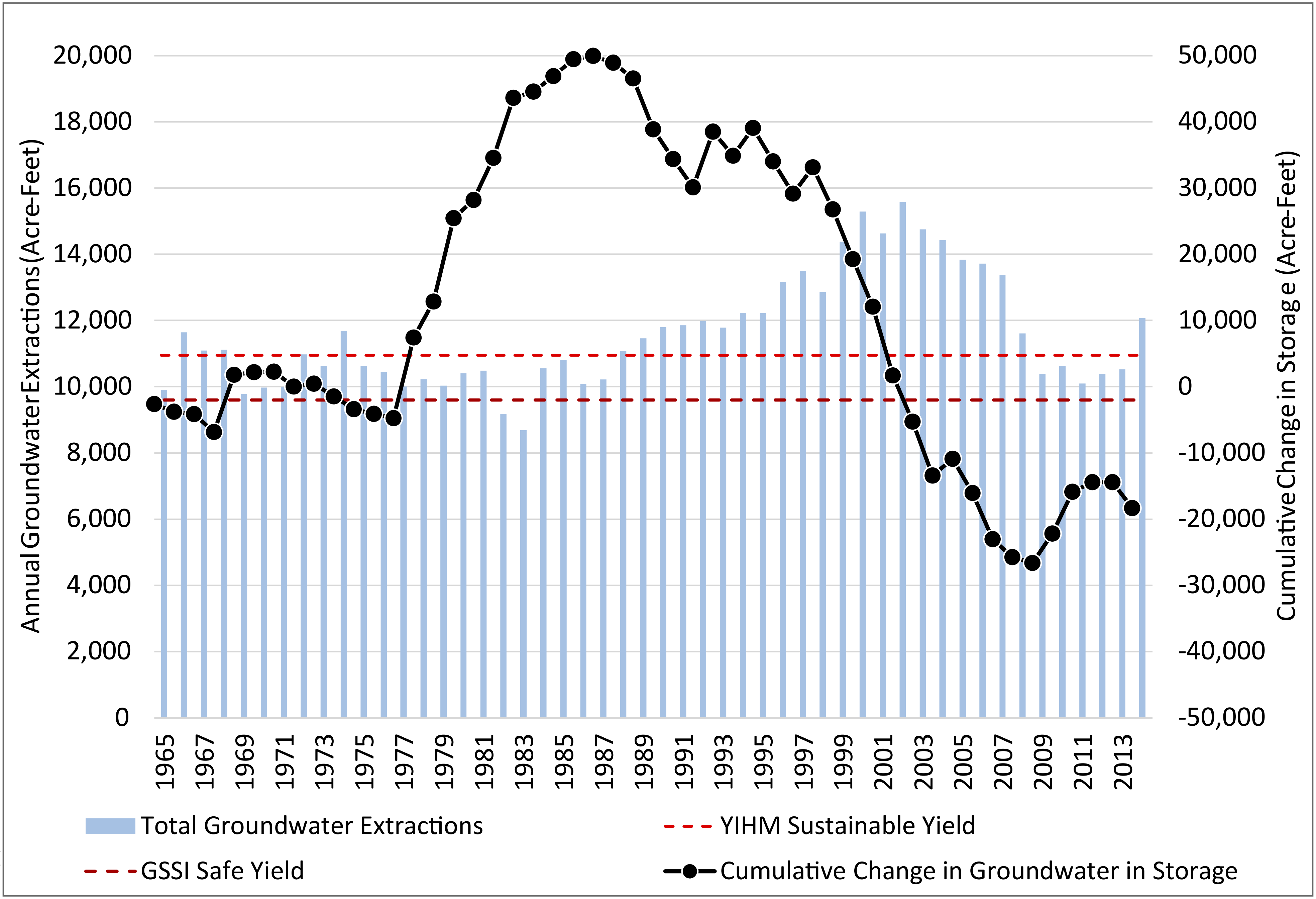

FIGURE 2-60

Historical Cumulative Change in Storage and Groundwater Production in the Yucaipa Subbasin

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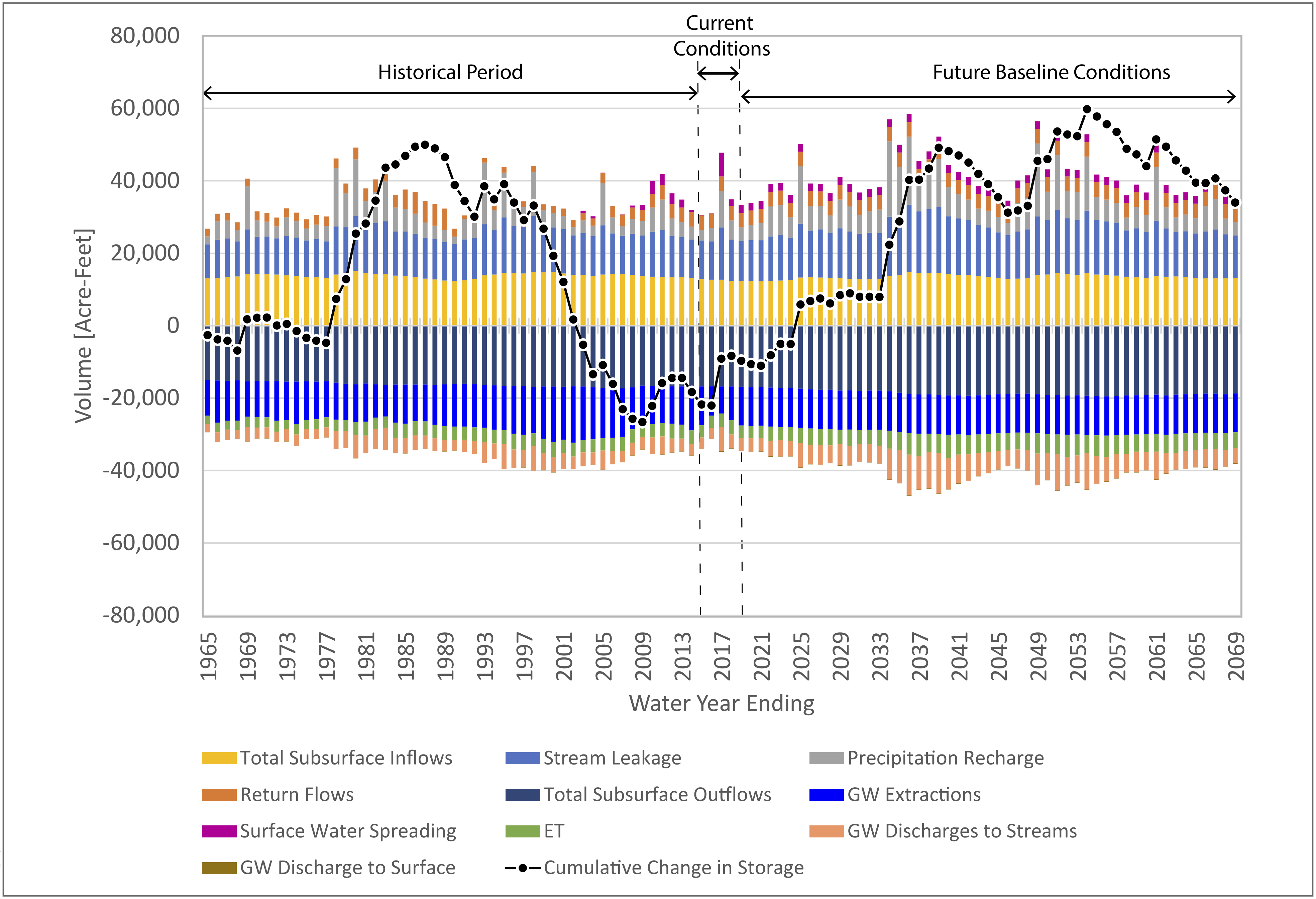

