DECISION MANAGEMENT ANALYSIS
(TASK 3: REPORT 1 OF 2)

- **Water Supply Uncertainties**
- **Monte Carlo Simulation Model**

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DECISION MANAGEMENT ANALYSIS (TASK 3: REPORT 1 OF 2)

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ENSI Draft dated 12/7/2018 (Included as Appendix D2 of the Draft GSP)

Appendix C: Assessment of Water Level Decline, Hydrogeologic Conditions, and Potential Overdraft Impacts For Active BWD Water Supply Wells.
ENSI Draft dated 1/7/2019

1.0 INTRODUCTION

Starting January 1, 2020, California State Law requires the implementation of a Groundwater Sustainability Plan[1] (GSP) to reduce groundwater use by the Borrego Springs Community by approximately 75% over the next 20 years. The community water supply is entirely reliant on local pumping- as explained in the GSP there are currently no feasible sources of imported water. It has long been recognized that the depleting groundwater is an issue that ultimately impacts the viability and quality of life.[2] Water use has exceeded the natural replenishment rate for decades and the groundwater sub-basin is in a state of critical overdraft per the State Department of Water Resources (DWR). This condition has existed for decades, has been the subject of ongoing debate and discussion, and is now subject to State Law under the Sustainable Groundwater Management Act (SGMA) enacted September 2014[3].

Borrego Springs is a small unincorporated community located on the western edge of the Sonoran Desert. It is a Severely Disadvantaged Community (SDAC[4]) and located within an Economically Distressed Area (EDA[5]). The Borrego Water District (BWD) is the sole public provider of potable water to the Borrego Springs SDA Community. Of concern are the potential impacts on the Borrego Water District's (BWD) ability to produce drinking water and related increase in water production costs should the target pumping rate fail to achieve the SGMA-mandated sustainability goals as described in the Groundwater Sustainability Plan.

This Report was developed to develop tools to allow the Borrego Water District (BWD) to look at potential water supply situations that may directly impact groundwater users in Borrego Springs, assess the probability of the water supply situations occurring, and make decisions accordingly. Included is assessment of the potential range of outcomes of the groundwater extraction restrictions that will allow the BWD to look at water supply situations, such as the potential need for water treatment, or loss of individual supply wells due to ongoing groundwater overdraft and be able to assess its probability of occurring. The assessment of the potential range of outcomes of the groundwater extraction restrictions is supported by the use of Monte Carlo simulation methods.

[1] The Draft GSP is currently being circulated for public review- a copy is available at the BWD website (www.BVGSP.org). It was developed by the newly-formed Groundwater Sustainability Agency comprised of the County of San Diego and the Borrego Water District.

[2] Borrego Springs Community Plan, August 3, 2011, Rev. 5-15-2013, 6-18-2014.

[3] https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

[4] As defined by DWR, Severely Disadvantaged Communities (SDAC) are Census geographies having less than 60% of the Statewide annual median household income ($37,091 [2017]). Map-based DAC information developed by the DWR can be reviewed at https://gis.water.ca.gov/app/dacs/

[5] As defined by DWR, an EDA is a municipality with a population of 20,000 persons or less, a rural county, or a reasonably isolated and divisible segment of a larger municipality with a population of 20,000 persons or less, with a median household income (MHI) that is less than 85% of the Statewide MHI, and with one or more of the following conditions: 1) Financial hardship 2) Unemployment rate at least 2% of higher than statewide average 3) Low population density.

This Report combines two deliverables specified in Task 3 of the grant agreement (see **Appendix A**):

- Water Supply Uncertainties. This includes assessment of the overall water balance, Subbasin-wide water quality over time, and potential impact of overdraft on BWD well production. **Sections 3 to 5** provide explanation of the underlying water components that are considered together to quantify overdraft.

  Sections 6 and 7 examines the uncertainty associated with the assessment of overdraft.

  Sections 8 and 9 provide in-depth review of water quality and BWD water well productivity and associated uncertainty. These sections reference two ENSI Reports that are included in their entirety.

- Monte Carlo Simulation (MCS) Model. The water balance and successful attainment of a sustainable groundwater is further examined specific to the proposed 5,700 AFY pumping target and groundwater recharge variability. **Section 6** details the results of the MCS.

A second Task 3 report (2 of 2) will address analyses will be performed of the potential impacts of various water reduction scenarios on the SDAC, rate payers, and BWD infrastructure. It will combine a cost structure uncertainty analysis with a larger scale impact assessment (SGMA/Environmental/Societal/Government Impacts) based on an economic model (IMPLAN) to examines community-wide socioeconomic impacts and changes that will result from the GSP.

All of the Task 3 reports follow, in part, from an overview analysis of SDAC impacts included in a separate ENSI document prepared for Task 2.

2.0 REPORT OVERVIEW

The intent of the work described in this Report is to develop decision management analyses and methodologies to look at potential water supply situations that may directly impact groundwater users in Borrego Springs, assess the odds that the problems may occur, assess impacts, and provide supporting analyses to make decisions accordingly. Following detailed review and analysis of the overall water supply, together with ongoing GSP development, the focus of the work shifted to a more fundamental analysis of the impact of critical overdraft to support the GSP going forward.

As described by the USGS[6] "Continued pumping has resulted in an increase in pumping lifts, reduced well efficiency, dry wells, changes in water quality, and loss of natural groundwater discharge." Further, the uppermost and most prolific portions of the aquifer system have been or are becoming dewatered[7]. While substantial quantities of water remain, the aquifer system with depth has lower yield and diminishing water quality. Given the current rates of groundwater level decline this means that water wells will become less efficient and more costly to operate, and that water treatment may be required for potable water supplies.

In essence there are two fundamental questions that impact the management of the water supply going forward, recognizing that water levels will continue to decline over the GSP compliance period before sustainable pumping rates are achieved. The questions include:

1) Can historical water quality data and ongoing water testing be used to predict future water quality?

2) How will water supply well production be affected by ongoing water level decline?

Underlying these questions specific to the attainment of sustainability is the need to understand the potential variability of groundwater recharge. Ultimately the magnitude of SGMA-mandated water use restrictions is directly tied to recharge given the absence of imported water to the Borrego Springs community. The GSP's target pumping rate of 5700 AFY, a value based on the long-term average annual recharge rate established in by the USGS' 2015 Report, represents just 26% of the Baseline Pumping Allocation.

The work done to develop the GSP has made substantial progress toward addressing these questions yet significant uncertainty remains. Additional supporting information and analyses will be developed as the GSP proceeds and a flexible, adaptive management strategy will be employed to manage the water supply.

[6] USGS Report 2015-5150 entitled Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California. By Claudia C. Faunt, Christina L. Stamos, Lorraine E. Flint, Michael T. Wright, Matthew K. Burgess, Michelle Sneed, Justin Brandt, Peter Martin, and Alissa L. Coes

[7] See detailed description included in the draft GSP, pages 2-44, 3-3, and 3-8. Historical changes in water are documented in ENSI 12/7/2018 included in Appendix D2 of the Draft GSP.

There are three draft ENSI documents incorporated into this Report as follows:

1) An assessment of the Subbasin-wide water balance that shows how recharge variability over time may affect GSP compliance (ENSI 9/12/2018). Monte Carlo simulation methodologies were used to examine how the aquifer will respond under pumping over time given highly variable groundwater recharge rates. The results were used to develop minimum thresholds for chronic lowering of groundwater levels in Section 3.3.1.1 of the Draft GSP.

The main body of this Task 3 Report follows from the 9/12/2018 ENSI report.

2) Multi-parameter evaluation of water quality trends based on general minerals that shows how water quality has changed due to long-term overdraft, and provides for a systematic overview of groundwater quality variations. Also included was an assessment of water quality indicators that may provide 'early warning' for elevated sulfate and arsenic concentrations (ENSI 12/7/2018, Included as Appendix D2 of the Draft GSP, and **Appendix B** of this Report).

3) A local-scale analysis of the expected changes in BWD water well production with ongoing overdraft based on well-specific review of the USGS Groundwater model water level calibration and development of lithology-based hydrogeologic aquifer properties developed from driller's logs. (ENSI 1/7/2019, **Appendix C** of this Report). The primary use of this report will be in the GSP's evaluation of water levels relative to groundwater model performance and predictive capabilities.

The findings of the 12/7/2018 and 1/7/2019 ENSI Reports are summarized in this Task 3 report with an emphasis on how the work can be used going forward to support water supply management decisions. These reports are included in their entirely as Appendices to this Task 3 document. Please note that the various values used as Baseline Pumping Allocations vary among reports as the BPA were under development as the reports were developed. While there are minor numerical differences among the BPA values as the prior value of 22,044 AFY has been revised to 21,963 AFY in the Draft GSP, the target pumping rate of 5700 AFY has not changed and the report conclusions remain essentially unchanged.

3.0 WATER BALANCE COMPONENTS

The Borrego Springs Subbasin (Borrego Basin) of the Borrego Valley Groundwater Basin is currently in a state of critical overdraft. Groundwater pumping reductions will be necessary under the Sustainable Groundwater Management Act (SGMA) to achieve long-term sustainability of the water supply for the Borrego Springs community. Chronic lowering of groundwater levels and reduction of groundwater storage are two of six Sustainability Indicators, if found to be significant and unreasonable, describe the undesirable results of critical overdraft to be addressed in the GSP (DWR, 2017. CA Department of Water Resources Sustainable Management Criteria Best Management Practice Guidance, November 2017). The GSP includes metrics to establish thresholds for all of the sustainability indicators.

