MONTECITO GROUNDWATER BASIN RECHARGE FEASIBILITY STUDY

Prepared for:

Heal the Ocean

Montecito Water District

Montecito Sanitary District

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KEY FINDINGS

- There is a limited opportunity to implement a groundwater recharge program with advanced treated recycled water in the Montecito Groundwater Basin (the Basin).
- The historical data shows that even after extended drought periods there is limited recharge potential in the Basin. Furthermore, average or above average precipitation rapidly fills the Basin, creating potential risks of liquefaction or increased surface flooding in the context of a recharge program with advanced treated wastewater. An additional obstacle to a recharge program with advanced treated wastewater is the fact that it will be difficult or impossible to achieve state mandated groundwater retention times in the Basin.
- The hydrogeologic units in which the greatest amount of storage capacity is available (Units 1 and 3) contain a high density of water supply wells, such that it would be difficult to find a location for an artificial recharge infiltration basin(s) or injection well(s) that could comply with State mandated subsurface travel times of advanced treated recycled water.
- While seawater intrusion has not been identified as a problem in the Basin to date, direct injection of advanced treated recycled water in order to limit seawater intrusion may be feasible and could be investigated by additional studies. Such a program may allow for the implementation of additional groundwater pumping in Storage Unit 3.

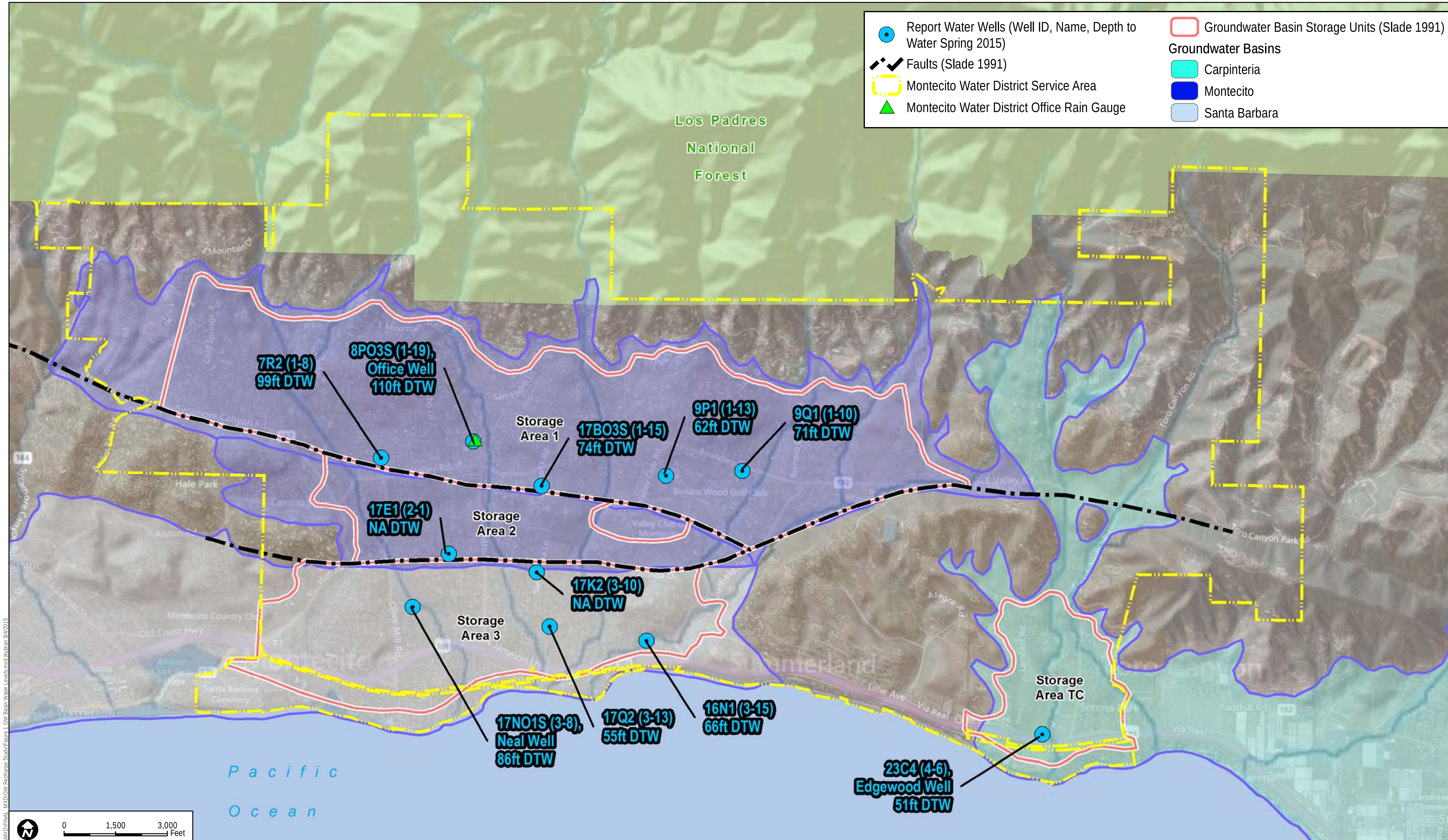
1 INTRODUCTION

This Study is intended to present findings related to potential artificial groundwater recharge in the Montecito Groundwater Basin (the Basin; Figure 1). This watershed-scale study was conducted to identify opportunities and constraints associated with advanced treated wastewater and imported water recharge, and includes considerations related to recharging by both injection wells and percolation basins. In this study, the term “groundwater basin” or sometimes simply “basin” is used to refer to an aquifer, while a percolation or infiltration basin is an engineered structure designed to receive water and hold it as it infiltrates through the soil into the groundwater.

The State Water Resources Control Board (SWRCB), the SWRCB’s Division of Drinking Water (DDW) (formerly California Department of Public Health (CDPH)) and to a lesser extent, the US Environmental Protection Agency (USEPA) have water policies for recharging groundwater with advanced treated wastewater and imported water. Table 1 presents the general guidelines on groundwater recharge regulations and groundwater recharge options considered in this feasibility study.

Table 1
Summary of Regulations for Groundwater Recharge

Recharge Method	Recharge Water Type	
	Recycled Water	*Imported Water*
Injection Wells	**SWRCB and USEPA (Class V underground injection well**) WATER CODE SECTION 13540-13541(No injection of wastewater into aquifer) - Requires high treatment - reverse osmosis to purified recycled water - and TITLE 17 AND TITLE 22 CODE OF REGULATIONS, Recycled municipal wastewater shall be retained underground for a period of time no less than the retention time required pursuant to sections 60320.208 and 60320.224. Notification Requirements to Well Owners section 60320.228. Recycled Municipal Wastewater Contribution (RWC) Requirements section 60320.216.	**SWRCB 2012-0010** GENERAL WASTE DISCHARGE REQUIREMENTS FOR AQUIFER STORAGE AND RECOVERY PROJECTS THAT INJECT DRINKING WATER INTO GROUNDWATER Drinking water that has been treated pursuant to a CDPH domestic water supply permit is placed in the aquifer by injection wells.
Percolation Basins	**TITLE 17 AND TITLE 22 CODE OF REGULATIONS** Regional Board Approval for Groundwater Replenishment Reuse Projects (GRRPs) Recycled municipal wastewater shall be retained underground for a period of time no less than the retention time required pursuant to sections 60320.108 and 60320.124. Notification Requirements to Well Owners section 60320.128. Recycled Municipal Wastewater Contribution (RWC) Requirements section 60320.116.	**No Treatment** - Well Setback Regulations (Groundwater Under the Influence of Surface Water) – Basin Objectives and Non-Degradation Considerations



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SEPTEMBER 2015

SOURCE: BING Maps 2015; Santa Barbara County 2010; Slade 1991

FIGURE 1

Montecito Groundwater Basin Map

MONTECITO GROUNDWATER RECHARGE FEASABILITY STUDY

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2 GROUNDWATER BASIN CHARACTERIZATION

This study will offer insight into the Basin's key characteristics as they relate to potential groundwater recharge. Key characteristics relating to groundwater recharge include: surface soil infiltration rates, depth to groundwater, horizontal and vertical barriers to groundwater flow, groundwater flow rates and the specific yield of the aquifer. All of these characteristics affect a basin's groundwater storage properties, and for recharge considerations, a basin's available storage capacity.

2.1 Available Storage Capacity

As used herein, the available storage capacity of a groundwater basin represents the volume of water that can be stored in the basin at a point in time. This differs from the total volume of water that can be held in underground storage by not including the amount of groundwater that is already in storage. A basin's available storage capacity is important when considering artificial recharge because it will fluctuate depending on the basin's total water in storage. The estimated available storage capacity can be used to evaluate the period of time in which groundwater recharge can take place to fill the available storage capacity. That is, of any given available storage capacity, there is a volume of water that can be supplied to utilize that available storage capacity, and a time period over which it can be recharged at a given recharge rate. A recharge rate is the rate at which water can enter the aquifer either by infiltration, in the case of a percolation basin, or by groundwater flow, in the case of injection well.

The concept of available storage capacity becomes somewhat more complicated when considering confined aquifers. Confined aquifers have groundwater that is isolated from the surface by impermeable geological material such as clay layers, and surface recharge by infiltration basins cannot generally be used to recharge the confined aquifer directly where the aquifer is confined. However, surface infiltration basins can recharge the aquifer where it becomes unconfined: an area that is generally referred to as the forebay. The Basin has aquifers that appear to be semi-confined and confined as well as unconfined aquifers. However, for recharge purposes, this study assumes no confining layer in the unsaturated zone between the surface and the aquifer in order to estimate the available storage capacity. But, before a specific site could be selected for surface infiltration basins, additional studies would be needed to verify that surface recharge to the aquifer is possible.

The available storage capacity is dependent on the specific yield of the aquifer material to be recharged, and the aquifer's available storage level or space (discussed below). The specific yield represents the ratio of the volume of water that can be drained by gravity from a saturated material to the total volume of that material, and expressed as a percentage of the total volume of the material. For example, an aquifer consisting of 100 acres with an available storage level of 10 feet (1,000 acre-feet, AF) and a specific yield of 5% could recharge 50 AF of water. Aquifer specific yield estimates are usually obtained from aquifer pumping tests and a large number of pumping tests could be needed to accurately characterize a basin's specific yield. For this study, specific yield estimates provided by Hoover (1980) and Slade (1992) provide a feasibility level estimate of the potential specific yield in each of the Basin's storage units as presented in Table 2.