FIGURE 2-61

Historical, Current, and Future Baseline Water Budget for the Yucaipa Subbasin

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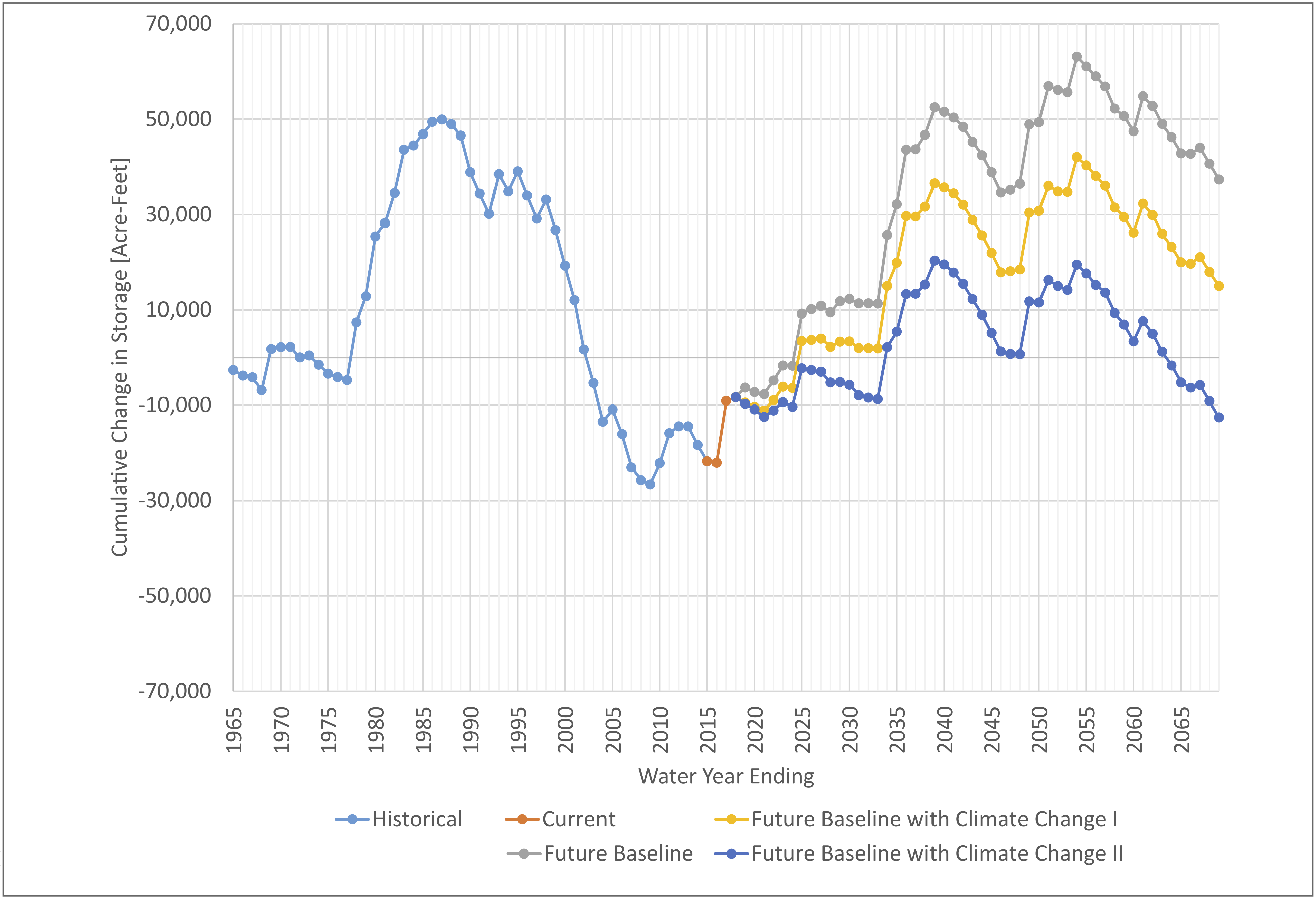

FIGURE 2-62

Historical, Current, and Projected Storage Change in the Yucaipa Subbasin

Yucaipa Subbasin Groundwater Sustainability Plan

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Yucaipa Groundwater Subbasin
Management Area Boundaries
Hydrogeologic Subareas

Geologic Units (CGS 2012)

Quaternary

Qa, Young Alluvium

Qsdloc, Sedimentary Deposits of Live Oak Formation

Tertiary

QTst, San Timoteo Formation (Middle Member)

Tsh, Mill Creek Formation

Tv, Dacite Dikes

Mesozoic and Older

pKm, Cretaceous and Pre-Cretaceous Metamorphic Formations of Sedimentary and Volcanic Origin

Trb, Granitic and Other Intrusive Crystalline Rocks, San Gabriel Mountains-type

Faults and Geologic Contacts

contact, identity and existence certain, location accurate

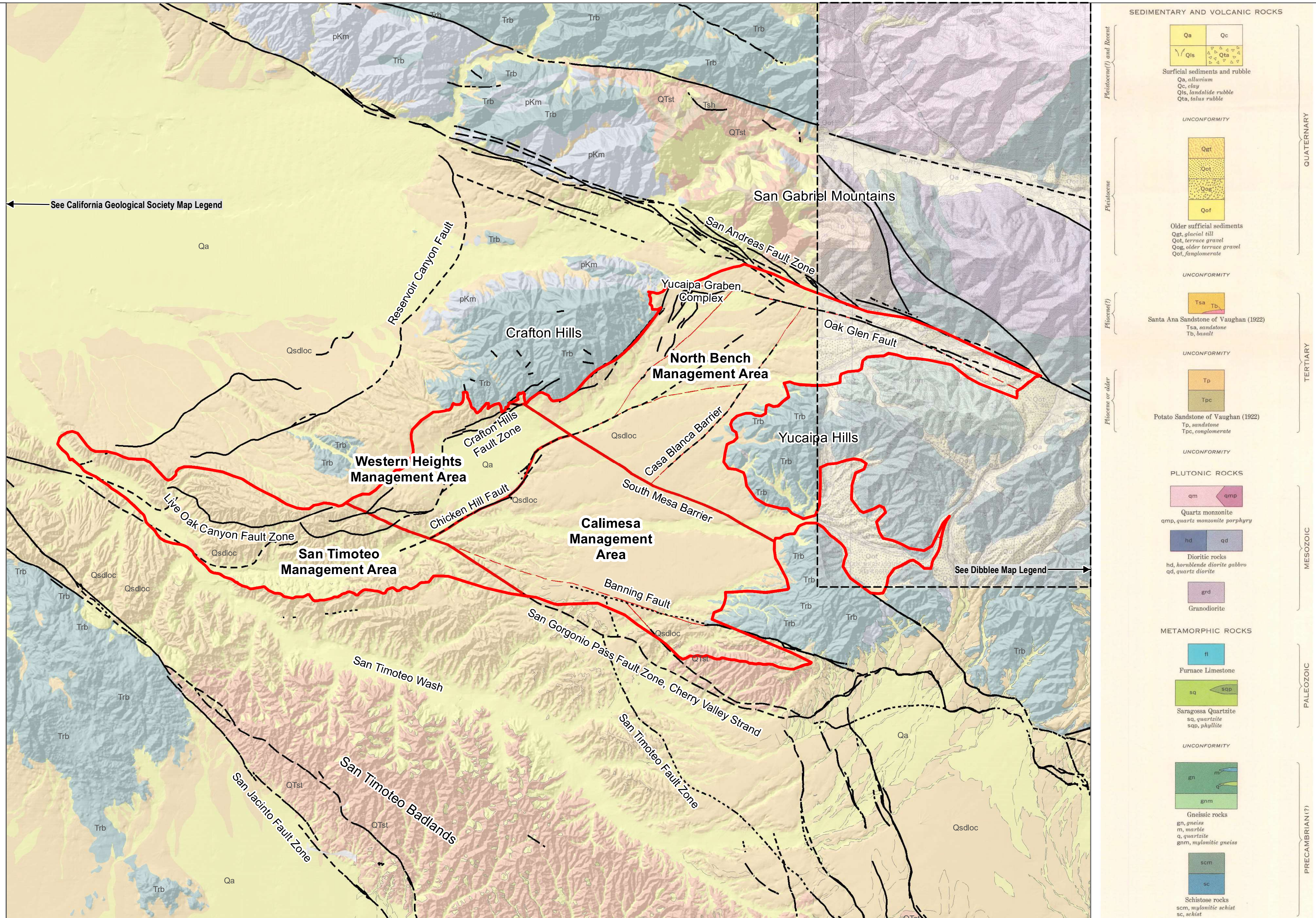
contact, identity and existence certain, location approximate