This section of the Report focuses on the basin-wide water budget, termed here as the water balance. DWR has established a maximum period of 20 years for the Borrego Basin to achieve sustainability where "the sustainable yield of a basin is the amount of groundwater that can be withdrawn annually without causing undesirable results. Sustainable yield is referenced in SGMA as part of the estimated basin-wide water budget and as the outcome of avoiding undesirable results…for the six sustainability indicators" (DWR, 2017. p.32). Potential changes in BWD supply well water quality and production rates associated with ongoing overdraft are also of concern and addressed in following sections of this Draft Report.

The purpose of this section is to present a methodology to examine the proposed 5700 AFY target pumping rate in terms of the overall hydrologic water balance and future overdraft that will occur as groundwater production rates decrease. The analysis is based on the maximum 20-year reduction period allowable under SGMA. The 5700 AFY target is based on the average groundwater recharge rate as determined by the US Geological Survey ([USGS Report, 2015] Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed, Michelle, Brandt, Justin, Martin, Peter, and Coes, A.L., 2015, Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California: U.S. Geological Survey Scientific Investigations Report 2015–5150, 135 p., http://dx.doi.org/10.3133/sir20155150).

The 5700 AFY target pumping rate is examined here based on an analysis of the hydrologic water balance (water budget) conducted by the USGS and is a water extraction rate equal to the amount of water that replenishes the Borrego Basin as groundwater recharge. The model can be viewed as a large box that is discretized into smaller rectangular boxes to track the flow of water over time into and within the alluvial basin. The target pumping rate was set equal to the average annual groundwater recharge inflow rate and is based on a combination of groundwater inflow (into the sides of the large box) and water that enters into the basin from adjacent watersheds and flows into the aquifer system as recharge (see **Figure 1**).

As stated in the USGS Report (Summary and Conclusions, p. 128*): "The main source of recharge to the system is underflow from the upstream portions of the watershed and runoff from creeks and streams draining the upstream portions of the watershed that, with the exception of runoff generated in response to exceptionally large and infrequent storms, quickly seeps into the* *permeable streambeds and infiltrates through the unsaturated zone. Over the 66-year study period [ed: 1945 to 2010], on average, the natural recharge that reaches to the saturated groundwater system is approximately 5,700 acre-ft/yr, but natural recharge fluctuates in the arid climate from less than 1,000 to more than 25,000 acre-ft/yr."*

The groundwater recharge rate, as noted above, varies widely over time in contrast to the stated average. This variability is examined here by examining the amount of overdraft that will occur over a 20-year period to evaluate how effective the target pumping rate of 5700 AFY will be towards meeting the SGMA goals. To date the overall aquifer water balance has been negative in that outflows have exceeded inflows, leading to an estimated cumulative depletion (or overdraft) of 440,000 acre-feet (AF) as of 2010 with associated water declines of over 150 ft (USGS, 2015. p.129). Cumulative overdraft was calculated to be 520,000 AF as of 2016 as described in the GSP (page ES-3).

The Borrego Basin water balance calculations provide a direct measure of the effect of pumping rate reductions on a basin-wide scale by tracking how much more water will be derived from storage. Long-term overdraft has been and will continue to occur because outflows exceed inflows.

The Borrego Basin aquifer water balance consists of six flow components:

- *Inflows* occur via groundwater inflow, surface (natural) recharge, and irrigation return flows.

- *Outflows* occur via groundwater outflow, deep-rooted groundwater dependent plant use (termed evapotranspiration), and groundwater pumping.

The six components are calculated in the USGS model. Annual values for each of the parameters used in this report were obtained from Dudek's update of the USGS model update (as presented in Appendix D of the Draft GSP). An overview of these parameters is included in this Report. Additional details are available in Dudeks' model update and in the USGS Model Report.

3.1 INFLOWS

Groundwater.
The USGS groundwater model allows for time-varying groundwater inflow rates but in this case the inflow rate was relatively constant over the model duration, approximately 1400 AFY as stated in the USGS Report. Most of this inflow occurs along the northwestern and western edges of the valley. Please refer to the GSP for additional details.

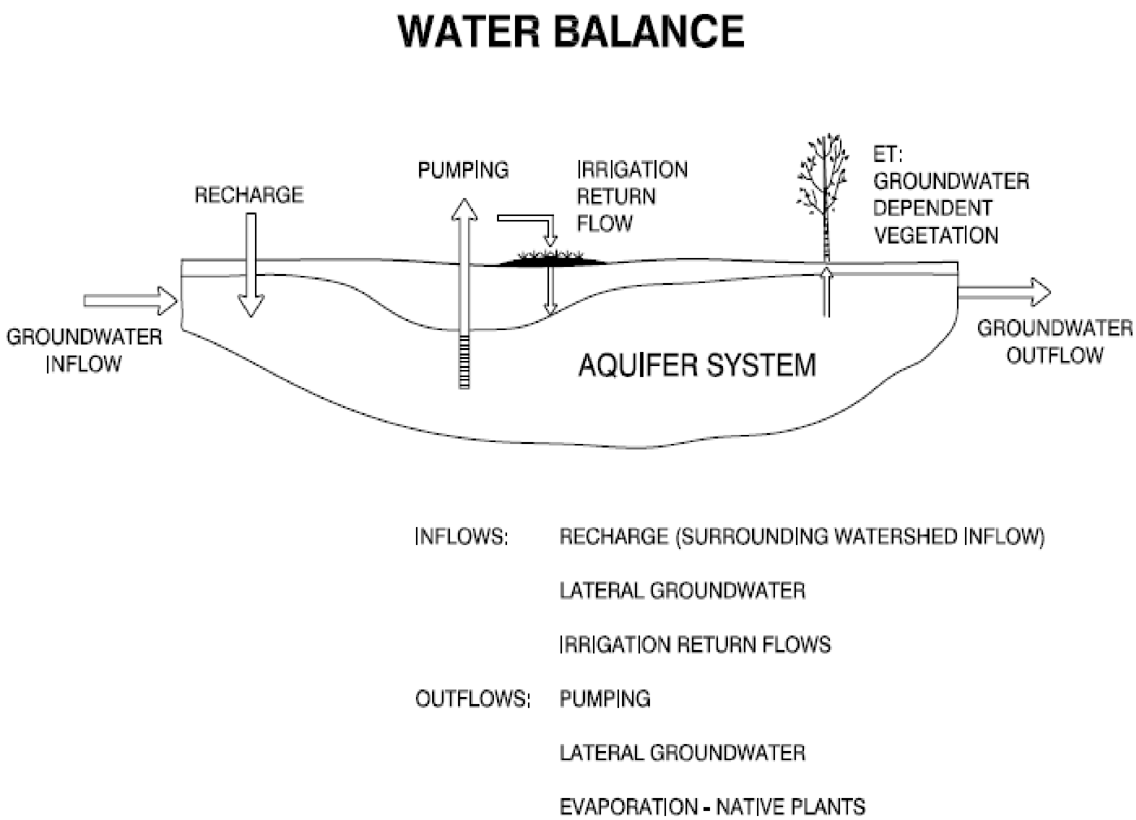
There is no groundwater flow in or out of the northeastern side model domain where the NW-SE trending Coyote Creek Fault occurs because it is assumed to be a no-flow boundary condition. The potential impact of this assumption has not been assessed in this report.

Natural Recharge.
The primary source of water to the Borrego Basin is surface water (stormwater and ephemeral stream flow) that flows into the valley from adjacent mountain watersheds and then infiltrates. Direct recharge by rainfall within the valley is very low compared to surface water inflows as the annual rainfall averages 5.8 in/yr. [USGS Report, page 43].

The contributory watersheds are approximately 400 mi^2 and much larger in area than the approximately 110 mi^2 Borrego Valley (USGS Model Report). Further, because the adjacent watersheds are higher in elevation and have higher precipitation rates they provide the bulk of the water that enters the Borrego Basin. Inflows from the adjacent watersheds were not directly calculated by the USGS groundwater model, instead these were determined using the USGS' regional scale Basin Characterization Model (BCM) for the watersheds located west and north of the Borrego Basin. Per the USGS Report (p. 48) "*The BCM calculates potential in-place recharge and potential runoff and generates distributions of both components. In this study, the BCM provided estimates of the underflow from the adjacent mountains and basins and potential runoff in stream channels into the basin. Moreover, the BCM can be used to compare the potential for recharge under the current climate (2010) and that for past wetter and drier climates (Flint and Flint, 2007a). The BCM model domain includes the watersheds that surround and drain into the Borrego Valley (fig. 16).*"

The BCM calculations rely on multiple types of hydrologic data and require streamflow measurements to support model calibration. Per the report "*[h]istorical discharge data are available for 1950–83 for Coyote Creek, 1950–2004 for Borrego Palm Creek, and 1958–83 for San Felipe Creek*". The BCM is a highly complex hydrologic model that incorporates parameters such as precipitation data, runoff coefficients, multiple soils data and estimated parameters, in-channel groundwater flow rates, and soil and plant evapotranspiration estimates. As noted (USGS Report p.48) it calculates both surface water and groundwater flows wherein "*the BCM provided estimates of the underflow from the adjacent mountains and basins and potential runoff in stream channels into the basin*". These inflow values were then re-assessed by allowing the BCM-determined inflows to vary when the Borrego Basin model was calibrated (USGS Report p.128).