Table 2
Area and Specific Yield Values

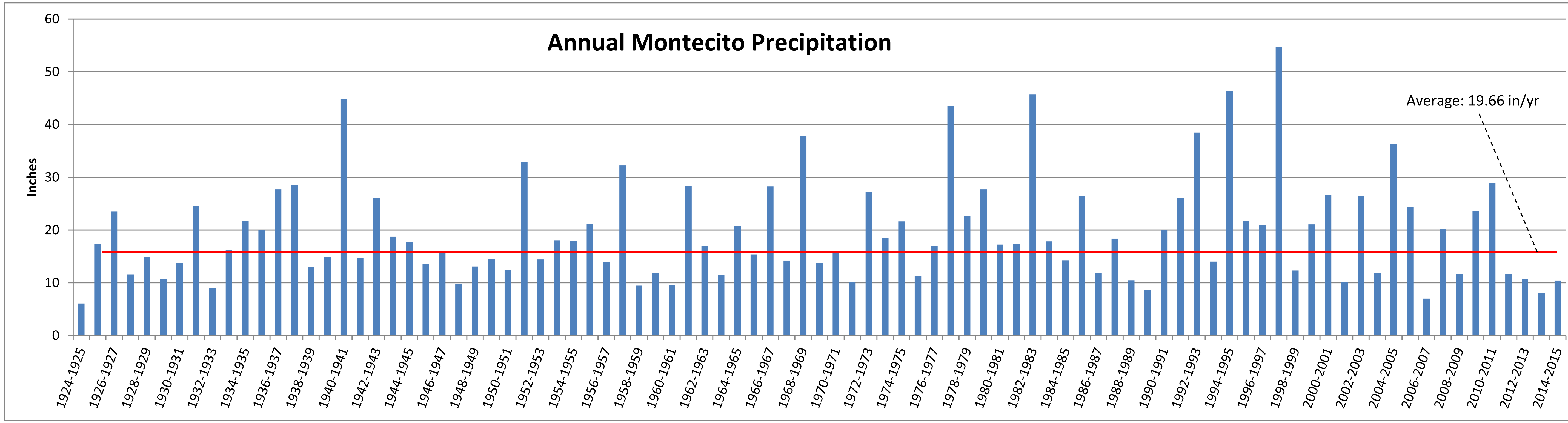
Area	Specific Yield (%)		Area (acres)
	Hoover (1980)	*Slade (1991)*	*Slade (1991)*
Storage Unit 1	4.5	3	2,040
Storage Unit 2	5	3	488
Storage Unit 3	7.4	3 to 9	1,040
Toro Canyon	6	5	247

2.1.1 Precipitation and Available Storage Capacity

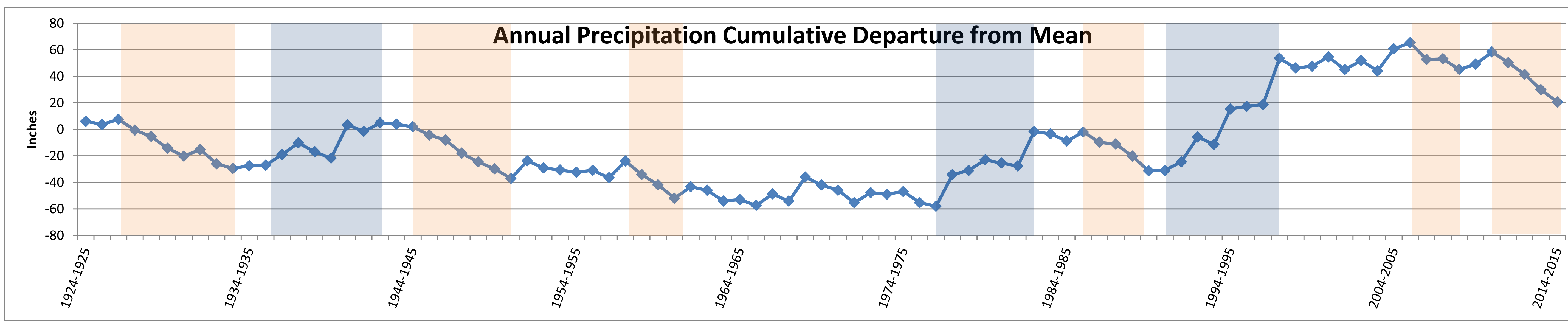
Natural precipitation directly impacts the Basin's available storage capacity. Recharge might be impractical during periods with high groundwater levels and normal or above normal precipitation. Recharge facilities could remain ideal for long periods of time if located where Basin recharge is limited by natural precipitation. To address which parts of the Basin could be recharged during a higher percentage of the time, groundwater levels were evaluated relative to natural precipitation. This analysis is similar to Slade's (1991) use of Montecito Water District (MWD) office rain gauge information from 1924-1925 to 1989-1990 to evaluate rainfall trends relative to hydrographs to estimate usable groundwater storage, but in the present study the available storage capacity and precipitation was considered. MWD provided annual rainfall data for the MWD District Office rain gauge from July 1924 through June 2015. The MWD office rain gauge is at an approximate elevation of 226 feet amsl (Figure 1). Figure 2 shows the inches of precipitation from water years 1924-1925 to 2014-2015 relative to the average of 19.7 inches. Figure 3 shows the cumulative departure from mean for the precipitation and is a better tool to evaluate precipitation trends.

The cumulative departure from mean plot shows that from 1936 to 1941, from 1977 to 1982, and from 1991 to 2005 were generally periods of above average precipitation and that from 1926 to 1933, 1943 to 1951, 1957 to 1960, 1983 to 1989, 2007 to 2009 and from 2012 to current were dry periods.

Figures 2 and 3 Hydrograph of Montecito Precipitation and Cumulative Departure from Mean Precipitation



Annual rainfall, in inches, measured at the Montecito Water District Office Rain Gauge, from water year 1924-1925 to 2014-2015.



Cumulative departure from the mean, in inches, measured at the Montecito Water District Office Rain Gauge, from water year 1924-1925 to 2014-2015. Cumulative departure from the mean is calculated by subtracting the long-term average (19.7 inches) from each year's annual rainfall and summing the differences cumulatively. It is used to assess long-term trends of drought or water surplus. The orange hatched areas indicate dry periods, the blue hatched areas indicate wet periods and the areas not hatched indicate normal or average periods of precipitation..

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The cumulative departure from mean plot was used with well hydrographs to help determine when recharge could likely be used in each of the Basin's storage units. Storage units in this study are those from Plate 2 of the Slade (1991) report (Figure 1).

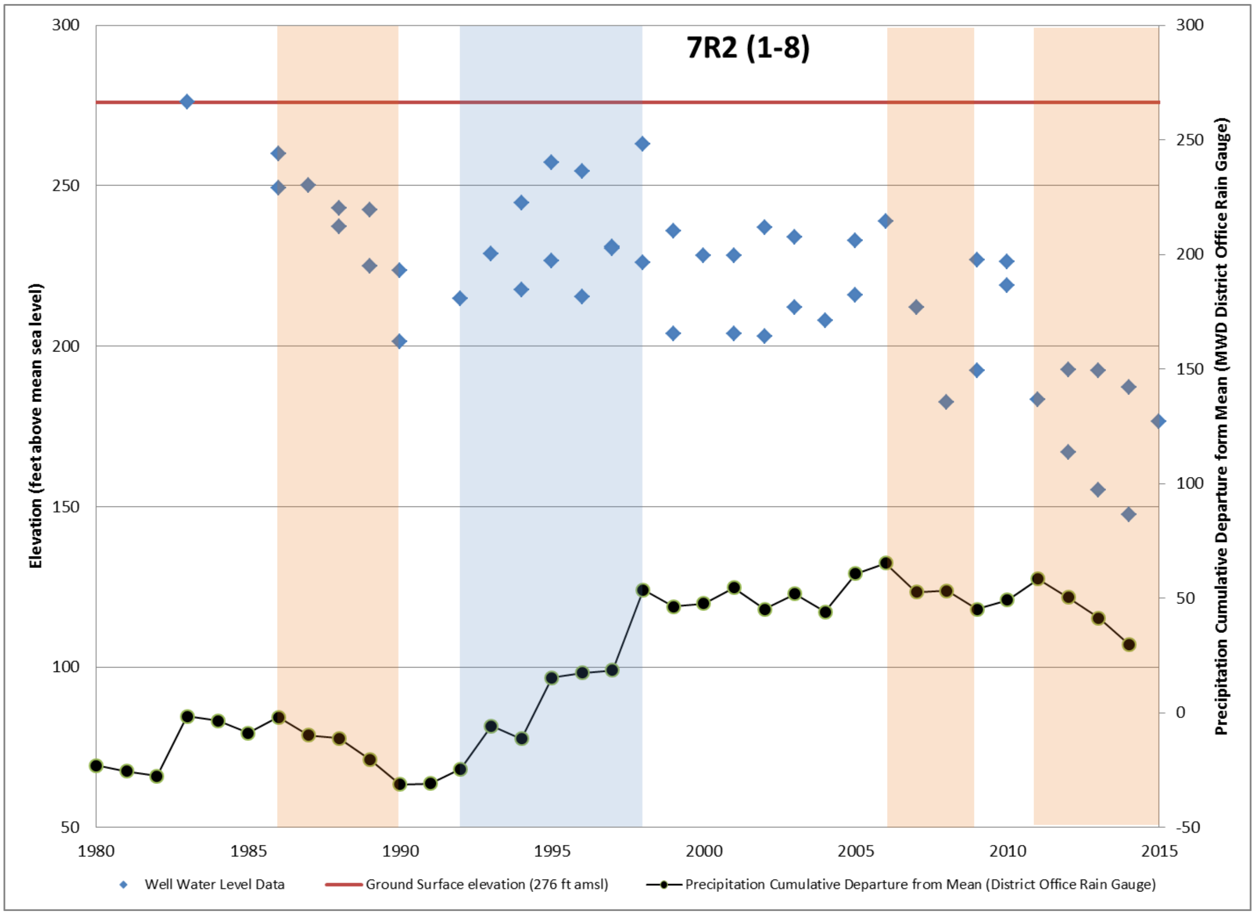
2.1.2 Storage Unit 1 Recharge Potential

Several hydrographs and cumulative departure from mean plots were constructed to evaluate the available storage levels during historical periods in Storage Unit 1. Figures 4 through 8 show groundwater levels in wells located along the southern part of Storage Unit 1 and generally have similar patterns. The drought period ending in about 1991 shows varying degrees of impact to groundwater levels in Storage Unit 1 with the hydrographs showing declines in groundwater levels that indicate an available storage level from about 20 feet (Figure 5) to about 100 feet (Figure 8) compared to their average baseline groundwater levels. Generally, the groundwater level declines during this 5-year period from 1988 to 1993 were about 50 feet (Figures 4, 6 and 7).