fault, identity and existence certain, location accurate

fault, identity and existence certain, location approximate

fault, identity and existence certain, location concealed

fault, identity and existence certain, location inferred



SOURCE: CGS 2012, USGS 1999

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0 0.5 1 2 Miles

FIGURE 2-63

Geologic Map and Management Area Boundaries in the Yucaipa Subbasin

Yucaipa Subbasin Groundwater Sustainability Plan

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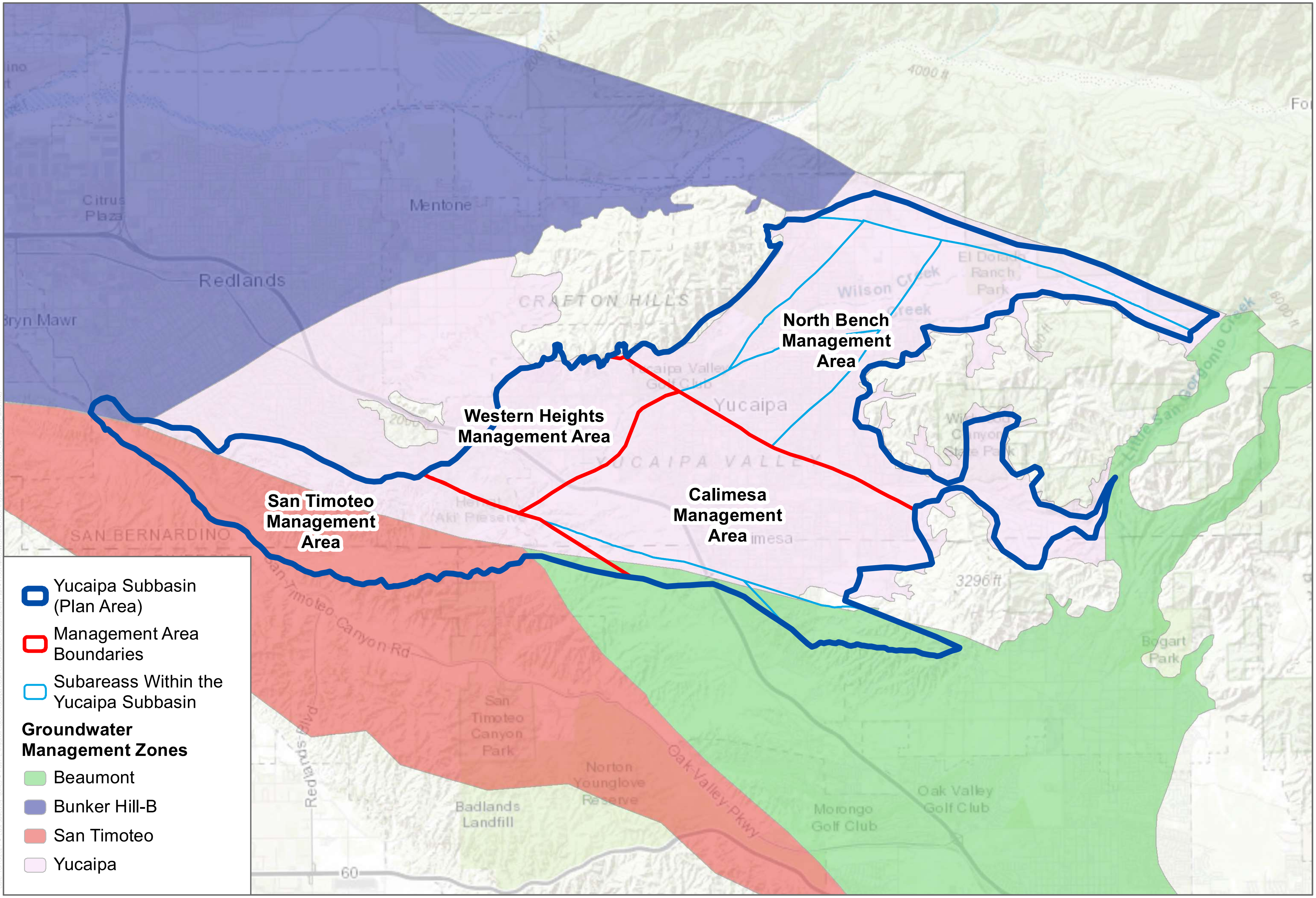

SOURCE: ESRI, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordanance Survey, ESRI Japan, METI, ESRI China (Hong Kong), swisstopo, OpenStreetMap contributors, and the GIS User Community; DWR 2015; USGS NHD 2017

FIGURE 2-64

Groundwater Management Areas, Subareas, and Groundwater Management Zones in the Yucaipa Subbasin