FIGURE 1

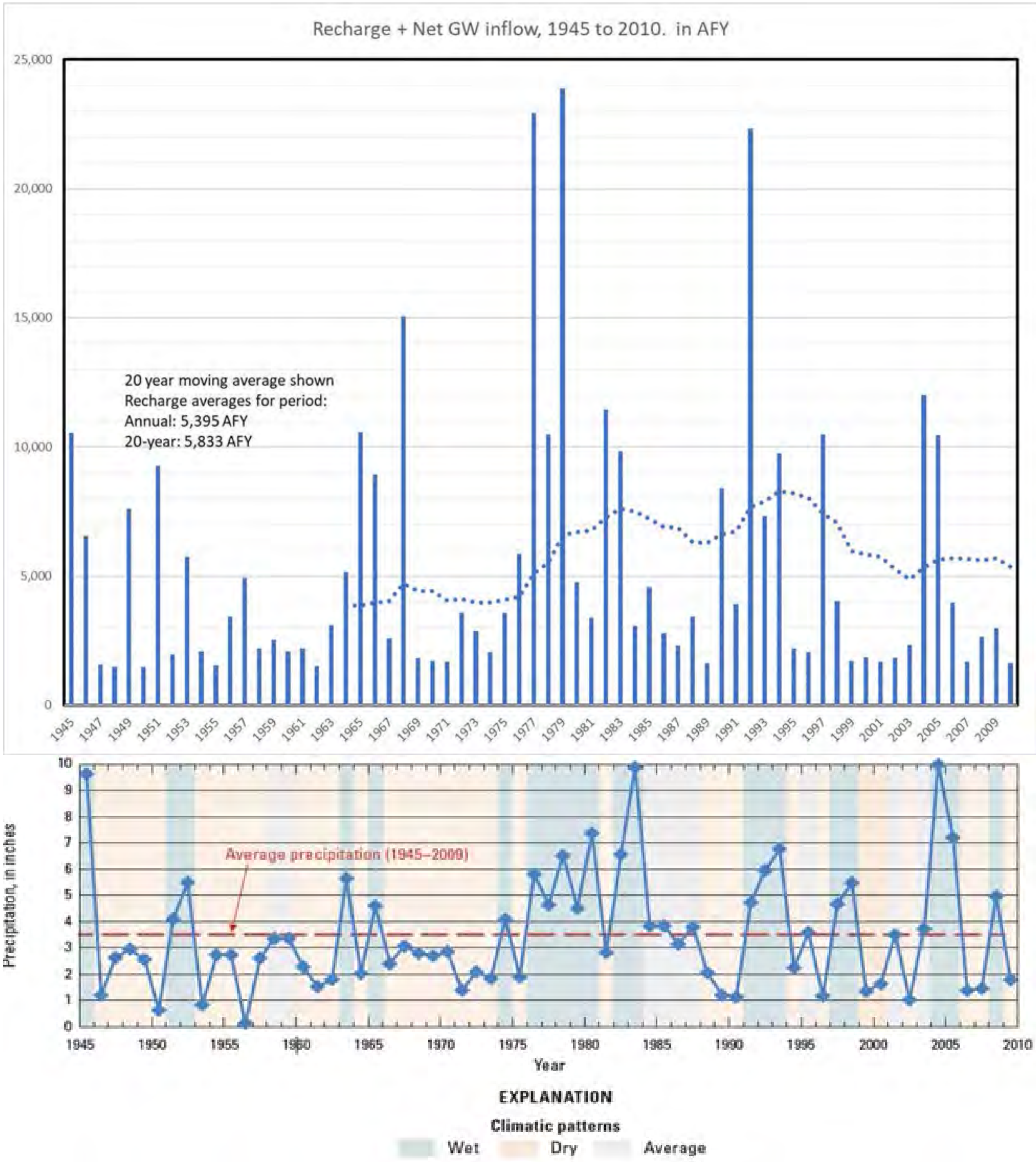


	Current		Target	
	Inflows	Outflows	Inflows	Outflows
Groundwater	1400	525	1400	525
Natural Recharge	4300		4300	
GW-Dependent ET		400		400
Irrigation Return Flow (10%)	2204		570	
Pumping		**22,044**		**5,700**
totals	7904	22969	6270	6625
net		-15065		-355

The basin-wide water balance is based on the USGS Model and uses a baseline pumping (BPA) allocation of 22,044 AFY.

The USGS model's annual recharge rates calculated for the 1945 to 2010 model period of 66 years are shown in **Figure 2**. Also shown is the rainfall record for Borrego Desert State Park (station 040983) presented as Figure 3 in the USGS Model Report.

FIGURE 2. Annual Recharge



The recharge rates shown in **Figure 2** include groundwater inflow and the water that enters from adjacent watersheds- a value that varies over time. As noted above, the watershed inflows were calculated independently of the groundwater model by the USGS' BCM. Review of the recharge values shows that the inflows have a wide range of values, that high recharge events occur on a decadal scale, and there is some periodicity to the time series. The average value for the 1945 to 2010 period generally cited as the model period was 5,395 AFY. The 20-year average, a period equal to that described under SGMA, is also shown in **Figure 2** to also illustrate how the average recharge rate varies over time when viewed over the 20-year time GSP planning period. The years with high recharge, though infrequent, cause the 20-year averages to generally be higher than the annual recharge rates.

Figure 2 also includes a graph of the rainfall record included in the USGS Report for Borrego Valley. Visually there is a good correlation between precipitation and recharge events. Recharge predominantly occurs as a result of inflows along the basin margins so the correlation indicates that the inflows are readily recharged as they occur.

The USGS groundwater model focused on the 1945 to 2010 period and was updated through 2016 by Dudek (their report was included as an Appendix to the GSP). The target pumping rate of 5700 AFY was established based on a recharge inflow rate that consists of 1400 AFY of groundwater inflow and 4300 AFY of surficial recharge per the USGS Report. **Table 1** summarizes the statistics of the recharge values.

Table 1. Recharge Values (Inflow) from USGS Model (1945 to 2016)

Year Ending	GW Inflow AFY	Recharge AFY	Total Recharge AFY	20-yr Average AFY	Year Ending	GW Inflow AFY	Recharge AFY	Total Recharge AFY	20-yr Average AFY
1945	1,366	9,182	10,548		1981	1,366	2,011	3,377	6,771
1946	1,366	5,201	6,568		1982	1,366	10,071	11,437	7,266
1947	1,366	196	1,562		1983	1,366	8,443	9,809	7,601
1948	1,370	112	1,482		1984	1,370	1,679	3,049	7,496
1949	1,366	6,232	7,599		1985	1,366	3,183	4,549	7,195
1950	1,366	127	1,493		1986	1,366	1,402	2,769	6,888
1951	1,366	7,915	9,282		1987	1,366	926	2,293	6,872
1952	1,370	594	1,964		1988	1,370	2,039	3,409	6,291
1953	1,366	4,375	5,741		1989	1,366	233	1,600	6,280
1954	1,366	725	2,091		1990	1,366	7,016	8,382	6,614
1955	1,366	174	1,540		1991	1,366	2,515	3,882	6,723
1956	1,370	2,067	3,437		1992	1,370	20,913	22,283	7,659
1957	1,366	3,566	4,932		1993	1,366	5,915	7,282	7,879
1958	1,366	828	2,195		1994	1,366	8,348	9,714	8,263
1959	1,366	1,151	2,517		1995	1,366	787	2,153	8,191
1960	1,370	696	2,066		1996	1,370	656	2,026	8,000
1961	1,366	835	2,202		1997	1,366	9,088	10,454	7,377
1962	1,366	163	1,529		1998	1,366	2,625	3,992	7,054
1963	1,366	1,741	3,108		1999	1,366	318	1,684	5,944
1964	1,370	3,785	5,155	3,851	2000	1,370	450	1,820	5,798
1965	1,366	9,204	10,570	3,852	2001	1,366	283	1,650	5,712
1966	1,366	7,548	8,915	3,969	2002	1,366	428	1,795	5,230
1967	1,366	1,231	2,597	4,021	2003	1,366	932	2,298	4,854
1968	1,370	13,666	15,036	4,698	2004	1,370	10,615	11,985	5,301
1969	1,366	459	1,825	4,410	2005	1,366	9,034	10,401	5,593
1970	1,366	337	1,704	4,420	2006	1,366	2,563	3,929	5,652
1971	1,366	330	1,697	4,041	2007	1,366	292	1,658	5,620
1972	1,370	2,193	3,563	4,121	2008	1,370	1,229	2,599	5,579
1973	1,366	1,512	2,878	3,978	2009	1,366	1,572	2,938	5,646
1974	1,366	671	2,037	3,975	2010	1,366	234	1,601	5,307
1975	1,366	2,215	3,581	4,077	2011 (update)	1,366	1,182	2,548	5,240
1976	1,370	4,482	5,852	4,198	2012 (update)	1,370	6,493	7,863	4,519
1977	1,366	21,545	22,912	5,097	2013 (update)	1,366	1,948	3,314	4,321
1978	1,366	9,100	10,467	5,510	2014 (update)	1,366	1,617	2,983	3,985
1979	1,366	22,504	23,871	6,578	2015 (update)	1,366	2,313	3,679	4,061
1980	1,370	3,372	4,742	6,712	2016 (update)	1,370	1,768	3,138	4,116
					Averages: 1945 to 2010	1,367	3,905	5,395	5,833
					1945 to 2016				
					Average	1,367	3,905	5,272	5,668
					Median	1,366	1,858	3,226	5,593
					Maximum	1,370	22,504	23,871	8,263
					Minimum	1,366	112	1,482	3,851
					Range	4	22,392	22,388	4,412

Review of the model recharge values in **Table 1** emphasizes how much the recharge varies over time and the relative impact of infrequent ‘wet’ years. The annual recharge rate (1945 to 2016) has a wide range of 1,482 to 23,871 AFY with an average of 5272 AFY (versus the USGS’ stated average of 5700 AFY for the 1945 to 2010 period). The median, the midpoint of all of the values, is 3226 AFY. This statistic indicates that half of the time the recharge rate was 3226 AFY or less.