Groundwater levels returned to average baseline conditions in about 1993 and indicate that there would be no available storage level in Storage Unit 1 for approximately 13 years until about 2006 when groundwater levels again showed a decline due to the most recent drought. Groundwater condition in Storage Unit 1 currently shows groundwater level declines similar to those of the 1991 drought and indicate an available storage level of about 50 feet.

Using an available storage level of 50 feet (current conditions) and the specific yield estimates provided by Slade (1991) of 3% and 4.5% by Hoover (1980, Table 2), the available storage capacity in Storage Unit 1 would be from 1.5 feet to 2.25 feet of water per acre. If Storage Unit 1 showed a similar groundwater available storage level of 50 feet over its' entire area, estimated by Slade (1991, Table 4) at 2,040 acres, the total available storage capacity for Storage Unit 1 would be from about 3,060 AF to 4,590 AF. This estimate assumes that the entire 2,040 acres has available storage capacity based on the available storage level, which could be an over estimate. Many more groundwater levels would be needed to make a more precise estimate. This assumption is used for the storage unit calculation below as well.

Figure 4 Storage Unit 1 Well 1-8



Elevation of groundwater in feet AMSL (blue diamonds) is shown over time. The available storage capacity of an aquifer is directly related to the distance between the water table and the ground surface (shown in red at top of graph).The precipitation cumulative departure from the mean in inches (black circles, on the right hand axis), and color-coded bars to indicated multi-year precipitation trends (blue for higher-than-average rainfall; red for lower-than-average rainfall), are shown to provide long term water supply context.

Figure 5 Storage Unit 1 Well 1-10

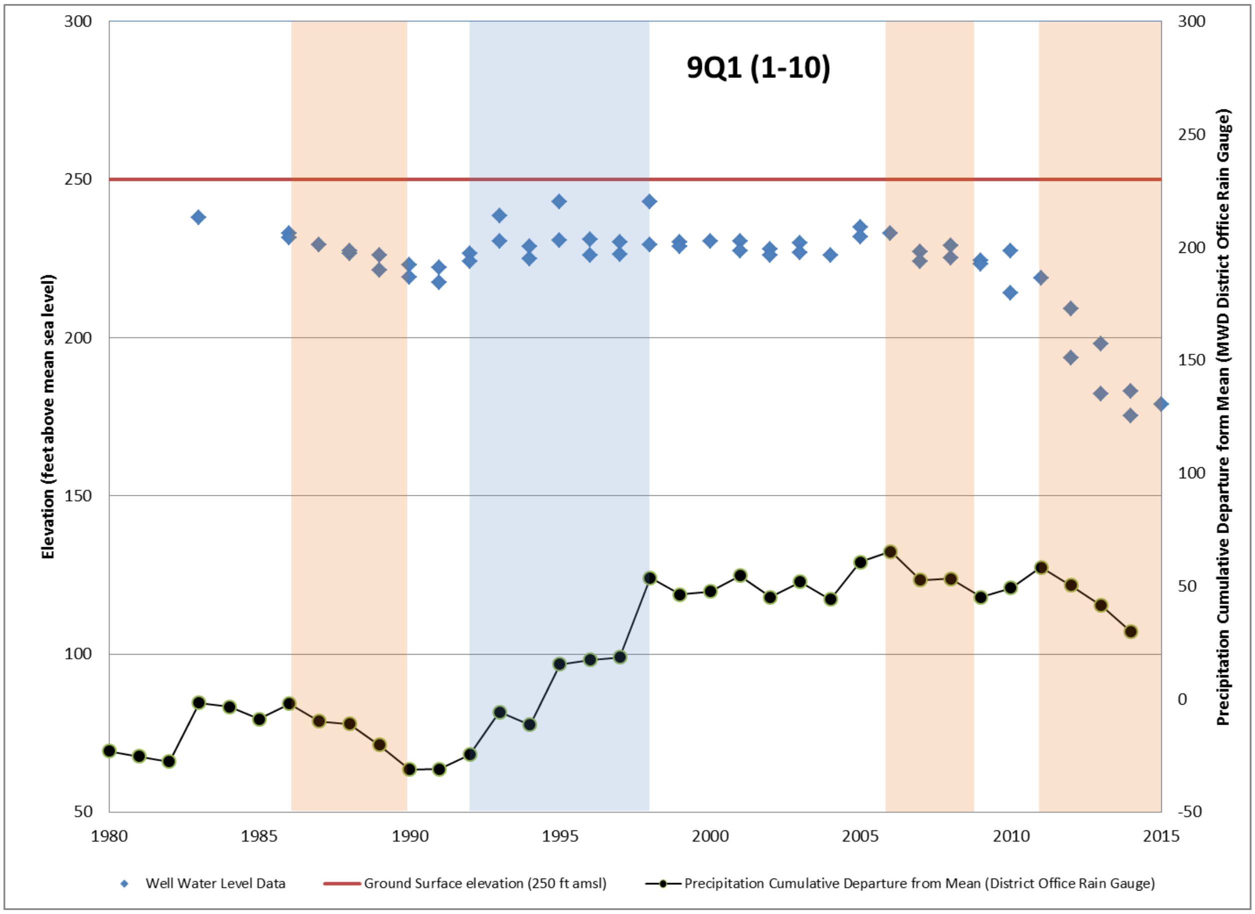


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Figure 6 Storage Unit 1 Well 1-13

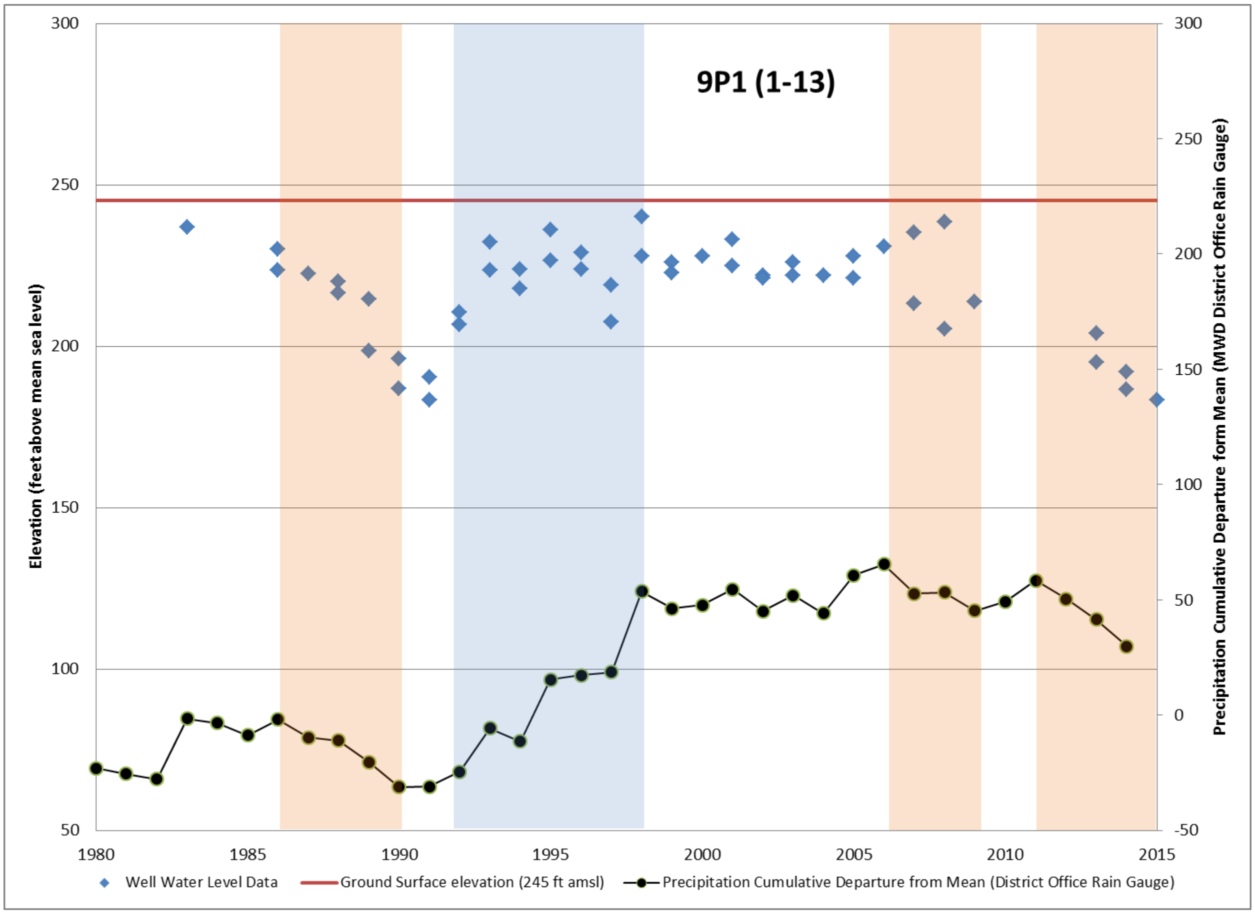

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Figure 7 Storage Unit 1 Well 1-15