DUDEK 0 0.5 1 Miles

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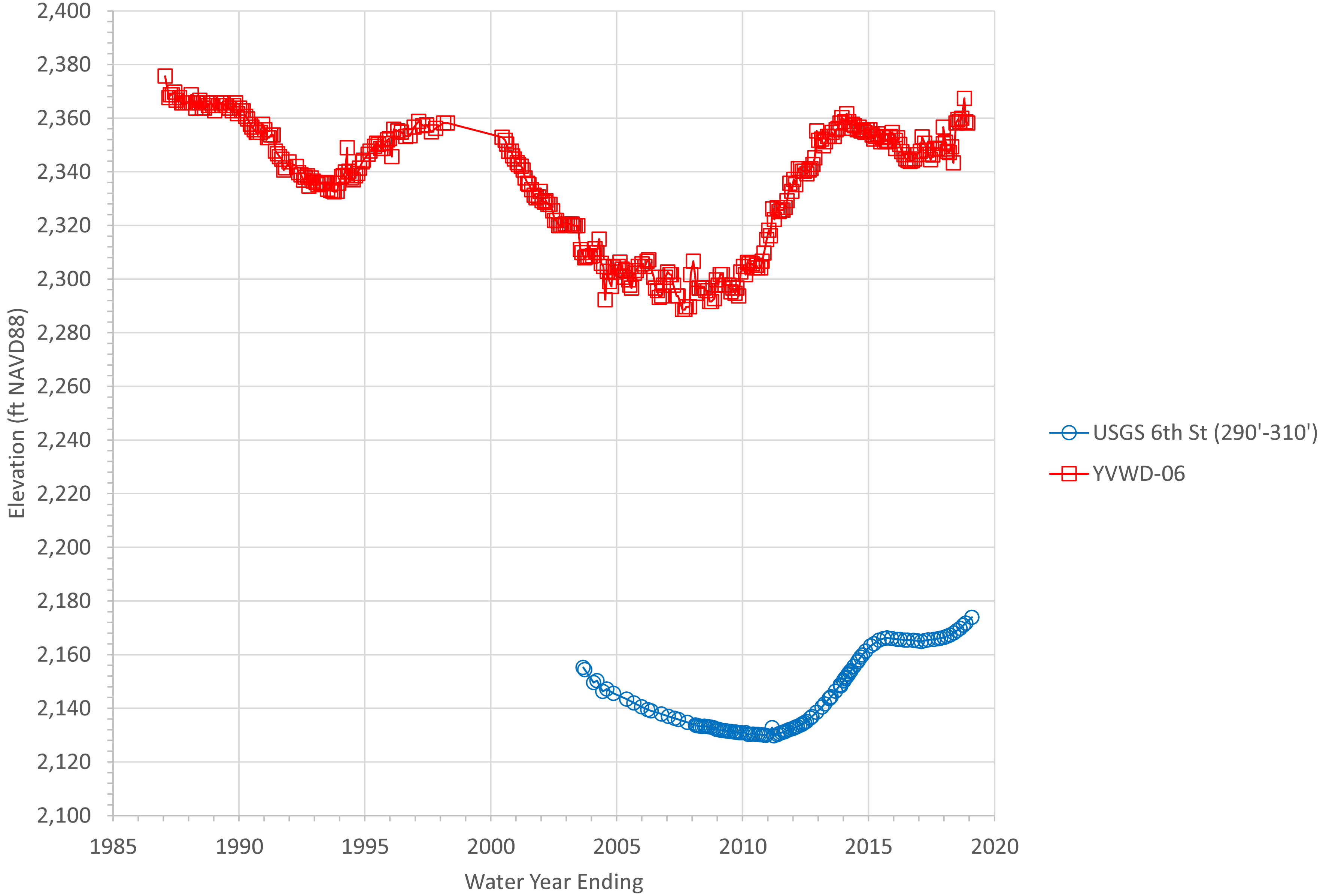
Figure 2-65. Groundwater Elevations Across the South Mesa Barrier



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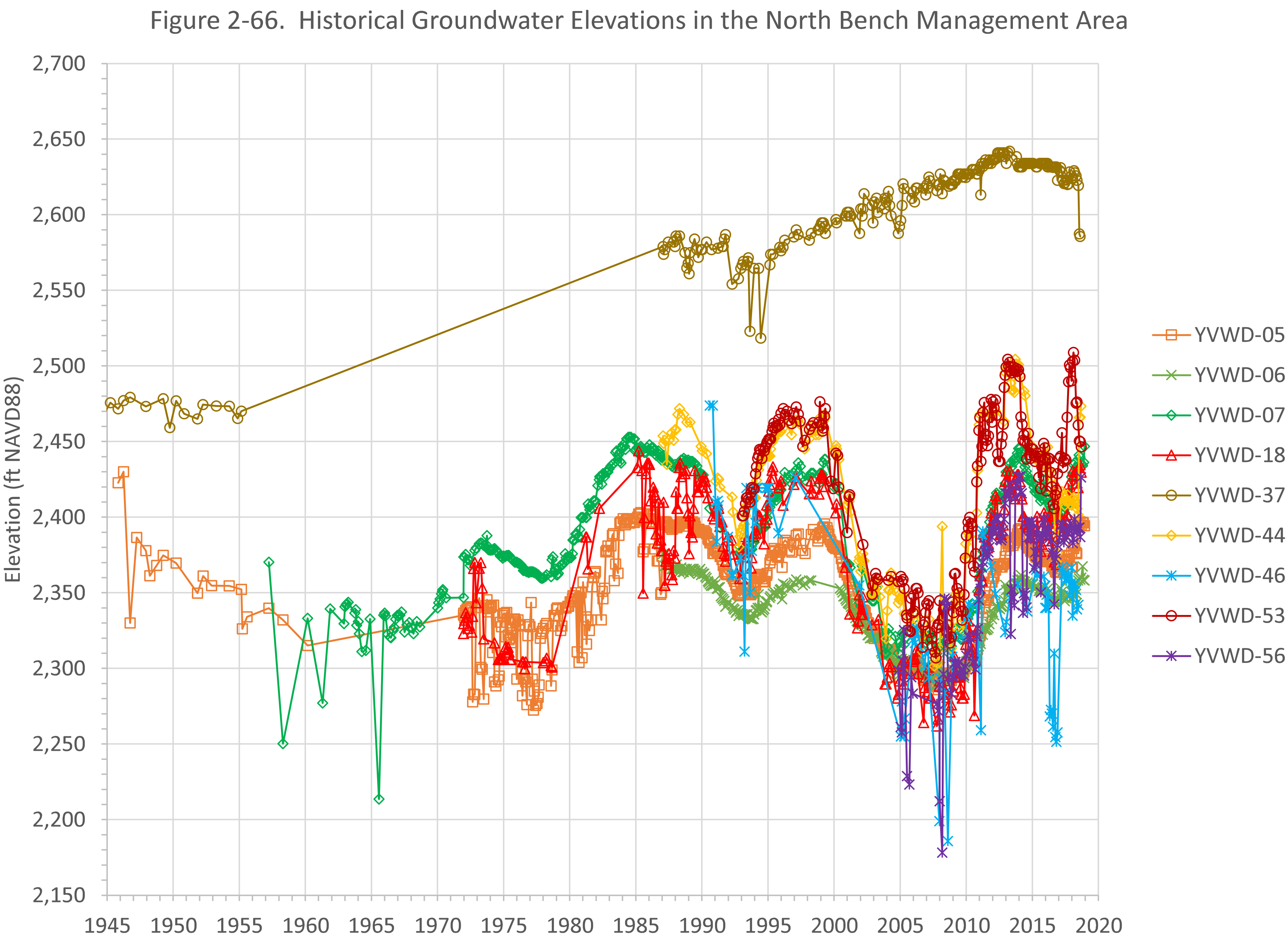

Figure 2-66. Historical Groundwater Elevations in the North Bench Management Area
Elevation (ft NAVD88)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
2,150
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
YVWD-05
YVWD-06
YVWD-07
YVWD-18
YVWD-37
YVWD-44
YVWD-46
YVWD-53
YVWD-56

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Figure 2-67. Historical and Current Volume of Groundwater in Storage in the North Bench Management Area