The 20-year averages provide time intervals in the context of the 20-year GSP planning period. Due to the occurrence of a few years with very high recharge rates the 20-year values are, on average, greater than the annual values. Especially noteworthy is comparison of two 'back to back' periods- 1955 to 1974, and 1975 to 1994 where the 20-year averages were 3,975 AFY and 8,263 AFY, respectively (refer to the 20-year values for 1974 and 1994). The effect of pumping reductions over a 20-year GSP would be very different during these two 'dry' and 'wet' periods.

Irrigation Return Flows

The bulk of current groundwater use is for farm and golf course irrigation. A portion of this water returns to the aquifer as a 'return flow'. The rate and timing of irrigation return flows to the aquifer depend on multiple factors. Among these include:

1. How much the application rate exceeds plant and crop demand. For example, irrigation may be applied at a rate that exceeds crop or turf demand to manage the soil so as to reduce soil salinity for plant health. Overwatering and system leakage may also occur.

2. Surface soil moisture conditions. Soils have a 'soil moisture capacity' and can retain a significant quantity of water that will not pass downward when the moisture levels are less than the moisture capacity. Water will then be lost as evaporation from wet soils.

3. Plant root depth. Crops and plants will have varying root depths and thus varying ability to extract water from soil after it is applied.

4. Movement and potential storage of water in the unsaturated zone above the aquifer. Unsaturated flow is highly dependent on soil moisture (or residual moisture- water that is retained in soil following a wetting event). As noted by the USGS Report (p. 3), *"[D]epending on the thickness, permeability, and residual moisture content in the relatively thick unsaturated zone, it takes tens to hundreds of years for the bulk of return flow to reach the water table. In addition, not all water that reaches the root zone reaches the water table because some water is lost through evapotranspiration or goes into storage in the unsaturated zone. Therefore, in many areas, water that is applied to previously unirrigated land arrives at the underlying water table decades or longer after it is applied."*

A distinction needs to be made here between recharge that occurs as a result of surface water inflows versus infiltration of irrigation return flows. Comparison of the annual precipitation record and the recharge calculated by the model (**Figure 2**) suggests that groundwater recharge may be occurring fairly rapidly. The typical conceptual model for infiltration is that of piston flow where infiltration is transmitted rapidly through the vadose zone. Most of this type of recharge occurs along the edges of the basin as a result of surface water flows entering stream channels and floodplains in the valley. In contrast the volume of recharge that occurs within the valley by direct infiltration of rainfall and irrigation return flow is relatively low and has the potential to occur more slowly as discussed above. The USGS model included a 16 year 'spin up' period (prior to 1945) to allow for the delay associated with vadose zone recharge (see page 86 of the USGS Report).

Irrigation return flows are determined in the groundwater model using the Farm Process Package, or FMP. As described in the USGS Model Report (Table 9) the FMP is used to *"Setup and solve equations simulating use and movement of water on the landscape as irrigated agriculture, municipal landscape, and natural vegetation."* In turn it supports the time-dependent calculation of water flow within the unsaturated zone using the unsaturated zone flow package, or UZF, that *"Simulates the infiltration and exfiltration of water below the root zone through the unsaturated zone in combination with FMP."* The calculations are used in the model to determine the volume of irrigation that flows below the root zone and enters the unsaturated zone. The UZF simulates the downward flow of water from beneath the root zone to the water table and thus incorporates a time delay.

The vadose zone flow rate (UZF flow) is compared here to the total pumping rate based on review of Dudek's model update report (as presented to the Borrego Advisory Committee 11/2017 and included in Appendix D of the Draft GSP). Appendix B of the report tabulates, by year, the UZF flows and total pumping rates. Over the last 10 years of the model the UZF flows are approximately 10% of total pumping, and range from 7 to 13%. Combined agricultural and golf course irrigation represent approximately 80% of total pumping so these rates correspond to irrigation-specific return flow rates of approximately 9 to 16%.

The return flow values used here are derived from the model output and may appear lower than what is stated in the USGS report introduction (p.2) where: "*Since agricultural, recreational, and municipal land uses have been developed, a relatively small amount of recharge also occurs from excess irrigation water and septic-tank effluent. Recharge from irrigation return flows, as indicated by the model results, was about 10–30 percent of agricultural and recreational pumpages*". Review of the model results do show irrigation return flow (UZF) rates historically occurred in the range of 10 to 30 percent; however, the rates have decreased over time and are now approximately 10 percent (see, for example, Figure 6 of the model update report). The current model-determined irrigation return flow rate of 10 percent (of total pumping, roughly 13% of irrigation-related pumping) is used in this Draft Report.

For reference a 15% excess water application rate for soil management is stated without basis to be necessary for irrigation done in the Coachella Valley per RWQCB-Colorado Region Order R9-2014-0046 [https://www.waterboards.ca.gov/coloradoriver/board_decisions/adopted_orders/orders/2014/0046cv_ag_waiver.pdf]. The UZF-calculated rates are similar given that not all of the water can be assumed to pass through the relatively deep vadose zone that occurs in the Borrego Valley. The amount of water required for soil management will vary with irrigation method, soil type, season, and crop type.

These water balance calculations do not address water quality impacts due to irrigation return flows. Irrigation return flows will contain elevated levels of dissolved salts due to the evaporation of applied water and water in excess of crop demand is necessary to manage soil salinity and maintain soils for cultivation. Return flows also have the potential to mobilize minerals such as naturally-occurring evaporites from the vadose zone. In addition, contaminants such as nitrates and pesticides can accumulate in the vadose zone and subsequent transport may indeed take years. As a result, irrigation water applied at the start of the 20-year GSP planning period has the potential to contaminate the aquifer both during and possibly after the planning period.

3.2 Outflows

Per the USGS model description (p.115): *"Groundwater discharge occurs from three primary sources - (1) evapotranspiration in areas where the water table is shallow and direct uptake from plants (mostly in and around the Borrego Sink) can occur; (2) a small amount of seepage from the southern end of the basin; and (3) groundwater pumpage for agricultural, recreational, and municipal uses."*

Evapotranspiration (ET).

Consumptive use of groundwater by native plants (phreatophytes) within the Borrego Basin is primarily associated with mesquite trees located mostly in and around the Borrego Sink where shallow groundwater condition historically occurred. The current ET rate is estimated to be 400 AFY. Historically it is estimated that ET was 7,100 AFY prior to development-related groundwater extraction (USGS Report, p. 129). It has declined over time and was estimated to be approximately 1,220 AFY in 1980 (Moyle, 1982). The decrease is due to the loss of phreatophytes due to the long-term groundwater level decline.

Groundwater Outflow.

Similar to groundwater inflow, while the USGS model can allow for time-varying groundwater outflow rates, the outflow rate was relatively constant over the model duration, approximately 525 AFY. Note that since groundwater outflow is less than groundwater inflow (1400 AFY) there is a net accumulation of groundwater in the Borrego Basin at an approximate rate of 875 AFY.

Total Pumping

A starting value of 22,044 AFY is used in this draft report that corresponds to the currently-estimated baseline pumping allocation (BPA). The water balance calculations assume for demonstration purposes that pumping rates decline at a constant annual rate over a 20-year period until the rate is reduced to 5700 AFY. This methodology can assume various pumping schedules to examine overdraft over time.

3.3 Current Water Balance

The current water balance is shown in **Figure 1**. The rate of overdraft is approximately 15,000 AFY. As previously described, this is based on the overall water balance parameters established by the USGS groundwater model and the currently-estimated baseline pumping allocation.

Note that when the target pumping rate of 5700 AFY is applied there is a net negative balance of 355 AFY equal to approximately 6% of the target pumping rate. Given the overall uncertainties in the water balance, future refinements of the water balance parameters may be required should this methodology be used to assess cumulative overdraft under the GSP.

4.0 SUSTAINABLE PUMPING RATE: BASELINE RATE AND REDUCTIONS

SGMA describes a maximum 20-year attainment period starting in 2020 with 5-year assessment periods (refer to the GSP for further details). SGMA does not mandate a 20-year period and therefore does not preclude using shorter timeframes for attainment. Calculations are presented here for a baseline case that includes:

- A baseline pumping allocation of 22,044 AFY[8]
- An average annual groundwater recharge (inflow) rate of 5700 AFY (The stated value in the USGS Model Report. **Table 1** includes the annual values and summary statistics.)
- Evapotranspiration (native plant ET) rate of 400 AFY
- Groundwater outflow rate of 525 AFY
- Irrigation return flow rate of 10% pf total pumping.