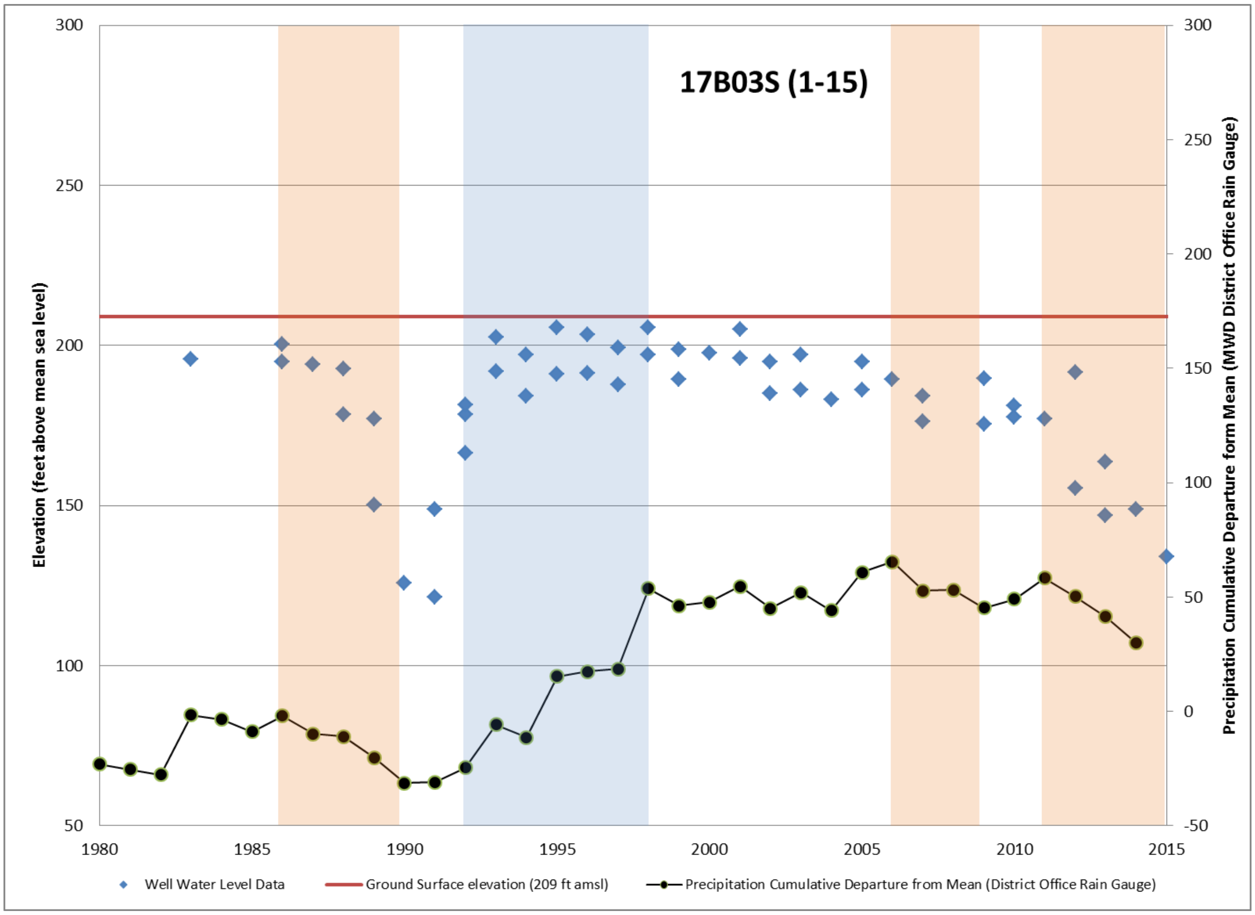

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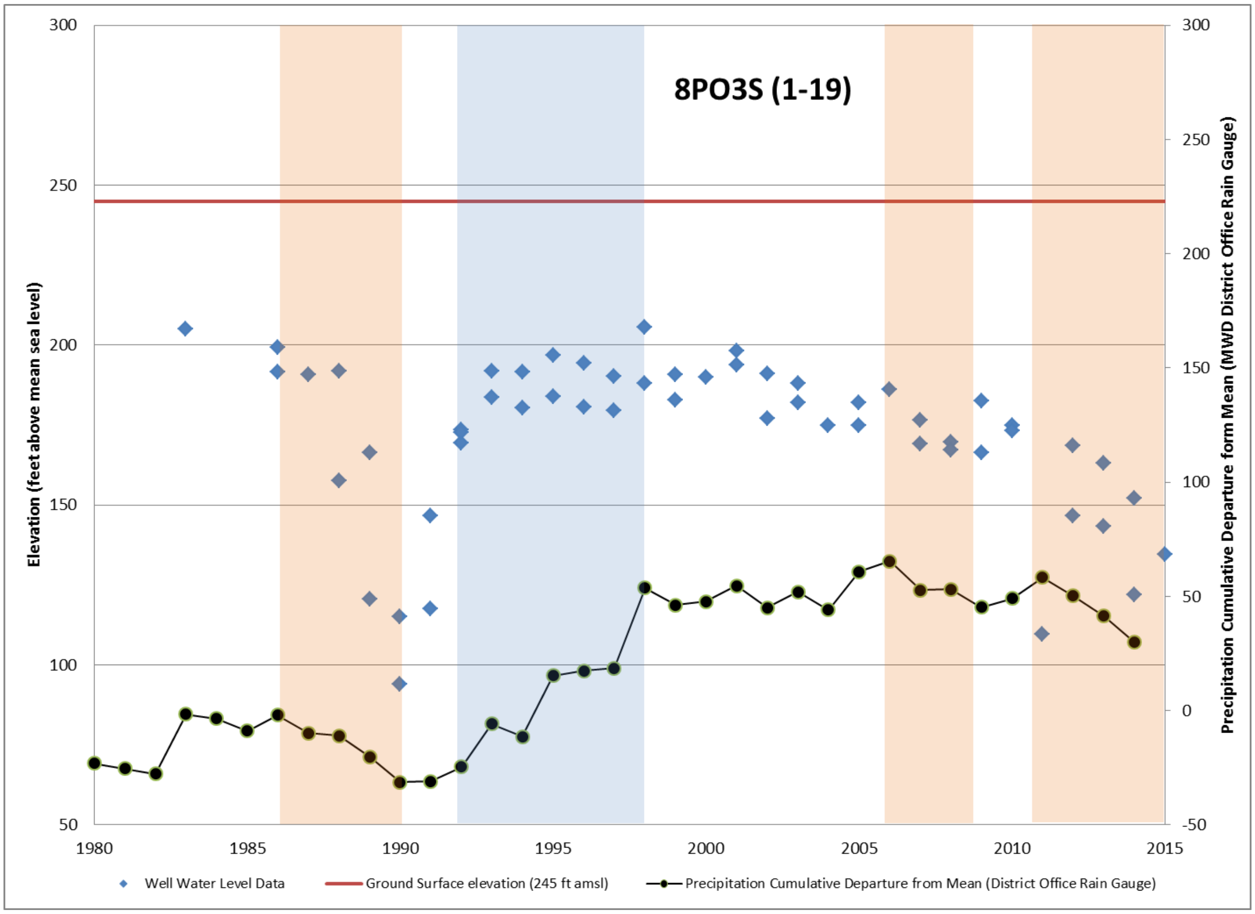
Figure 8 Storage Unit 1 Well 19



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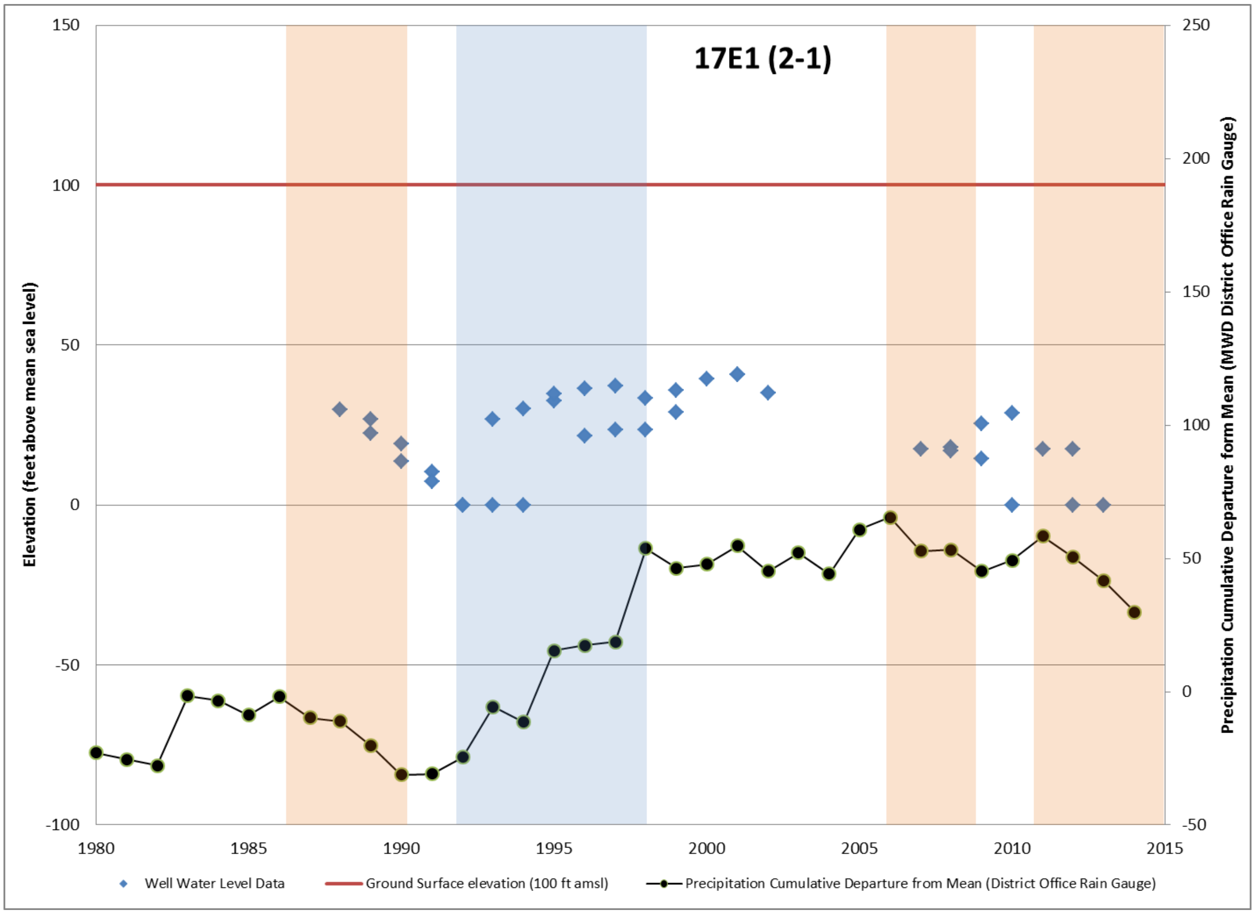
2.1.3 Storage Unit 2 Recharge Potential

Limited well data in Storage Unit 2 makes estimates of the available storage capacity difficult. Only well 17E1 (2-1) shown on Figure 9 could be used to estimate the available storage capacity of Storage Unit 2. Wells 17E3 and 17E4 (2-2 and 2-3), which have data available, are located along the western bedrock contact near Camino Viejo Road and do not show groundwater levels declines. These wells show only near surface static groundwater conditions with no available groundwater storage space.

Well 17E1 (2-1, Figure 9) shows an available storage level from 20 to 30 feet during the 1991 and current drought. Thus, using the specific yield values for Storage Unit 2, which range from 3% and 5% and an area of 488 acres (Slade, 1991, Table 2), the available storage capacity would range from 290 to 732 AF. This range was estimated using the minimum specific yield (3%) and available storage level (20 feet) and the maximum specific yield (5%) and available storage level (30 feet) for the entire area of 488 acres.