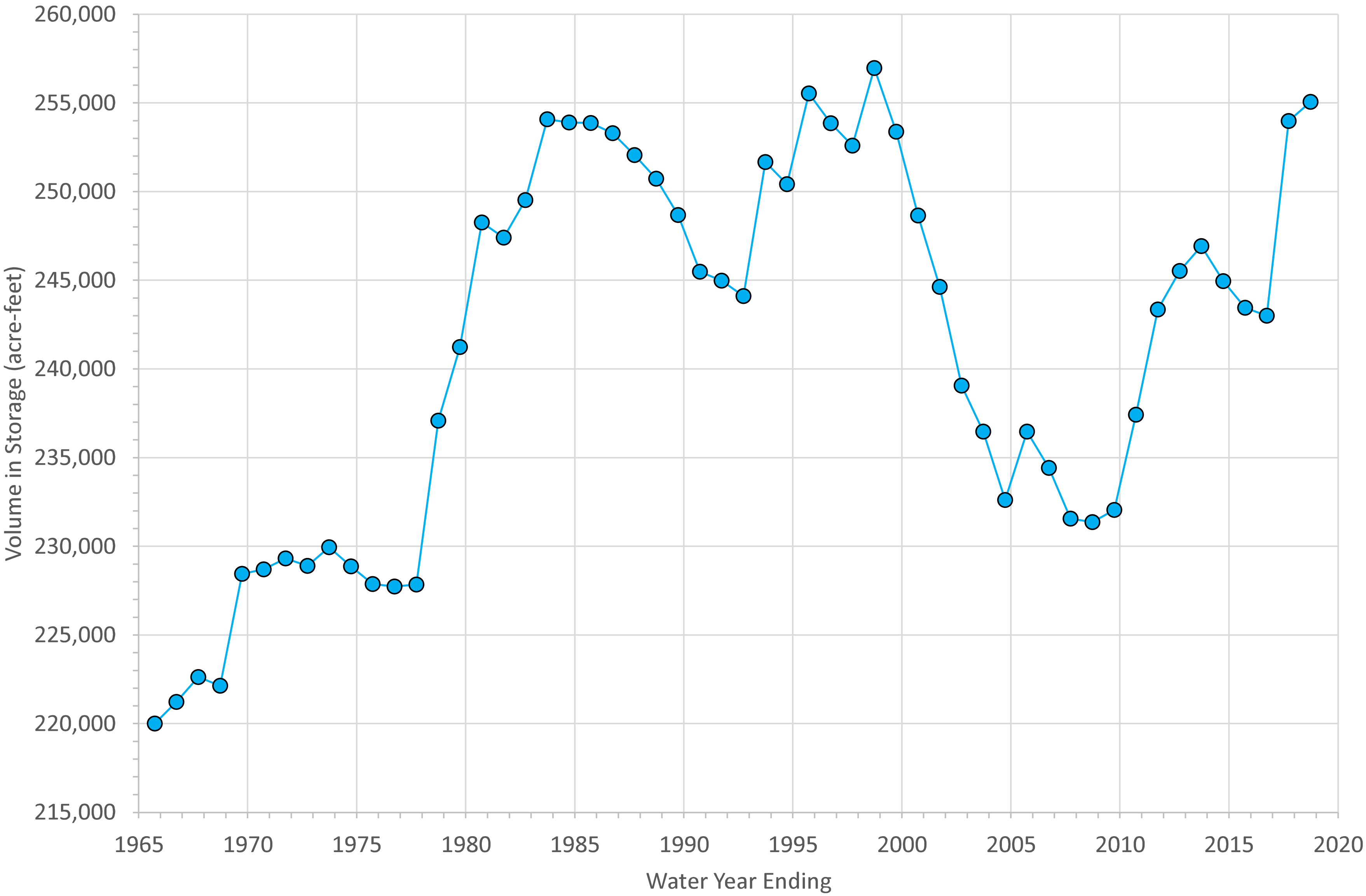

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Figure 2-68. Groundwater Elevations Across the Banning Fault in the Calimesa Management Area

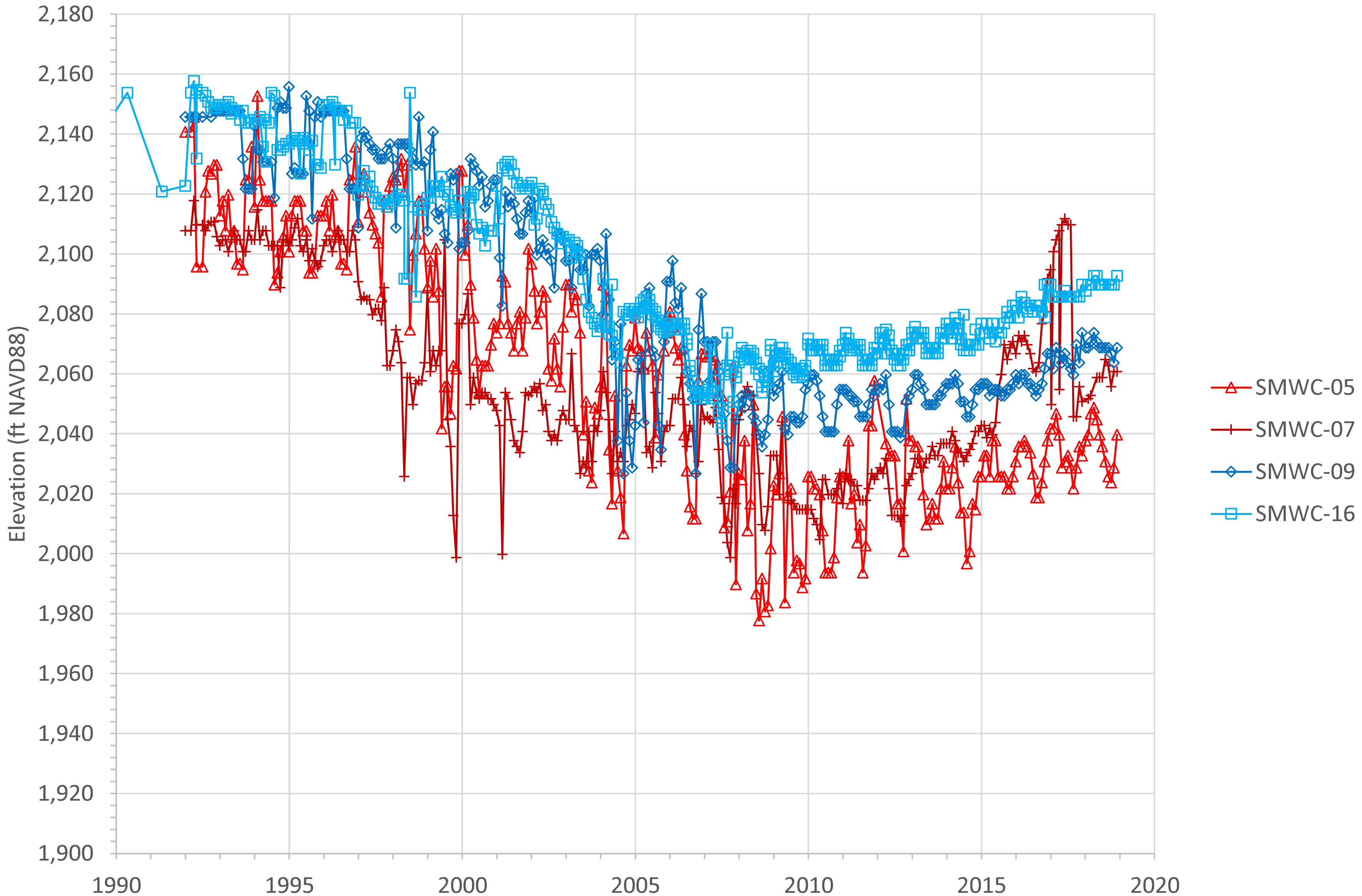

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Figure 2-69. Historical Groundwater Elevations in the Calimesa Management Area