An Excel spreadsheet was used to calculate the water balance where the pumping rate is reduced by a fixed percentage each year until the pumping rate is reduced from 22,044 to 5700 AFY at the end of the 20-year period. This requires an annual reduction of approximately 6.5% per year. The cumulative volume of net groundwater removal from storage, or groundwater overdraft, is calculated over the 20-year SGMA planning timeframe.

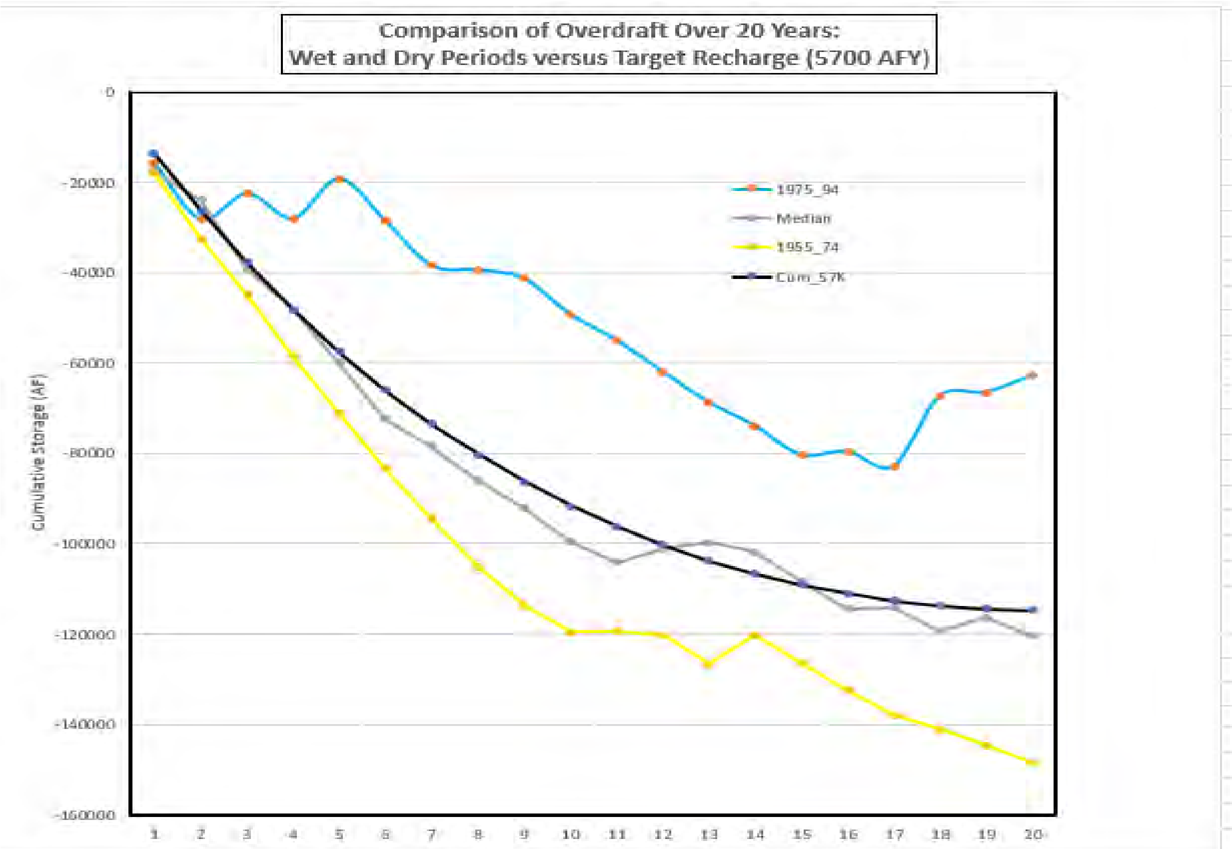
Figure 3 shows the results. Four groundwater recharge rates are used to calculate overdraft over the 20-year period using the same pumping rate reductions. The calculates the effect of using recharge values from the USGS Model for low, median, and high recharge periods. Here the periods of 1955 to 1974 (low), and 1975 to 1994 (high), are used to illustrate how the range of recharge rates compare to the rate used to set the target pumping rate. The median recharge rate is also shown.

Review of the results demonstrates

- Total overdraft is approximately 115,000 AF when an annual average recharge rate of 5700 AFY is assumed.
- Overdraft is as high as 149,000 AF under the low recharge conditions (29% more than for the average recharge rate of 5700 AFY).
- An overdraft of 63,000 AF occurs even under the 'wettest' recharge conditions

[8] The BPA was updated to a value of 21,963 AFY in the Draft GSP after this analysis was done. It was not revised as the difference is less than 0.5 percent and has no material effect on the this Report.