Figure 9 Storage Unit 2 Well 2-1



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2.1.4 Storage Unit 3 Recharge Potential

Storage Unit 3 is bounded to the south by the Pacific Ocean (Figure 1). Hoover (1980) indicates that Unit 3 is apparently sealed off from seawater in the deeper aquifers by an offshore fault, but open to the sea in the shallow aquifers. From Hoover's (1980) analysis of water quality data and electrical logs, he concludes that the shallow zone of poor water quality is generally less than 50 feet deep and that a deeper zone of poor water quality could be due to connate water trapped by movement of the offshore fault.

Hydrographs and cumulative departure from mean plots for Storage Unit 3 are shown in Figures 10 through 14 and do not show a consistent trend in groundwater pattern. Well 17N1 (3-8, Figure 10) does not show a declining groundwater trend related to the current drought, although the well, like the other three wells in Storage Unit 3, clearly shows a decline for the drought ending in 1991. Well 16N1 (3-15, Figure 13) does show a current drought groundwater level decline, but only since about 2013, whereas wells 17K2 (3-10, Figure 11) and 17Q2 (3-13, Figure 12) show trends that resemble wells in Storage Unit 1, but with less declines in groundwater levels during the drought periods. In Storage Unit 1, the groundwater declines for the current drought are similar to those of the 1991 drought at about 50 feet; however, in Storage Unit 3, the declines for the current drought are less or equal to those for the 1991 drought at about 20 feet.

Using an available storage level of 20 feet (current conditions) and the specific yield estimates provided by Slade (1992) of 6% (average of 3% and 9%) and 7.4% by Hoover (1980, Table 2), the available storage capacity in Storage Unit 3 would be from 1.2 feet to 1.5 feet of water per acre. Using 20 feet for the entire area, estimated by Slade (1991, Table 4) at 1,040 acres, the total available storage capacity for Storage Unit 3 would be from about 1,250 AF to 1,560 AF.

Figure 10 Storage Unit 3 Well 3-8

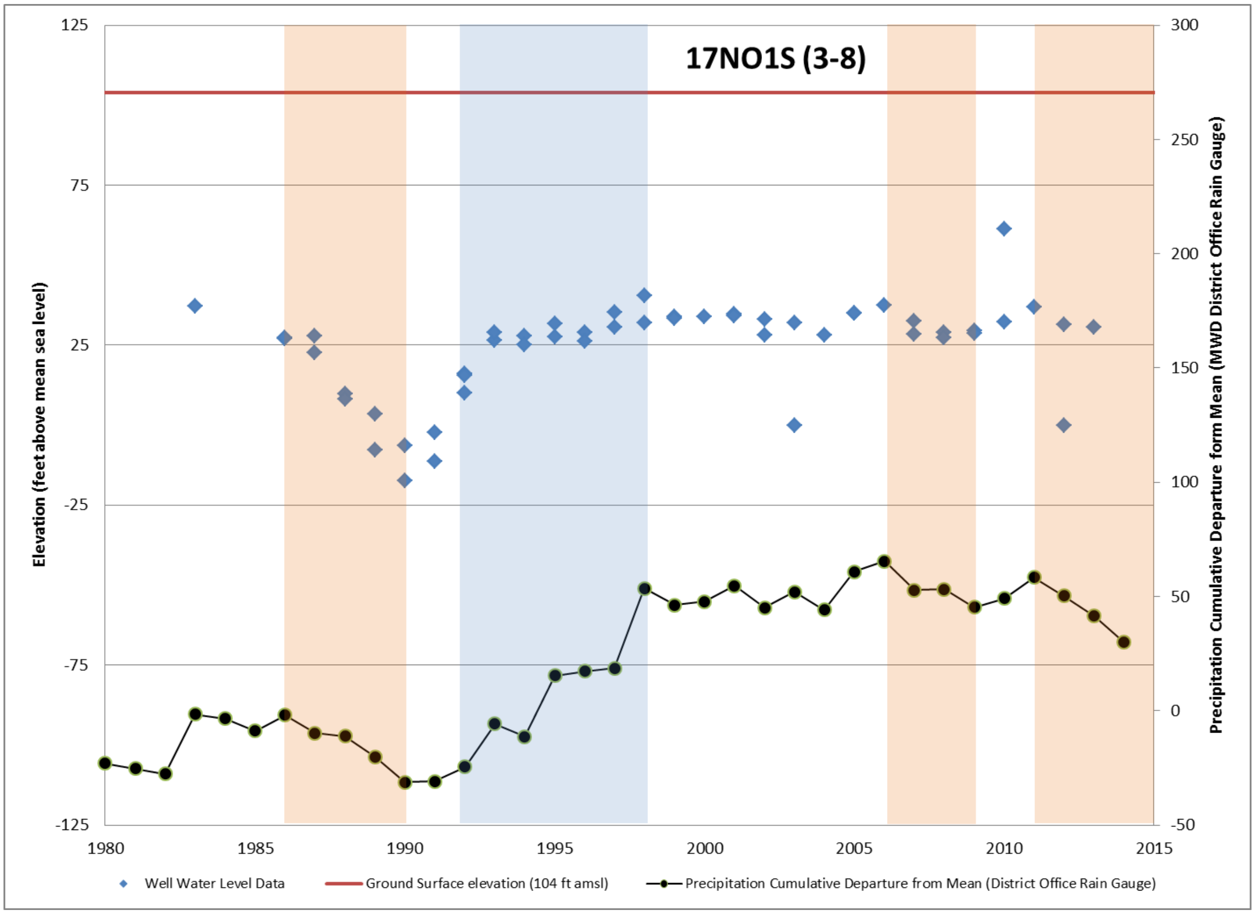

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Figure 11 Storage Unit 3 Well 3-10

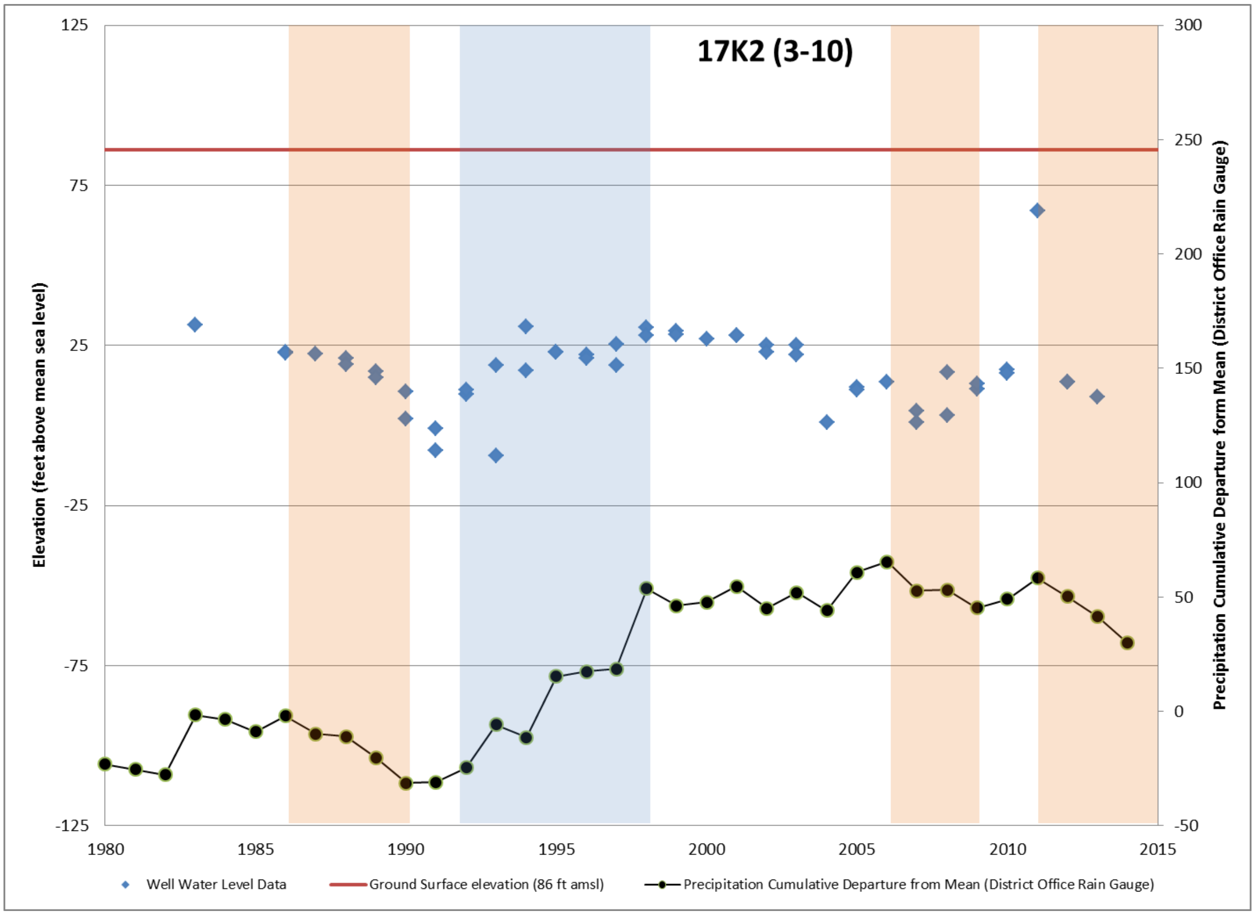

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Figure 12 Storage Unit 3 Well 3-13