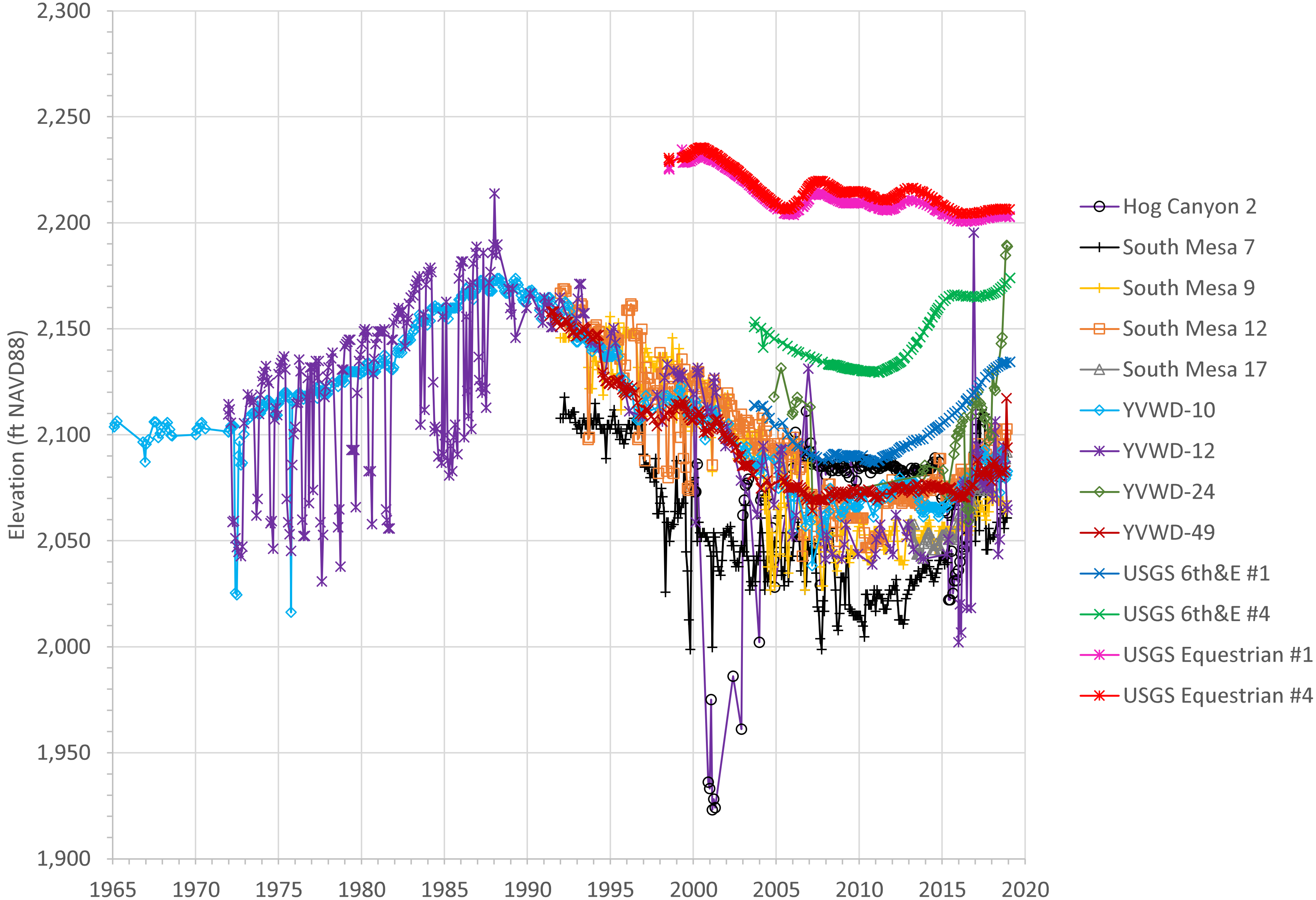

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Figure 2-70. Historical and Current Volume of Groundwater in Storage in the Calimesa Management Area

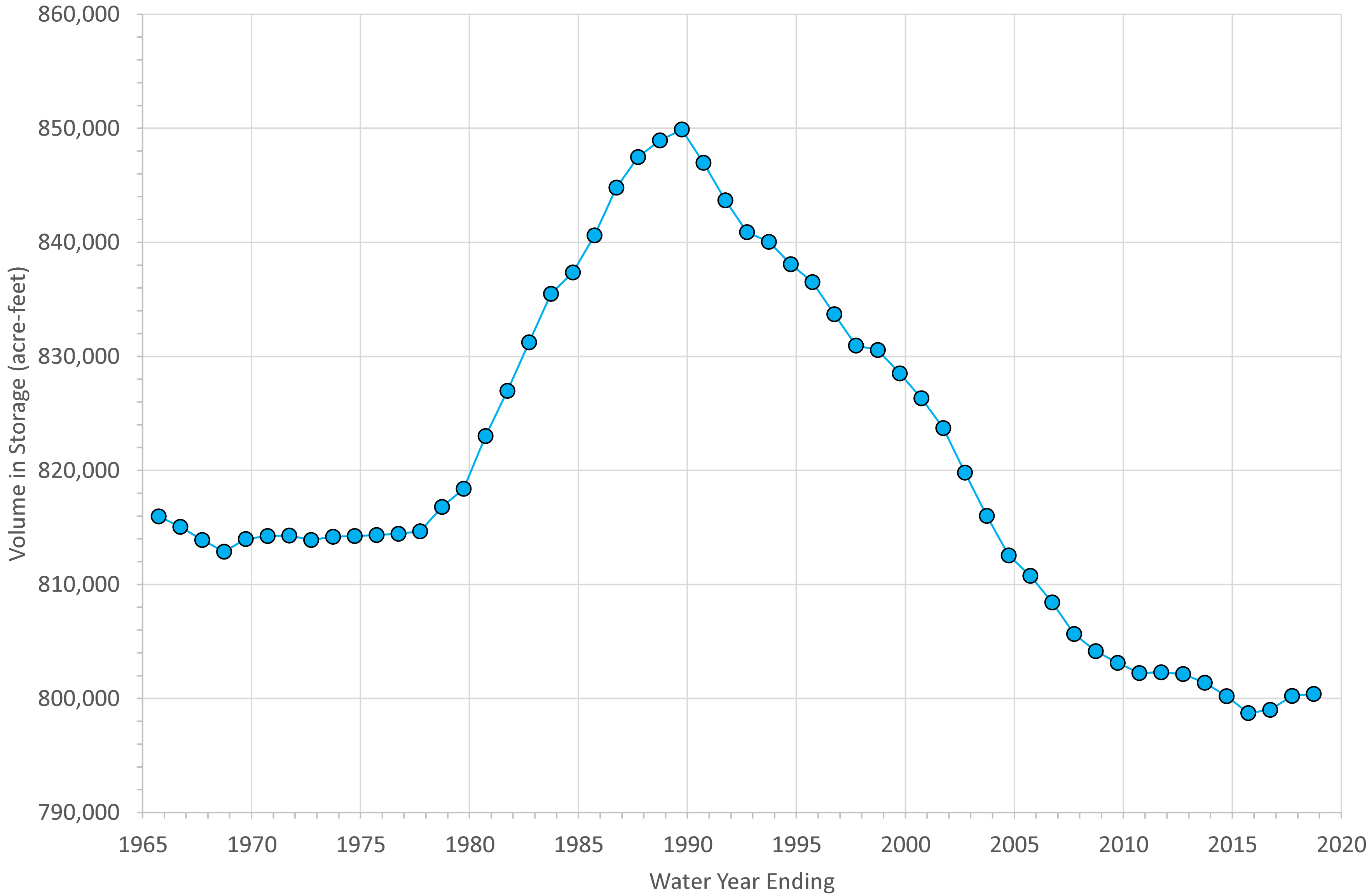

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Figure 2-71. Historical Groundwater Elevations in the Western Heights Management Area