FIGURE 3

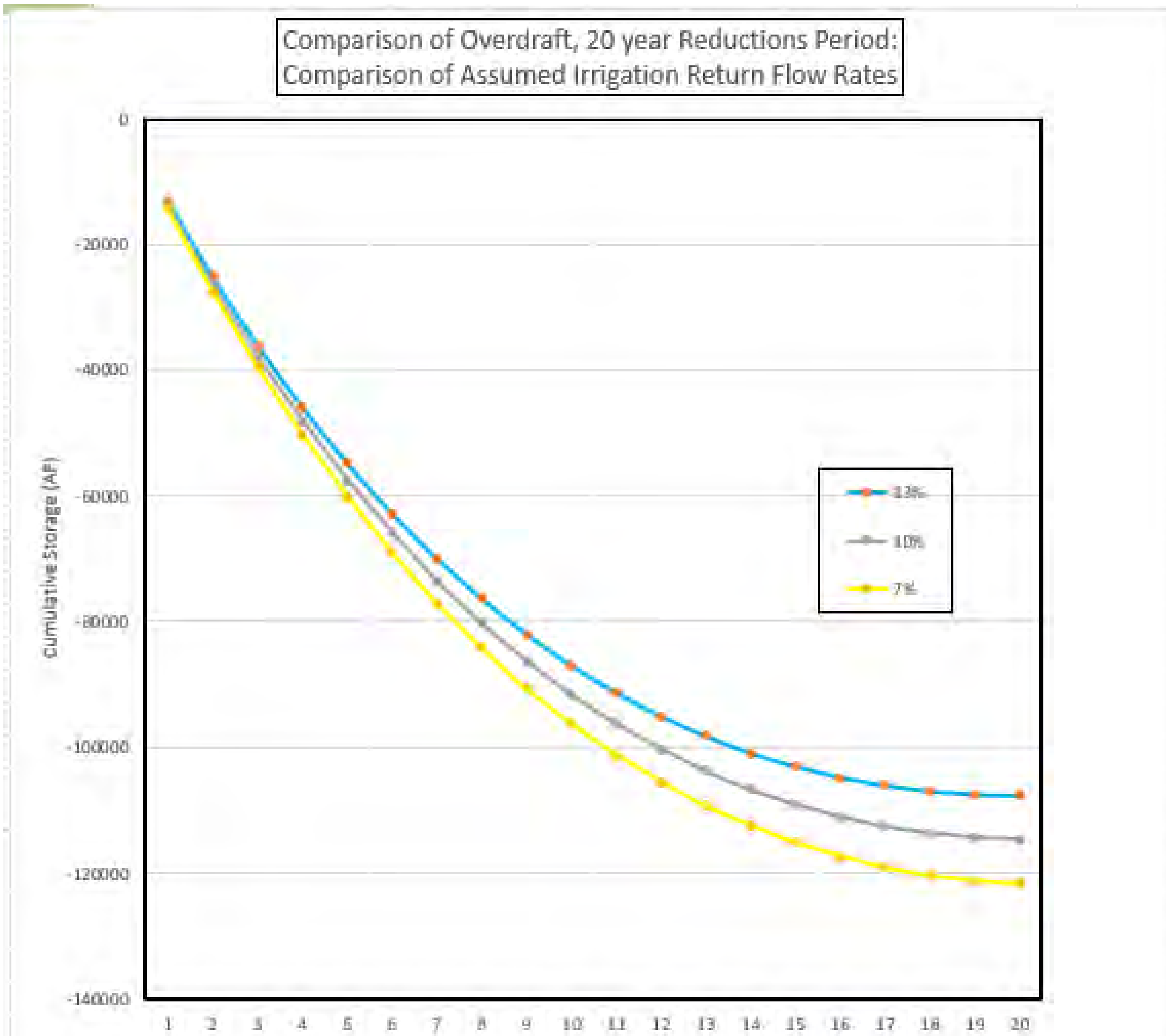


	INFLOW (AFY)					OUTFLOW (AFY)				NET: INFLOW-OUTFLOW (AFY)							
	GW-in	Natural Recharge			Irrigation Return	GW_out	ET	Q_total		Cumulative storage				Annual Change in Storage			
year	(GW BC)	1975_95	Median	1955_75				22044	yr	1975_94	5700 AFY	Median	1955_74	1975_94	5700 AFY	Median	1955_74
1	1400	2215	470	174	2060	525	400	20603	1	-15852	-13767	-17597	-17893	-15852	-13767	-17597	-17893
2	1400	4482	10540	2067	1926	525	400	19255	2	-28225	-26322	-23912	-32681	-12373	-12555	-6315	-14787
3	1400	21545	259	3566	1800	525	400	17996	3	-22401	-37744	-39374	-44836	5824	-11422	-15462	-12156
4	1400	9100	5894	828	1682	525	400	16819	4	-27963	-48106	-48143	-58671	-5562	-10363	-8769	-13834
5	1400	22504	1803	1151	1572	525	400	15720	5	-19131	-57479	-60013	-71193	8832	-9373	-11870	-12522
6	1400	3372	467	696	1469	525	400	14692	6	-28507	-65926	-72294	-83244	-9375	-8448	-12281	-12052
7	1400	2011	5808	835	1373	525	400	13731	7	-38379	-73509	-78369	-94292	-9872	-7583	-6075	-11048
8	1400	10071	3291	163	1283	525	400	12833	8	-39383	-80284	-86152	-105204	-1004	-6775	-7783	-10912
9	1400	8443	4380	1741	1199	525	400	11994	9	-41260	-86304	-92092	-113782	-1877	-6020	-5940	-8578
10	1400	1679	2223	3785	1121	525	400	11210	10	-49195	-91618	-99483	-119611	-7935	-5314	-7391	-5828
11	1400	3183	4325	9204	1048	525	400	10477	11	-54966	-96272	-104112	-119360	-5771	-4654	-4629	250
12	1400	1402	11249	7548	979	525	400	9792	12	-61901	-100309	-101200	-120150	-6935	-4037	2912	-789
13	1400	926	9182	1231	915	525	400	9151	13	-68736	-103770	-99780	-126680	-6835	-3461	1420	-6531
14	1400	2039	5201	13666	855	525	400	8553	14	-73920	-106693	-101801	-120237	-5184	-2923	-2021	6443
15	1400	233	196	459	799	525	400	7994	15	-80406	-109112	-108325	-126498	-6486	-2419	-6523	-6260
16	1400	7016	112	337	747	525	400	7471	16	-79639	-111061	-114461	-132409	767	-1949	-6137	-5912
17	1400	2515	6232	330	698	525	400	6982	17	-82933	-112570	-114038	-137888	-3294	-1509	423	-5479
18	1400	20913	127	2193	653	525	400	6526	18	-67418	-113669	-119310	-141093	15515	-1098	-5272	-3205
19	1400	5915	7915	1512	610	525	400	6099	19	-66517	-114383	-116409	-144596	901	-714	2901	-3502
20	1400	8348	594	671	570	525	400	5700	20	-62824	-114738	-120469	-148580	3692	-355	-4061	-3984
	avg:	6896	4013	2608									chk sum:	-62824	-114738	-120469	-148580
	yr end	1995	1952	1975													

Irrigation return flows represent a portion of the water balance that also has a degree of variability. A range of 7 to 13% (of total pumping, roughly 9 to 16% of irrigation pumping) is shown in **Figure 4** using the same parameters used in **Figure 3** to assess the relative impact of irrigation return flows on the water balance. The overdraft after 20 years is within 6 percent of the baseline case.

Overall the results demonstrate that the primary uncertainty associated with the overdraft calculations is due to the variability of the historically-observed recharge rates.

FIGURE 4

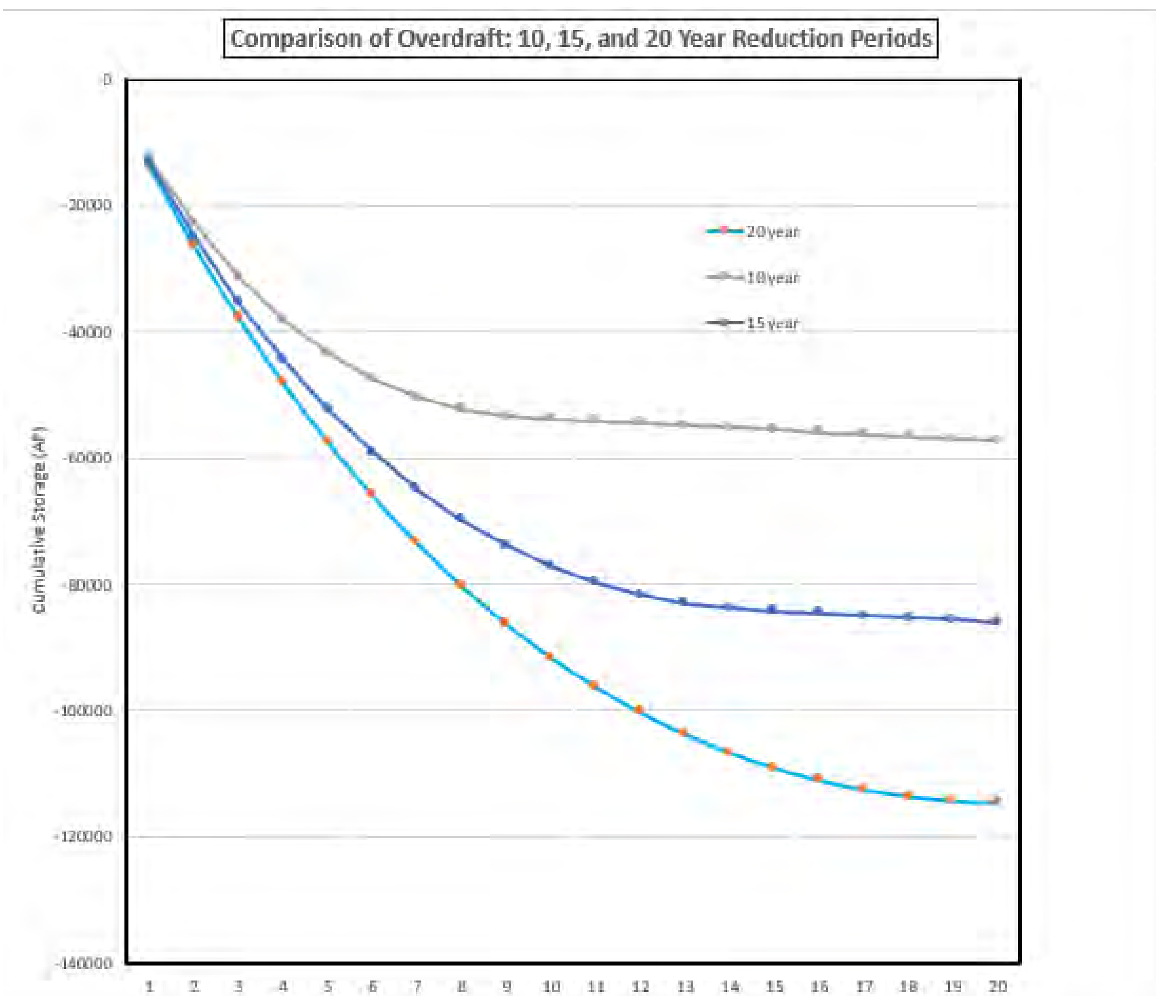


4.1 Effect of Reduction Periods Less Than 20 years

A maximum 20-year groundwater pumping reduction period is described in SGMA (DWR, 2017). The water balance calculations can be used to generally illustrate how overdraft will be affected by changing the reduction period. In this case the pumping reductions are done over 10, 15, and 20 years. Annual pumping rates are reduced for these cases by approximately 6.5, 8.6, and 12.7 % per year. The same water balance values are used as done for **Figure 3** with a target pumping rate of 5700 AFY.

The result of varying the reduction periods is that overdraft is substantially reduced. Since constant reduction rates were used the corresponding overdraft after 20 years went from approximately 115,000 AF to 86,000 AF for the 15-year period. Overdraft reduces to 58,000 AF for the 10-year period. These correspond to 75% and 50%, respectively, of the overdraft that would be experienced after 20 years.

FIGURE 5



The calculations are summarized in the following table. A 10% irrigation return flow (of total pumping) is assumed and the total amount of recharge entering the basin is held constant at 5700 AFY. Outflows are also held at average annual values of 525 AFY for groundwater and 400 AFY for native plant consumptive use (evapotranspiration, or ET).

Based on these values there is a net negative balance of 355 AFY using the target pumping rate. The relative impact of the negative balance is small compared to the magnitude of the cumulative overdraft for the 10, 15, and 20 year periods.