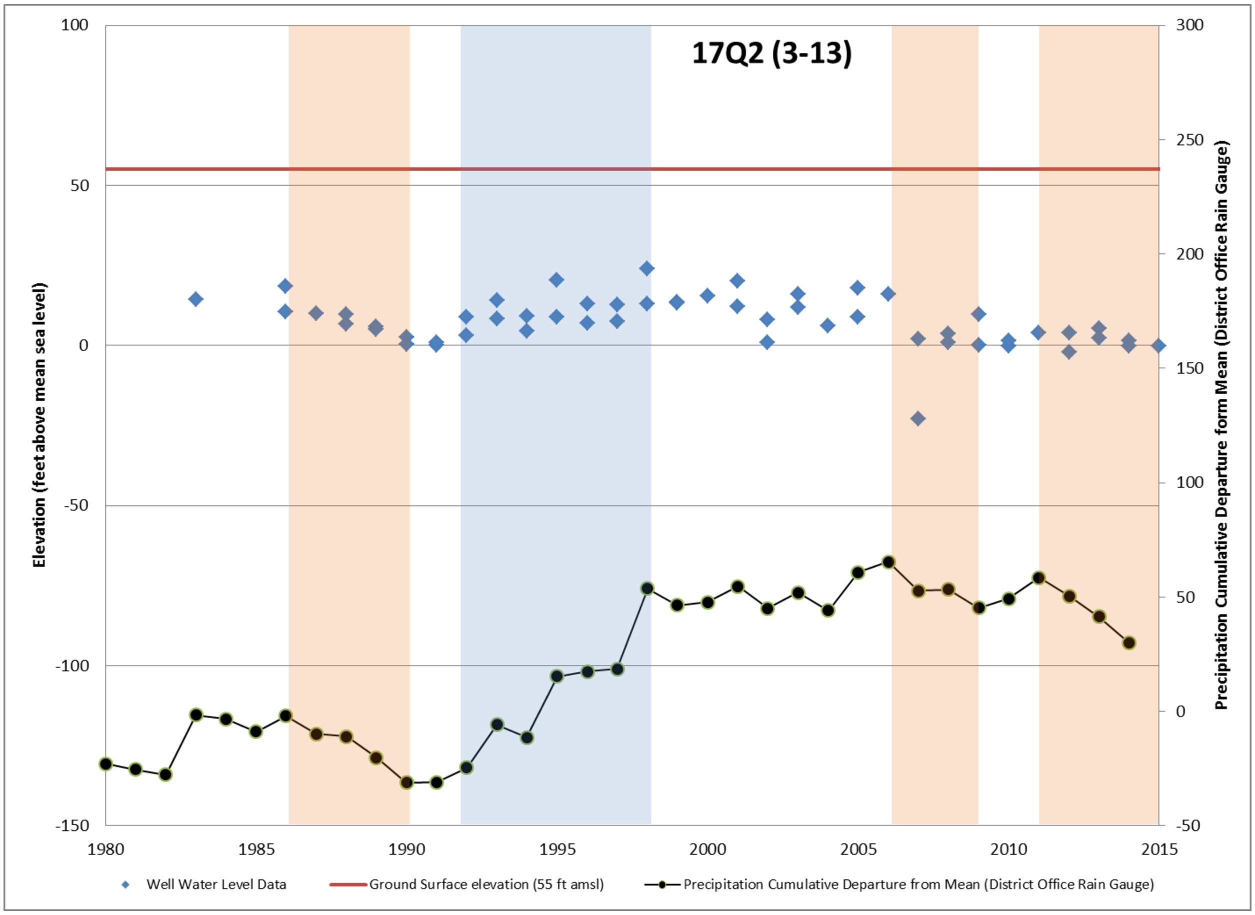

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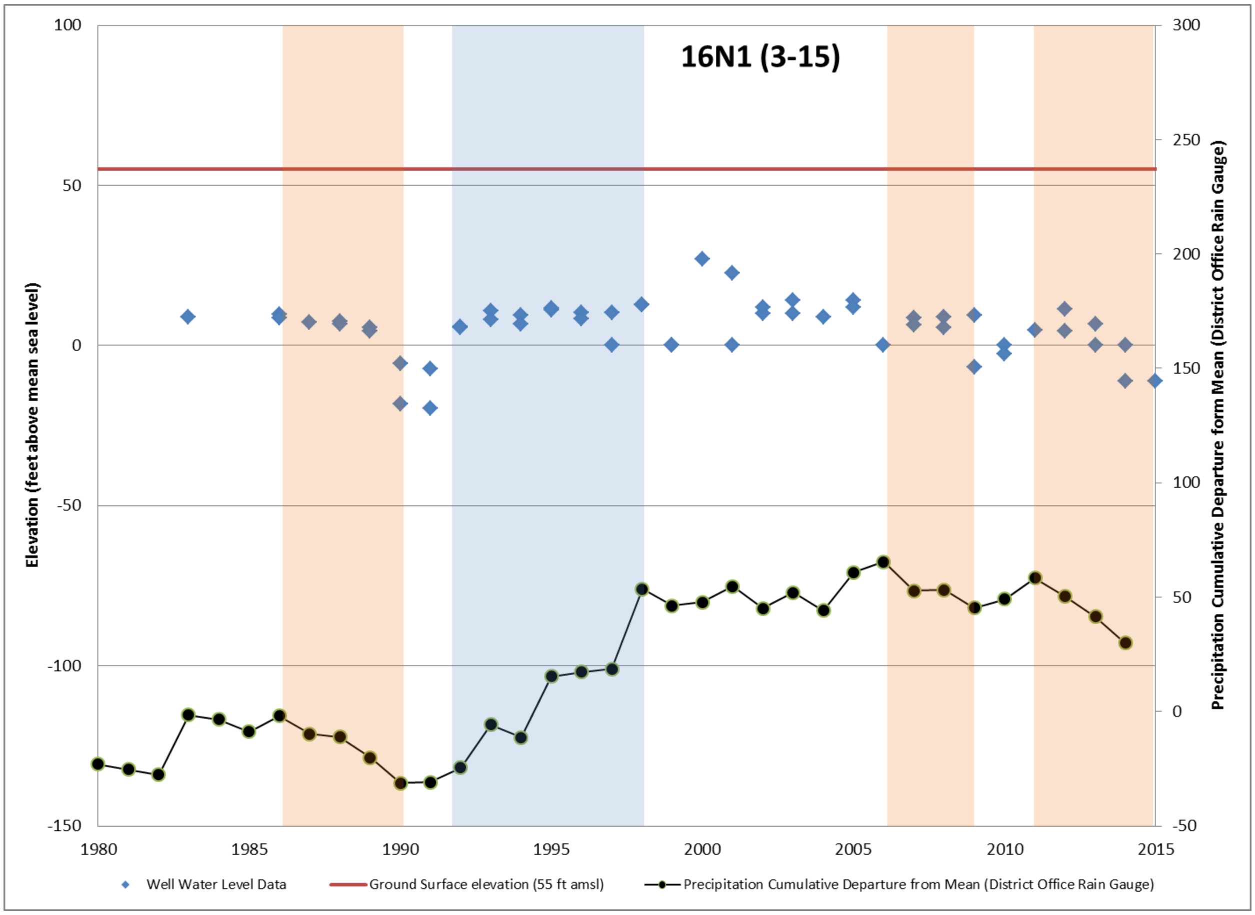
Figure 13 Storage Unit 3 Well 3-15



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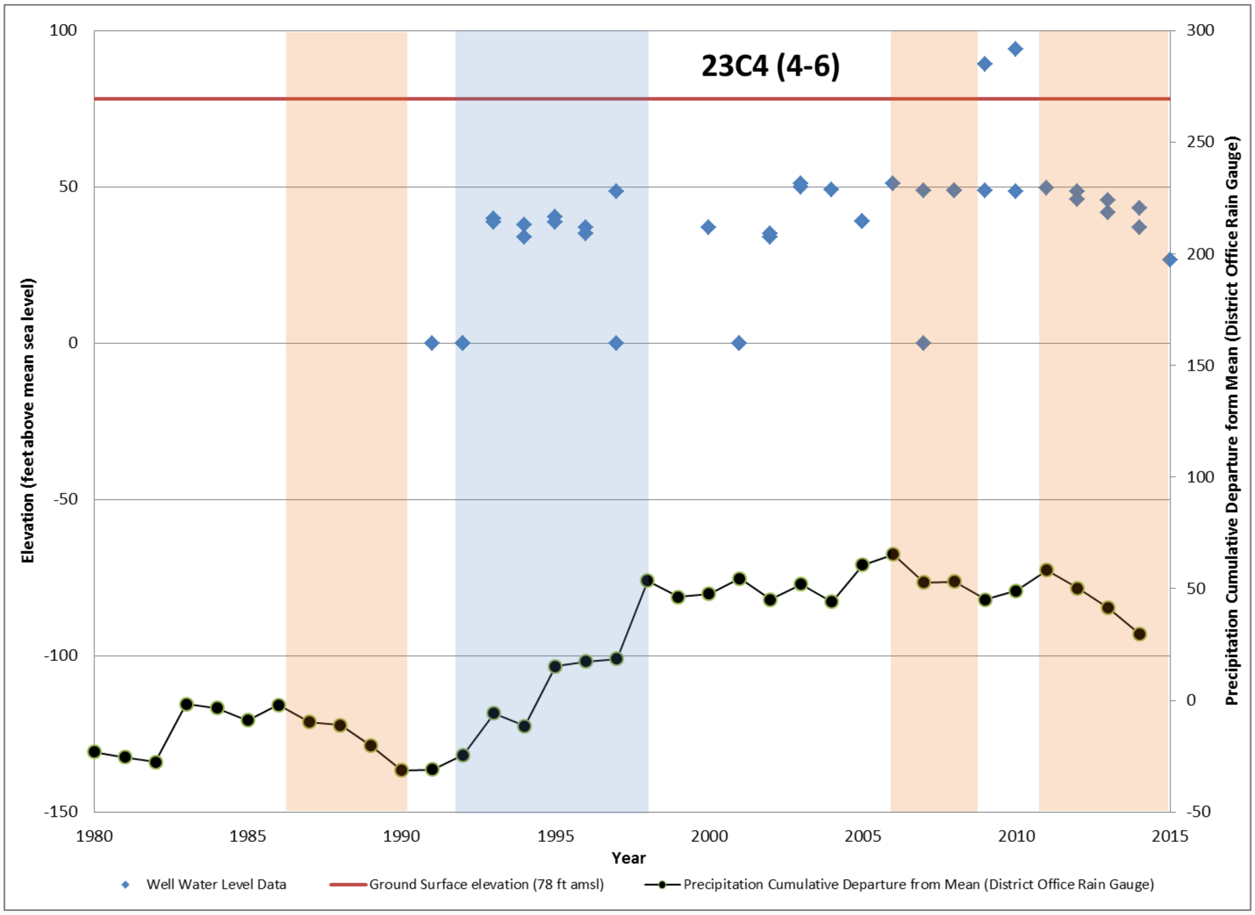
2.1.5 Toro Canyon Recharge Potential

Well 23C4 (4-6, Figure 14) shows that the groundwater levels in the Toro Canyon Storage Unit are currently about 20 feet lower than typical levels. During the 1991 drought period the well was perhaps 80 feet lower than typical levels. Slade (1991) has calculated the storage unit area (TC-A and TC-B, Slade's Plate 2) to be 347 acres. Assuming a storage level availability of 20 feet, and a specific yield estimate of 5% and 6% (Table 2), the potential available storage capacity in the Toto Canyon Unit would be from about 350 AF to 420 AF.

Figure 14 Toro Canyon Well 4-6



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2.2 Seawater Intrusion

Using injected advanced treated wastewater to mitigate seawater intrusion could be more seriously considered with further evaluation by geological and economic feasibility studies. The utilization of potable water and/or advanced treated wastewater for this purpose is not new and has been practiced successfully for decades in many areas. The Orange County Water Agency and the Replenishment District of Southern California operate the Dominguez Gap Barrier Project, the West Coast Basin Barrier Project, and the Alamitos Barrier Project in Los Angeles County. These three existing seawater barrier projects inject purchased imported water and advanced reclaimed water to prevent seawater intrusion. The seawater barriers use a series of injection wells positioned like a dam between the ocean and the groundwater aquifer. The wells inject water along the barrier to ensure that the groundwater water level near the ocean stays high enough to keep the seawater from seeping into the aquifer. In the Los Angeles area, a combination of high quality recycled water and imported water is injected and a large number of observation wells are used to monitor water surface elevations and groundwater chloride levels.