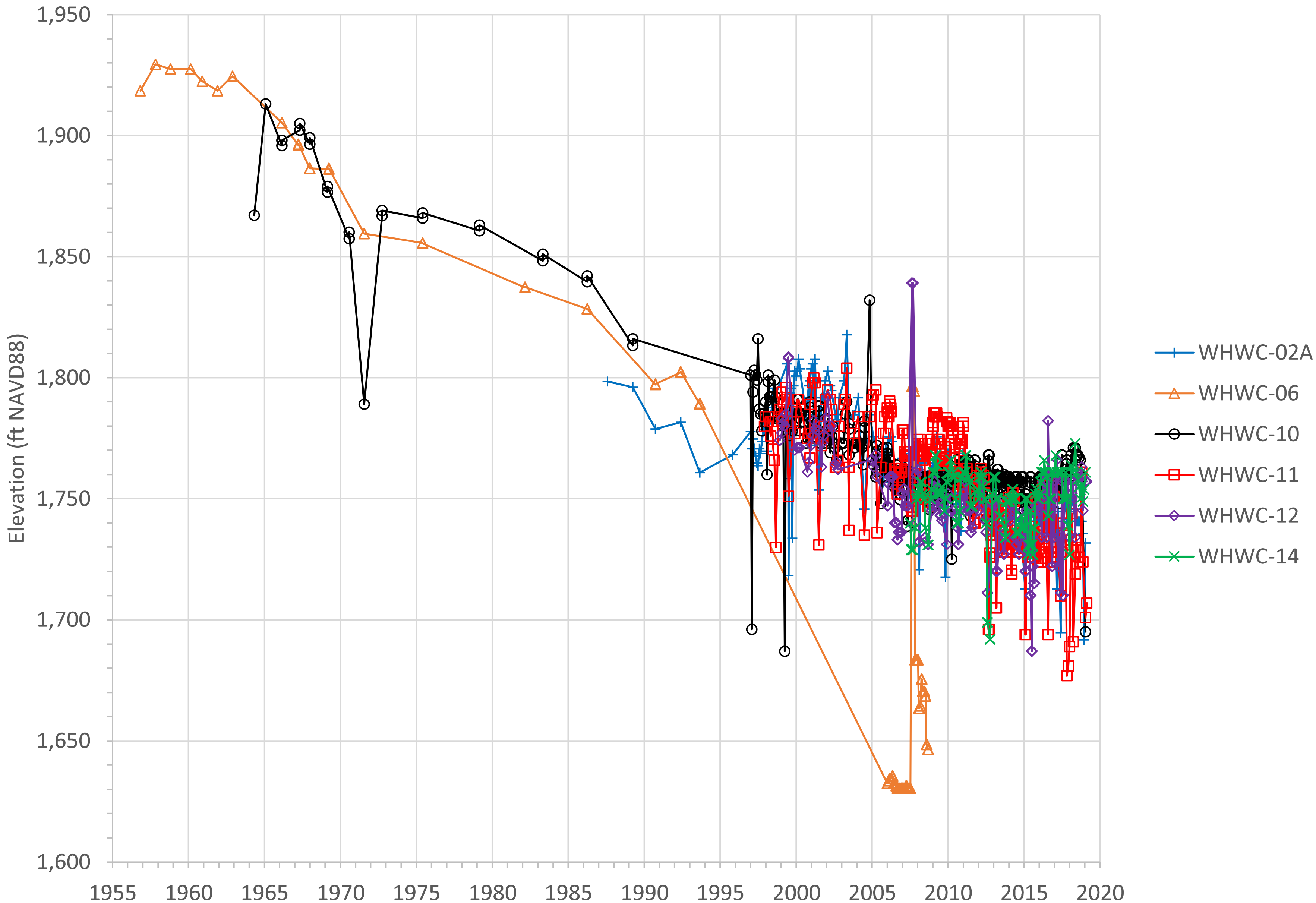

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Figure 2-72. Historical and Current Volume of Groundwater in Storage in the Western Heights Management Area

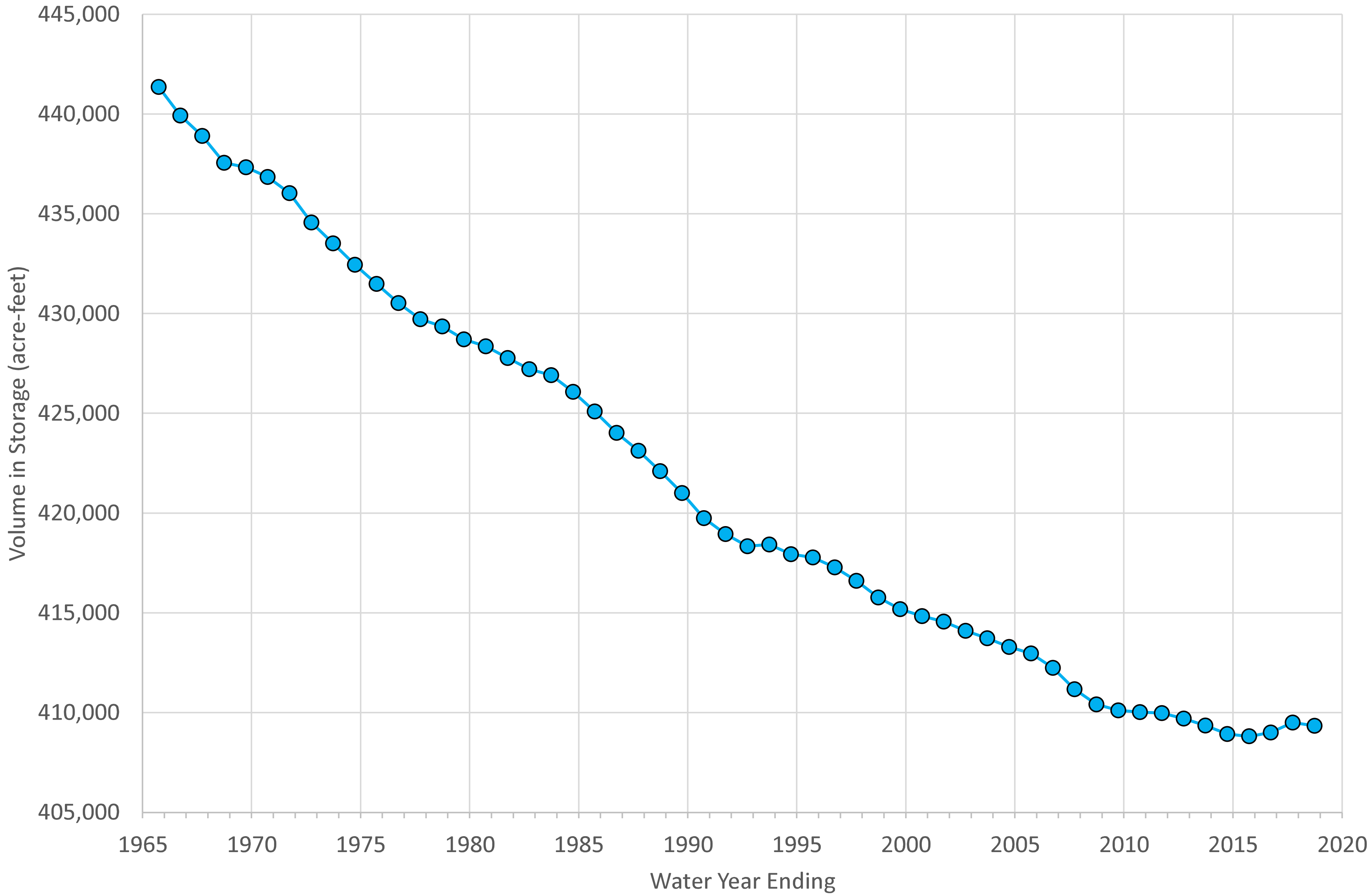

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Figure 2-73. Groundwater Elevations Measured in the San Timoteo Management Area