FIGURE 5, continued

	INFLOW (AFY)					OUTFLOW (AFY)						NET: INFLOW-OUTFLOW (AFY)					
	GW-in	Recharge	Irrigation Return			GW_out	ET	Q_20	Q_15	Q_10		Cumulative storage			Annual Change in Storage		
year	(GW BC)		20 year	15 year	10 year			22044	22044	22044	yr	20 year	15 year	10 year	20 year	15 year	10 year
1	1400	4300	2060	2014	1926	525	400	20603	20143	19255	1	-13767	-13354	-12555	-13767	-13354	-12555
2	1400	4300	1926	1841	1682	525	400	19255	18406	16819	2	-26322	-25144	-22917	-12555	-11791	-10362
3	1400	4300	1800	1682	1469	525	400	17996	16819	14691	3	-37744	-35507	-31364	-11422	-10362	-8447
4	1400	4300	1682	1537	1283	525	400	16819	15369	12833	4	-48106	-44563	-38139	-10363	-9057	-6775
5	1400	4300	1572	1404	1121	525	400	15720	14043	11209	5	-57479	-52428	-43452	-9373	-7864	-5313
6	1400	4300	1469	1283	979	525	400	14692	12833	9791	6	-65926	-59202	-47489	-8448	-6774	-4037
7	1400	4300	1373	1173	855	525	400	13731	11726	8553	7	-73509	-64980	-50412	-7583	-5778	-2922
8	1400	4300	1283	1071	747	525	400	12833	10715	7471	8	-80284	-69849	-52360	-6775	-4868	-1949
9	1400	4300	1199	979	653	525	400	11994	9791	6525	9	-86304	-73885	-53458	-6020	-4037	-1098
10	1400	4300	1121	895	570	525	400	11210	8947	5700	10	-91618	-77162	-53813	-5314	-3277	-355
11	1400	4300	1048	818	570	525	400	10477	8175	5700	11	-96272	-79745	-54168	-4654	-2583	-355
12	1400	4300	979	747	570	525	400	9792	7470	5700	12	-100309	-81693	-54523	-4037	-1948	-355
13	1400	4300	915	683	570	525	400	9151	6826	5700	13	-103770	-83062	-54878	-3461	-1368	-355
14	1400	4300	855	624	570	525	400	8553	6237	5700	14	-106693	-83900	-55233	-2923	-839	-355
15	1400	4300	799	570	570	525	400	7994	5700	5700	15	-109112	-84255	-55588	-2419	-355	-355
16	1400	4300	747	570	570	525	400	7471	5700	5700	16	-111061	-84610	-55943	-1949	-355	-355
17	1400	4300	698	570	570	525	400	6982	5700	5700	17	-112570	-84965	-56298	-1509	-355	-355
18	1400	4300	653	570	570	525	400	6526	5700	5700	18	-113669	-85320	-56653	-1098	-355	-355
19	1400	4300	610	570	570	525	400	6099	5700	5700	19	-114383	-85675	-57008	-714	-355	-355
20	1400	4300	570	570	570	525	400	5700	5700	5700	20	-114738	-86030	-57363	-355	-355	-355
avg:														chk sum:	-114738	-86030	-57363
																75%	50%

5.0 RELATIONSHIP BETWEEN OVERDRAFT AND WATER LEVELS

The water balance calculations provide a broad overview of hydrologic conditions within the Borrego Basin and directly relate to the effect of pumping restrictions specific to groundwater sustainability. Water level declines within the Borrego Basin will vary within the aquifer depending on localized pumping rates, localized aquifer response to pumping and overdraft, site-specific aquifer conditions, and recharge.

5.1 Calculating Water Level Decline in Response to Overdraft

Overdraft has caused and continues to cause water levels in the aquifer system to decline fairly rapidly over time. The water is coming from water stored in the aquifer. Here the aquifer is comprised of sand, silt, and clay- materials that have open pore space that contains water. When the water level is lowered most of the water drains from the aquifer with some of the water being retained.

A hydrologic parameter known as the specific yield (Sy) expresses how much water will freely drain from an unconfined aquifer, as a percentage of the aquifer volume, as water levels drop. For example, a Sy value of 10% means that a 1 cubic foot of aquifer will yield one 0.1 cubic foot of water for a water level drop of 1 foot[9]. However, locally under pumping, water levels at specific wells would also depend on the hydraulic conductivity (K) of the particular aquifer materials intersected by the well and on the well characteristics. For a well being pumped the drawdown (drop in water level in the well) is approximately proportional to pumping rates, and inversely proportional to hydraulic conductivity; hence an order of magnitude reduction in K would increase drawdown approximately by an order of magnitude. In addition to the general consideration of overdraft and storage depletion this has implications on the choice of well location, well construction (screen interval, etc.), and potential energy costs.

The USGS model uses three sets of Sy values for the upper, middle, and lower aquifers. Review of Table 18 of the USGS model report indicates that Sy varies spatially for each of the aquifers. The average Sy values for these three aquifers in the model are:

Upper Aquifer: 0.13
Middle Aquifer: 0.11
Lower Aquifer: 0.04

The model Sy values for the upper and middle aquifers are roughly similar and mean that the water level in the aquifer will drop at roughly the same rate as water is extracted from these aquifers. This is important because it means that current water level decreases are roughly proportional to the amount of overdraft. In contrast the rate of water decline due to removal of water from storage

[9] In terms of acre-feet (AF), an acre-wide area of the aquifer will yield 0.1 acre-feet of water when the water level drops one foot for a Sy = 0.10. Under these conditions a ten-foot drop in water level is required to release one AF of water from an acre of the aquifer. However, locally, water levels in production wells will also depend on the hydraulic conductivity (K) of the aquifer. Drawdown at a well will increase as K decreases in order to maintain a constant production rate.

will accelerate approximately 3-fold should the middle aquifer be dewatered. This comparison assumes that the middle and lower aquifers are unconfined- an assumption made in the model construction that may not be valid across the Borrego Basin.

The USGS Report examined six future pumping scenarios. Scenario 6 assumed that agricultural pumping would be reduced to 40% of the 2010 rates and that municipal and recreational pumping would be reduced by 50% (USGS report Table 20). After 20 years the pumping rates are held constant for another 30 years. The starting pumping rate was 18,271 AFY and total pumping in year 20 decreases to 7824 AFY. This Scenario does not comply with SGMA sustainability requirements but is used here to show how water levels relate to overdraft. The reduced pumping rate of 7824 AFY is 37% above the 5700 AFY target and is too high to prevent long-term overdraft and achieve sustainability.

Cumulative overdraft after 50 years, as shown in **Figure 6**, is approximately 200,000 AF for Scenario 6. Prior water balance calculations to achieve sustainability after 20 years under SGMA projected an overdraft of approximately 115,000 AF – a point that is reached after 14 years of pumping in Scenario 6.

Figure 7 (Figure 56 from the USGS Report) shows that water level drawdown calculated by Scenario 6 ranges from 26 to 75 feet in the northern half of the BGVB. The scenario does not specifically show where water levels occur relative to the upper and middle aquifer systems but it noted in the report that “the levels do not decline to the middle aquifer in most of the basin” (p. 124).

If the specific yields of the upper and middle aquifers are similar where overdraft occurs, then the change in water levels due to loss of water in storage will be directly proportional to the degree of overdraft. Under these assumptions the water levels associated with an overdraft of 115,000 AF will be roughly be just more than half of the drawdown indicated in **Figure 7**.

In summary, Scenario 6 is presented as an example of how overdraft as a total volume of water pumped from the aquifer can be related to water level decline. It is important to note that the USGS scenarios provide a large-scale depiction of groundwater conditions and may not represent conditions observed at individual wells or subareas of the Borrego Basin. While local trends may be able to be correlated to local pumping rates, the assessment of localized groundwater conditions under varying pumping conditions will require use of the model.