While it is important to note that seawater intrusion has not been identified in any parts of Storage Unit 3 to date, Hoover (1980) did identify seawater intrusion as a potential problem in the Basin due to the shallow groundwater aquifers being open to the ocean. Hoover’s (1980) Plates 13 through 16 show brackish water occurring as shallow and deep zones near the Rincon Creek Thrust and suggests that the deeper zone is likely connate groundwater trapped along the Rincon Creek Thrust. The thickness of the deeper zone is unknown; however, Hoover (1980) reports that e-logs available at the time suggest that the shallow zone is probably about 50 feet thick and of limited extent only occurring near the ocean.

Given the limited information available on the Basin’s current seawater intrusion status, groundwater quality, and hydrogeology, it is in not possible to provide any reliable estimate on the feasibility of using injected advanced treated wastewater to mitigate seawater intrusion. A study similar to that being conducted by the Santa Barbara City Water Resources Division (SBCWRD) would identify seawater intrusion problems and, if needed, help identify potential seawater intrusion mitigation measures. The SBCWRD project will update their Multiple Objective Optimization Model and add a 3-dimensional water quality component to accurately assess seawater intrusion. Their goal is to conduct a new modeling effort in Santa Barbara Storage Basin 1 to accurately evaluate seawater intrusion, and to guide future placement of new wells in the basin, assist in scheduling well operation to minimize intrusion, and provide the ability to estimate the benefits of groundwater recharge for basin replenishment and creating barriers to seawater intrusion. A similar study could be considered for the Basin’s Storage Unit 3 and the Toro Canyon area.

2.3 Additional Recharge Considerations

The recycled municipal wastewater contribution, limited available storage capacity, and groundwater retention times must be considered when determining feasibility of artificial recharge.

2.3.1 Recycled Municipal Wastewater Contribution

Additional considerations that could affect the feasibility of using wastewater for recharge projects, also referred to as Groundwater Replenishment Reuse Projects (GRRPs) by the DDW, are the amount of recycled water that may be used for a recharge project. The initial maximum Recycled Municipal Wastewater Contribution (RWC) is not to exceed 20%, or an alternative initial RWC approved by the DDW. An alternative initial RWC up to 100% may be approved based on, but not limited to, DDW's review of the engineering report, the information obtained as a result of the public hearing(s), and a project sponsor's demonstration that the treatment processes preceding the soil-aquifer treatment process will reliably achieve total organic carbon (TOC) concentrations no greater than 0.5 mg/L divided by the proposed initial RWC. For example, the treated TOC concentration could only be 2.5 mg/L if the RWC is 20% (0.5 mg/L/0.20 = 0.25 mg/L).

2.3.2 Available Storage Capacity Limitations

A clear understanding of potential risks associated with groundwater recharge impacts should also be considered. As indicated above, a general rule for groundwater levels within a basin are that they should not be encouraged to rise to levels at which liquefaction or other groundwater problems could become an issue to the recharging agency. Specific constraints on groundwater levels depend on site geotechnical data and on the seismic susceptibility of the recharge area. The California Geological Survey (CSG, 2004) states that for areas with limited or no geotechnical data, seismic susceptibility zones may be identified by geologic criteria. Liquefaction can occur in areas containing soil deposits of late Holocene age (i.e., current river channels and their historic floodplains, marshes, and estuaries), where earthquake Magnitude 7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g (gravitational constant) and the water table is less than 40 feet below ground surface (bgs).

Typically, to avoid the need for potentially basin-wide detailed geotechnical drilling studies for potential recharge projects, a worst case of 40 feet below ground surface is assumed for the entire groundwater basin, and an additional 10 feet is generally added to provide for extra safety – i.e., a recharging agency would cease artificial recharge when water levels rise to within 50 feet of the ground surface. In basins with shallow groundwater, limiting groundwater levels to depths greater than 50 feet bgs can significantly reduce the basin's available storage capacity, so detailed geotechnical studies might be needed even for soil deposits older than late Holocene age. The near surface deposits in the Basin range from Pleistocene to Holocene in age.

As noted above, groundwater levels in each of the Storage Units show groundwater levels that are generally closer to the surface than 50 feet. A review of Figures 4 through 14 shows that only Storage Unit 2 Well 2-1 (also known as 17-E1; Figure 9) would allow for limited recharge before the groundwater level would rise to within 50 feet of the surface. Thus, artificially raising groundwater levels by recharge could pose potential increased risk of adverse impacts such as liquefaction, increased surface flooding, ground saturation problems, and increased storm water runoff. These impacts, and even natural impacts associated with storm water and natural precipitation, could be perceived as caused or heightened by a decrease in storm water infiltration resulting from the loss of the available storage capacity by artificial recharge.

For this study, because historical groundwater levels in most wells in the Basin are less than 50 feet below the ground surface elevation, available storage level refers to the elevation difference between a well's drought groundwater level and the well's average historical water level. Figure 1 shows the depth to groundwater for the spring 2015 well measurements in Figures 4 through 14.

Other factors that can limit a basin's available storage capacity include the presence of horizontal and vertical barriers to groundwater flow, such as clay layers or faults, and shallow groundwater, which mounds or rises to the surface or near the surface. Additionally, horizontal and vertical barriers can significantly reduce infiltration rates for recharge basins and groundwater flows from injection wells. Thus, potential recharge projects need to consider proximity to adjacent faults and the permeability of the unsaturated zone material before recharge site selection.

2.3.3 Groundwater Retention Times (Groundwater Travel Distance Considerations)

A minimum two months groundwater retention time is required for recharge projects using infiltration basins and advanced treated recycled water. Retention time is also referred to as Response Retention Time by the DDW, and is currently required for all recycled municipal wastewater projects to provide sufficient response time to identify treatment failures and implement actions necessary for the protection of public health. The calculation of the response retention time required must be approved by the DDW and is based on an engineering report conducted utilizing one of the methods in Table 3.

Table 3
Calculation of Retention Time

Method Used to Estimate Retention Time	Response Time Credit Per Month
Tracer Study utilizing an added tracer. [1]	1.0 month
Tracer study utilizing an intrinsic tracer. [1]	0.67 months
Numerical modeling consisting of calibrated finite element of finite difference models using validated and verified computer code used for simulating groundwater flow.	0.50 months
Analytical modeling using existing academically-accepted equations such as Darcy's law to estimate groundwater flow conditions based on simplifying aquifer assumptions	0.25 months

[1] The retention time shall be the time representing the difference from when the water with the tracer is applied at the GRRP to when either; 2% of the initially introduced tracer concentration has reached the downgradient monitoring point, or 10% of the peak tracer unit value observed at the downgradient monitoring point reaches the monitoring point.

There is limited data available on the Basin's aquifer properties. However, sufficient well pumping tests are available to make a general estimate of the two, four, six and eight-month retention time. The retention time can be represented as the travel distance from a recharge basin to a nearby production well for a specified time, or by the travel distance from a production well in any direction. The latter allows for estimating where recycled water recharge basins could be placed without well impacts. The estimated distance from extraction wells maintaining an eight-month retention time as required in Table 3 (Analytical Method) utilized the following average groundwater velocity equation calculation:

Average Groundwater velocity (G_v) = (hydraulic conductivity (*K*) times the hydraulic gradient (*i*)) divided by the effective porosity (assumed to approximate specific yield (S_y))

Where:

- K, the hydraulic conductivity, was estimated using the well pumping test results included in Table 4,
- *i*, the hydraulic gradient, was estimated using the steepest hydraulic gradient from groundwater level contours mapped by Slade (1991) on Plate 4 (200 feet in 2500 feet), and
- S_y, the lower specific yield estimate in Table 2 of 3%

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Table 4
Basin Pumping Test Results and Horizontal Conductivity

Well	Well Number	Storage Unit	Test Pumping Rate (GPM)	Date	Report	T (gallons/day/ft)*	Well Depth+ (feet)	Horizontal Conductivity (K) (feet/day)	Used in Average	Average K (feet/day)
Birnam Wood Golf Club Wells #6**	NA	1	25	March 2009	Michael Hoover	33,000	55	80.2	No	1.2
Birnam Wood Golf Club Wells #8	1-3	1	20	March 2009	Michael Hoover	406	165	0.3	Yes	
Birnam Wood Wells #4**	NA	1	100	July 1999	Hoover & Associates	18,857	22.5	112.0	No	
EVR Well #7	NA	1	54	August 1990	Hoover & Associates	1,650	150	1.5	Yes	
Las Entradas Well #2	NA	1	300	1983	William Anikouchine	1,863	490	0.5	Yes	
Las Fuentes Well	1-53	1	50	September 2011	Adam Simmons	322	700	0.1	Yes	
Office Well #2	1-19	1	100	May 1982	Hoover & Associates	1,148	400	0.4	Yes	
Seaview MWC Wells	1-51	1	NA	April 1982	Hoover & Associates	7,000	200	4.7	Yes	
Amapola Well	3-22	3	250	December 1978	Richard Slade	9,000	620	1.9	Yes	1.2
Benon Well	NA	3	113	May 1990	Richard Slade	1,863	490	0.5	Yes	
Boeseke Well #2	NA	3	200	January 1985	Hoover & Associates	1,737	500	0.5	Yes	
Ennisbrook Well #2	3-25	3	100	April 1989	Hoover & Associates	3,771	500	1.0	Yes	
Ennisbrook Well #3	NA	3	100	April 1989	Hoover & Associates	3,300	320	1.4	Yes	
Montecito Meadows #1 (Amapola)	NA	3	73	December 1978	Donald Weaver	11,000	NA	NA	No	
Montecito Valley Ranch #1	NA	3	200	May 1990	Richard Slade	6,200	490	1.7	Yes	
Morgan Well #2	3-23	3	150	May 1990	Richard Slade	6,100	435	1.9	Yes	
Morgan Well #2	3-23	3	150	November 1985	Rick Hoffman & Associates	6,092	435	1.9	Yes	
Paden Well #2	3-12a	3	200	May 2012	Adam Simmons	880	650	0.2	Yes	
Edgewood Well #3	4-6	TC	150	May 2012	Adam Simmons	2,200	304	1.0	Yes	1.0

* if both drawdown and recovery T values were provided the high value was used.
+ assumed aquifer thickness
** Not included in calculation of average horizontal conductivity due to unusually high T and shallow well depth

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Based on these calculations, the average groundwater velocity would suggest an estimated distance from extraction wells for a two, four, six, and eight-month retention time of 192 feet, 384 feet, 576 feet, and 768 feet, respectively. These results are presented in Table 5. These distances are generally low for average groundwater velocity, but reflect the low hydraulic conductivity estimated from the pumping tests (1.2 feet/day) and the low specific yield of the aquifer of 3%. These distances would be even shorter using a lower hydraulic gradient. Results for the 8-month retention time of 768 feet is presented graphically in Figure 15 using known well locations and a diameter of 1,536 feet for each well. However, there are more wells in the Basin than those shown on Figure 15 for which well locations have not been provided for in this study.