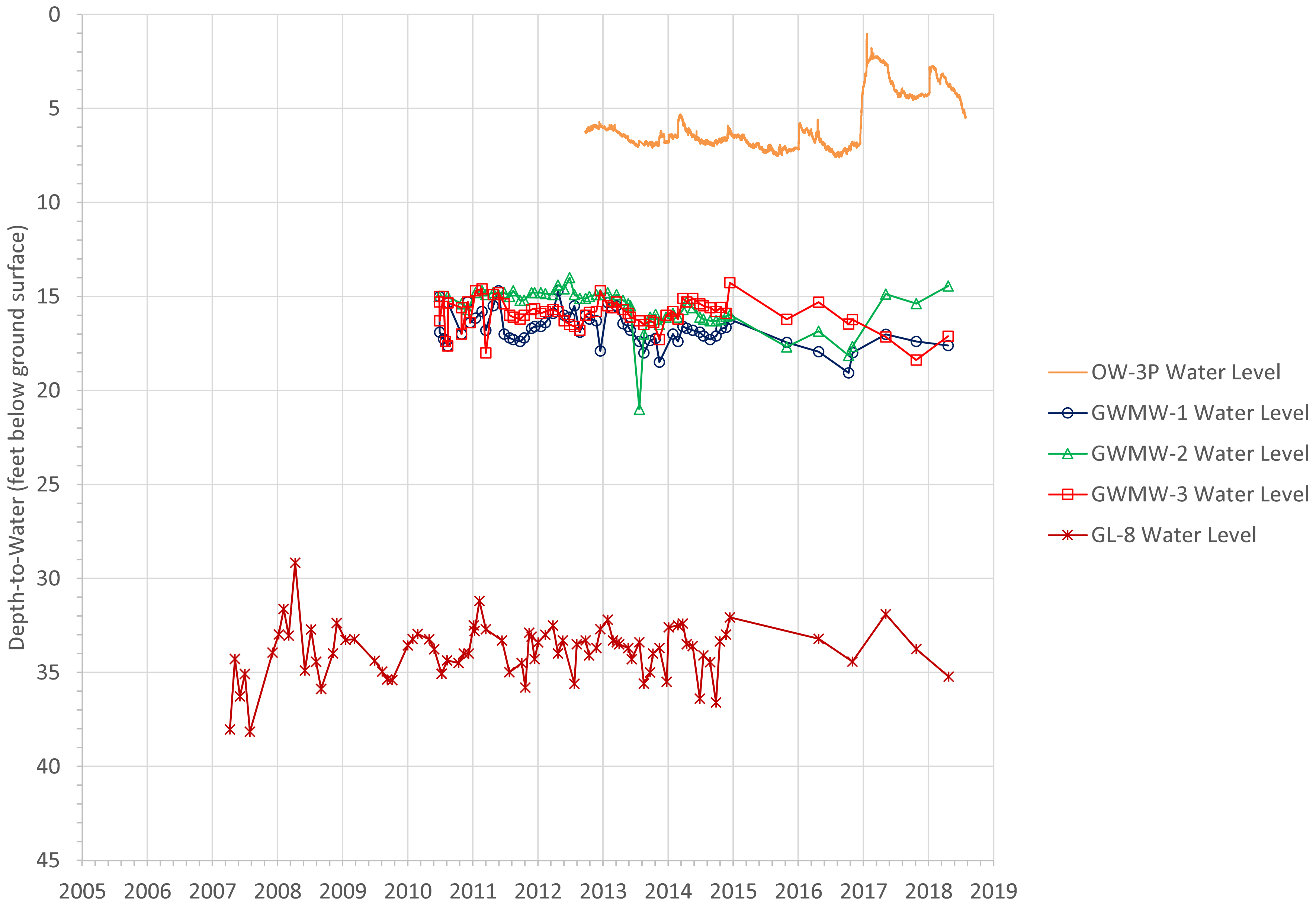

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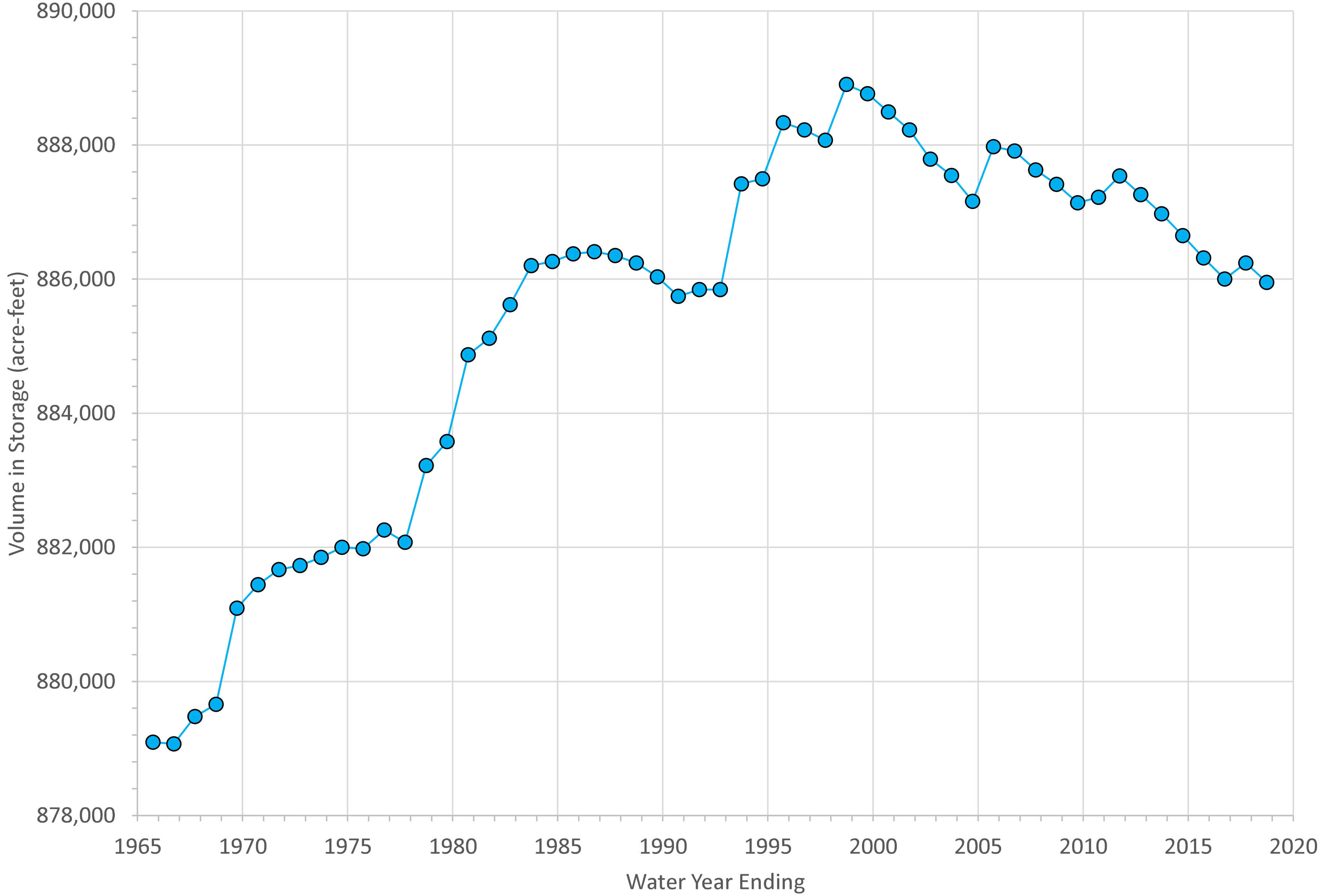
Figure 2-74. Historical and Current Volume in Storage in the San Timoteo Management Area



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