Table 5
Groundwater Distances Traveled for Different Groundwater Retention Times

2-month	4-month	6-month	8-month
192 feet	384 feet	576 feet	768 feet

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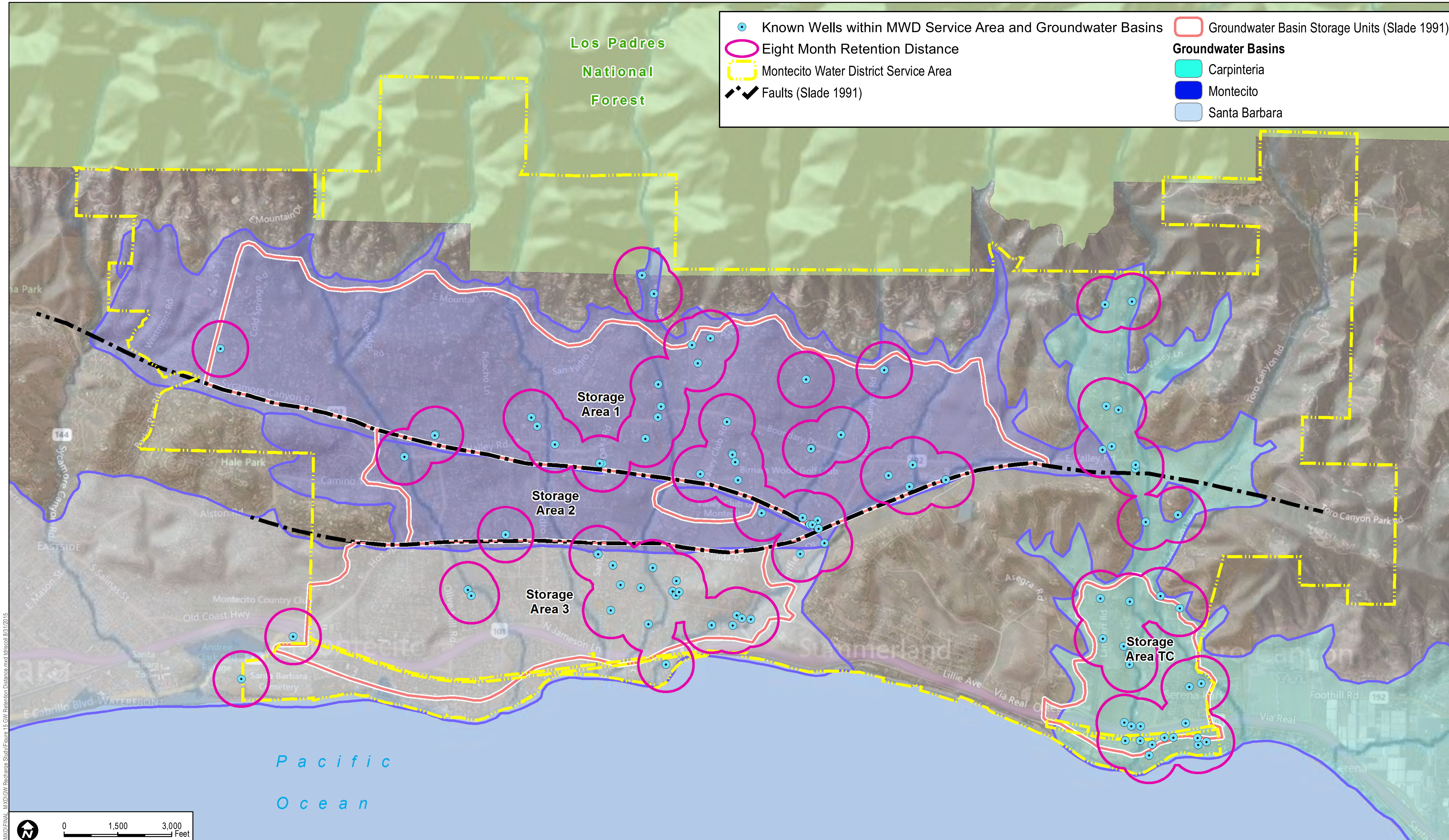

DUDEK

SEPTEMBER 2015

SOURCE: BING Maps 2015; Santa Barbara County 2010; Slade 1991

FIGURE 15

Potential Groundwater Retention Distance Based On Retention Time

MONTECITO GROUNDWATER RECHARGE FEASABILITY STUDY

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3 CONCLUSIONS

This Study considered opportunities and constraints for using advanced treated wastewater and imported water to recharge the Montecito Groundwater Basin by injection wells and percolation basins. This section presents a summary of these opportunities and constraints related to the groundwater recharge.

Artificial groundwater recharge is most successful when a large amount of storage capacity is available at all times. This situation is common for groundwater basins where overdraft has lowered groundwater levels to a point where they do not recover naturally during prolonged wet periods.

Basins are considered unsuitable for artificial recharge if the available storage capacity of the basin is limited by natural recharge under average or normal precipitation conditions. If artificial recharge were attempted in an unsuitable basin, it is possible that the injected water could effectively displace future natural recharge. This is undesirable not just because of the lost value of naturally recharged groundwater, but also because, if the water table rises excessively, a recharging agency could risk adverse impacts due to liquefaction, increased surface flooding, ground saturation problems, and increased storm water runoff. These potential impacts will need to be addressed by a California Environmental Quality Act (CEQA) analysis conducted to evaluate basin impacts associated with any artificial recharge project.

A review of historical precipitation and groundwater levels suggests that the Basin has a limited amount of available storage capacity even during periods of drought. The data indicates that from about 1989 to 1993 the Basin had some available storage capacity in Storage Unit 1, Storage Unit 2, and Toro Canyon. The Basin in 1991 had between 4,950 and 7,300 AF of available storage capacity (Table 6). However, this period from 1989 to 1993 began years after the onset of the relevant drought period. Based on precipitation records, it appears that the region experienced a drought from 1985 to 1991 (Figures 2 and 3).

Table 6
Available Storage Capacity during the 1991 Drought

Storage Unit	1991 Drought	
	Minimum (AF)	*Maximum (AF)*
Storage Unit 1	3,060	4,590
Storage Unit 2	290	732
Storage Unit 3	1,250	1,560
Toro Canyon Unit	350	420
Total	**4,950**	**7,302**

The current drought period started in about 2007 (Figures 2 and 3), but the majority of the currently-available storage capacity only became available starting in about 2011 (Figures 4 through 14). Thus, it can be hypothesized that the Basin must experience drought conditions for between 4 and 8 years before storage capacity becomes available for artificial recharge under current pumping demands. Figures 2 and 3 indicate that during the 91 year period of record, precipitation generally ranged near normal with 6 identified extended dry periods, suggesting that there was likely limited available storage capacity in the Basin during much of the period.

Based on the available data, the limiting factor for a recharge program with advanced treated recycled water is the quantity of available storage capacity. Available storage capacity in the basin is seriously limited during periods of normal or above average precipitation. This study also shows that although some historical periods with significant available storage capacity have been recorded (i.e., the period from 1989 to 1993), these periods only follow extended periods of drought (i.e., the drought that began in 1985 and ended in 1991).

Artificial recharge by infiltration basins is usually preferable over injection wells due to lower initial capital and operating cost and to recharge efficacy. As a general rule injection wells can inject about one-half of their production rates and require significantly more maintenance than do regular production wells. Exceptions to this preference include areas where aquifers are confined and surface recharge cannot directly recharge the aquifer, or where land costs and availability limit surface basins. If imported water recharge by surface basins is considered, then the addition of recycled water should naturally be considered. However, recycled water recharge only by infiltration basins may not be possible due to initial maximum RWC limitations.

Currently, except to limit seawater intrusion, the direct injection of advanced treated recycled water for reuse has not been implemented anywhere in California. This is due to the highly detailed hydrogeological studies required to insure compliance with the (SWRCB recycled water regulations (Table 1), the extensive groundwater monitoring requirements, and the public's perception of recycled water reuse.

Hydrogeologic units 1 and 3 have the greatest amount of storage capacity in drought conditions, but these units also contain a high density of water supply wells making it very difficult to find a location for artificial recharge infiltration basin(s) or injection well(s) that could comply with SWRCB mandated subsurface travel times for advanced treated recycled water.

The direct injection of advanced treated recycled water to limit seawater intrusion could be further investigated by additional studies, but any additional studies should include evaluating how much additional groundwater could be extracted from Storage Unit 3 in the context of a seawater intrusion barrier program. From the limited hydrogeological information on Unit 3, seawater intrusion to the deeper aquifer may not be occurring due to the aquifer being sealed off by an offshore fault. If seawater intrusion is limited to the upper 50 feet as suggested by Hoover (1980), injection of advanced treated recycled water to limit seawater intrusion might not even be feasible. The seawater barrier would need to be designed to allow adequate groundwater travel time of the treated water before being recovered by production wells. This would suggest that the seawater intrusion barrier, which would consist of a system of injection wells, monitoring wells, and recycled water distribution pipelines, would likely need to be constructed near the coastline.

To evaluate the feasibility of using advanced treated recycled water to limit seawater intrusion, exploration boreholes would need to be drilled along the coastline of Unit 3 to determine the depth and water quality of the aquifers. Pumping tests would need to be conducted on the exploration boreholes to estimate the hydraulic conductivity of the aquifers to determine the groundwater travel time of the injected water, and where monitoring wells would need to be located to insure SWRCB compliance.

If the results of the exploration boreholes and testing suggest that advanced treated recycled water is still feasible, groundwater modeling will need to be used to evaluate the recharge plan and help determine the distance that monitoring wells are to be located from the injections wells. Construction of a test injection well and two monitoring wells will then be needed and a tracer study conducted to prove the groundwater retention time.

With the data collected from these studies, a project CEQA analysis can be done to identify potential environmental impacts. This will likely require development of an Environmental Impact Report (EIR).

4 REFERENCES

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