FIGURE 6

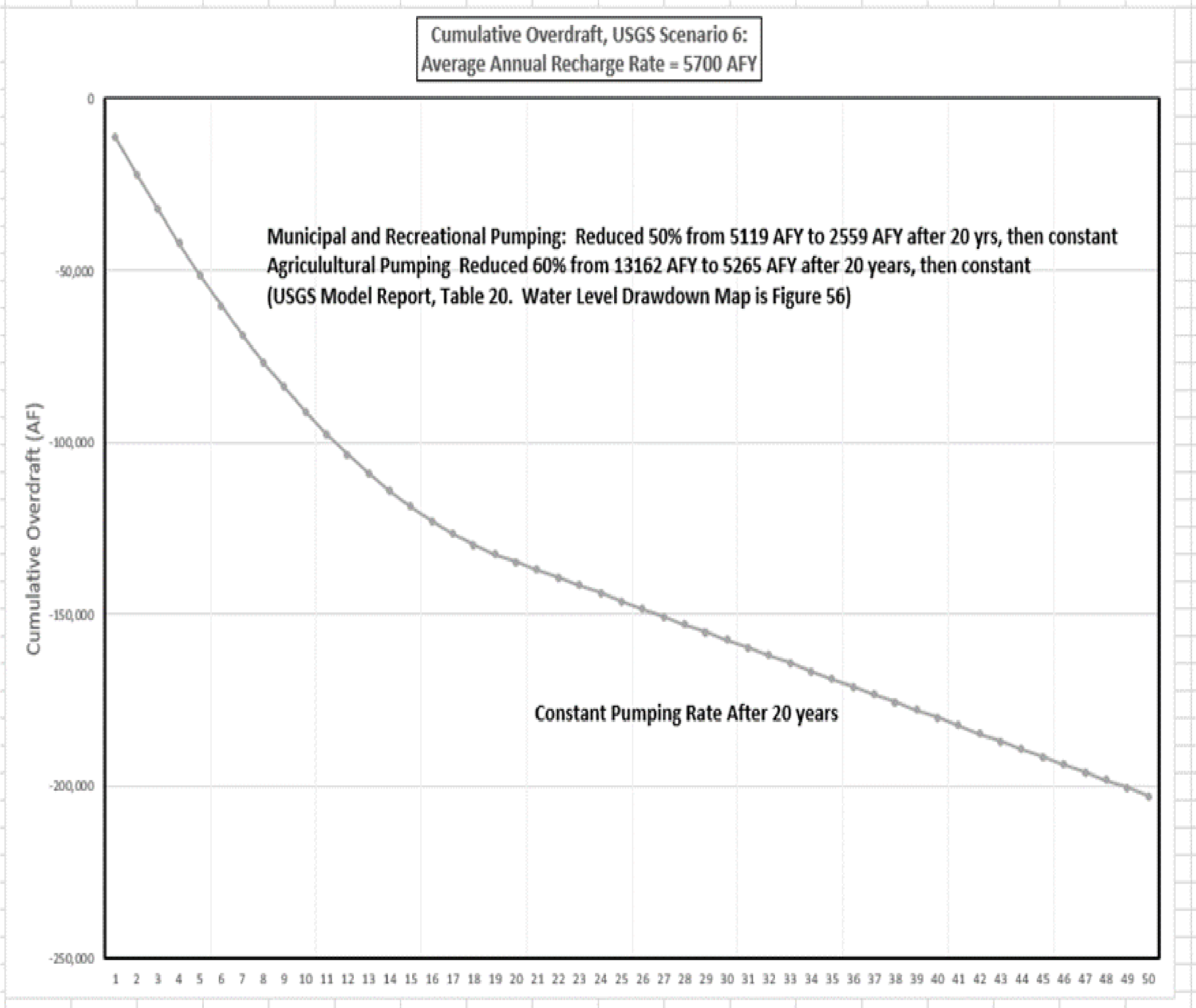

Cumulative Overdraft, USGS Scenario 6:
Average Annual Recharge Rate = 5700 AFY
Municipal and Recreational Pumping: Reduced 50% from 5119 AFY to 2559 AFY after 20 yrs, then constant
Agriculultural Pumping Reduced 60% from 13162 AFY to 5265 AFY after 20 years, then constant
(USGS Model Report, Table 20. Water Level Drawdown Map is Figure 56)
Constant Pumping Rate After 20 years
Cumulative Overdraft (AF)
0
-50,000
-100,000
-150,000
-200,000
-250,000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

FIGURE 7

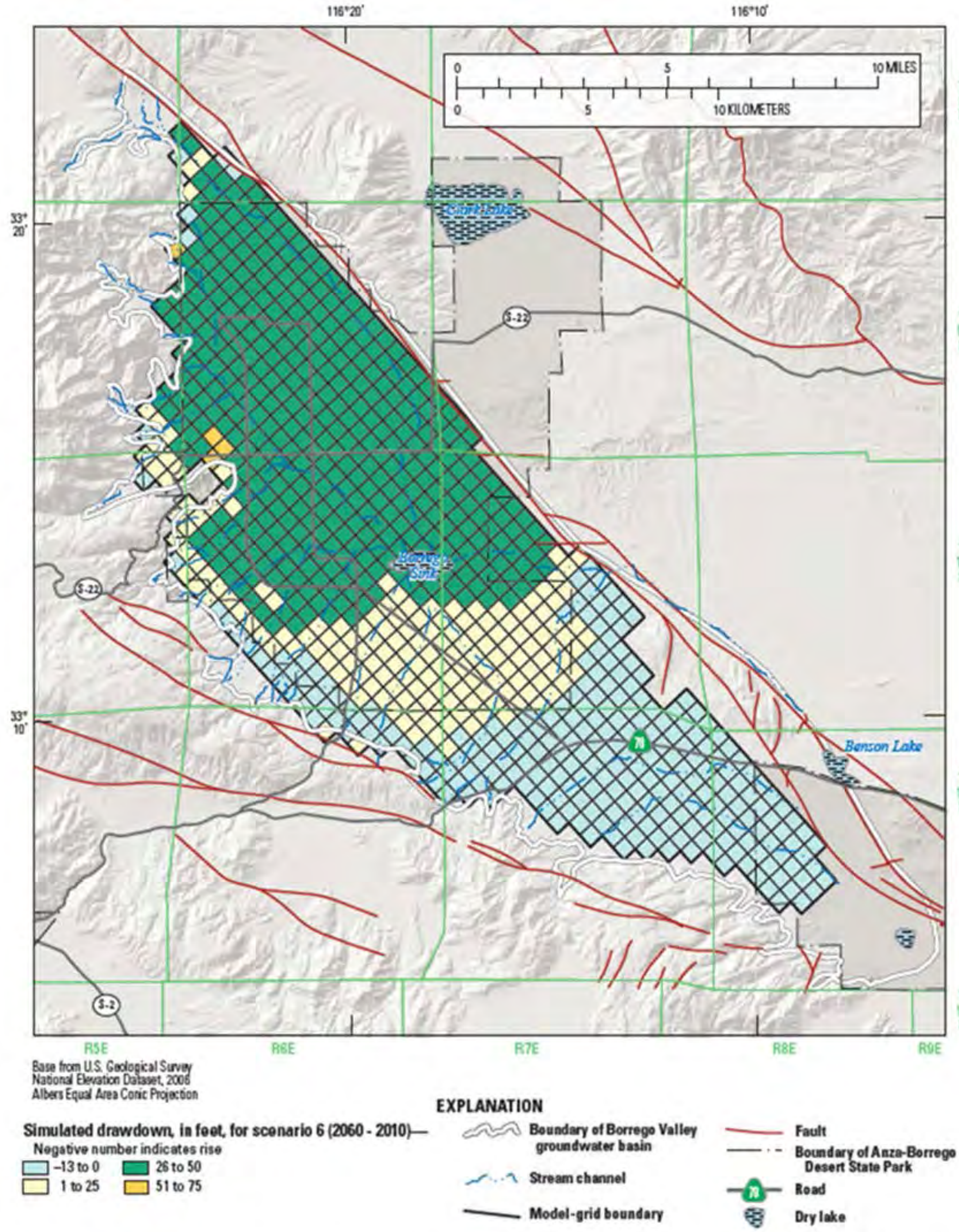


Figure 56. Simulated drawdown projected for Scenario 6, 2060 minus 2010, Borrego Valley Hydrologic Model, Borrego Valley, California.

5.2 Water Level Decline in BWD Production Wells

The BWD currently operates eight production wells located in all three groundwater management areas (north, central, and south). The current rate of water level decline in the basin is on the order of 1 to 3 feet per year (refer to the GSP for additional information).

Conceptually groundwater occurs in three aquifers denoted as the upper, middle, and lower aquifers. Long-term overdraft has effectively led to the loss of much of the upper aquifer as a viable water source across much of the valley. Wells completed in the middle aquifer to date, while not as prolific as wells that were originally installed in the upper aquifer, have been observed to have good water production rates. Of concern is that the once water levels drop into the deeper aquifers with finer-grained materials and lower permeability, water level declines at BWD production wells have the potential to increase in response to pumping.

A well-by-well analysis is included in **Appendix C** and is the subject of further threshold analysis in the GSP.

6.0 MONTE CARLO SIMULATION (MCS) UNCERTAINTY ANALYSIS:

All of the water balance inflow and outflow parameters are subject to uncertainty. One way to explicitly incorporate uncertainty into the calculations is using a methodology known as Monte Carlo Simulation (MCS). Each of the parameters is assigned a range of values. The water balance calculations presented in **Figure 3** are then done multiple times by repeated random sampling within the parameter ranges to obtain numerical results. The calculations provide a range of values, rather than a single value.

The essential idea is to create a set of randomly-generated values to examine how the overall water balance is affected by parameter uncertainty. The results are then examined statistically and can be used to assess a plausible range of outcomes and support decision making. In other words, the range of potential overdraft shown in **Figure 3** can be expressed statistically instead of being shown as two extremes.

6.1 Constant Recharge Rate Case (5700 AFY)

The following constant recharge case assumes that recharge occurs at the stated average of 5700 AFY and pumping is reduced from 22,044 AFY to 5700 AFY over a 20-year simulation period. The following are used for the constant recharge rate case MCS:

Inflow:
Groundwater Inflow: A value of 1400 AFY that ranges +/- 10 percent. A normal distribution ("bell curve") is used for the range as the USGS model had little flow variation.

Natural Recharge: Held for this first example at the target value of 4300 AFY to assess the effect of uncertainty related to the other water balance parameters independent of recharge. (Recall that total recharge is groundwater inflow + surficial recharge, and totals 5700 AFY as stated in the USGS Model Report)

Irrigation Return Flow: An irrigation return flow rate of 10% is used, with a range of 5 to 15% based on a normal distribution to fully capture the range of 7 to 10%.

Outflow:
Groundwater Outflow: A value of 525 AFY that ranges +/- 10 percent. A normal distribution is used for the range as the USGS model had little flow variation.

Evapotranspiration: 400 AFY with a range of +/- 100. A Uniform Distribution is used where the ET rate varies from 300 to 500 AFY.

Pumping Rate: Reduced over the 20-year period from 22,044 to 5700 AFY, as done in **Figures 5 and 6**. It is a time dependent variable- no uncertainty or range of values has been assigned.

Here the MCS was repeated 10,000 times to develop a range of values for the cumulative overdraft as shown in **Figure 8**. Since irrigation return flows have the highest uncertainty in the MCS simulation the figure appears very similar to **Figure 3**, with the except that the range of values can now be expressed in terms of a probability distribution function (PDF) as shown as a histogram in **Figure 9**.

FIGURE 8

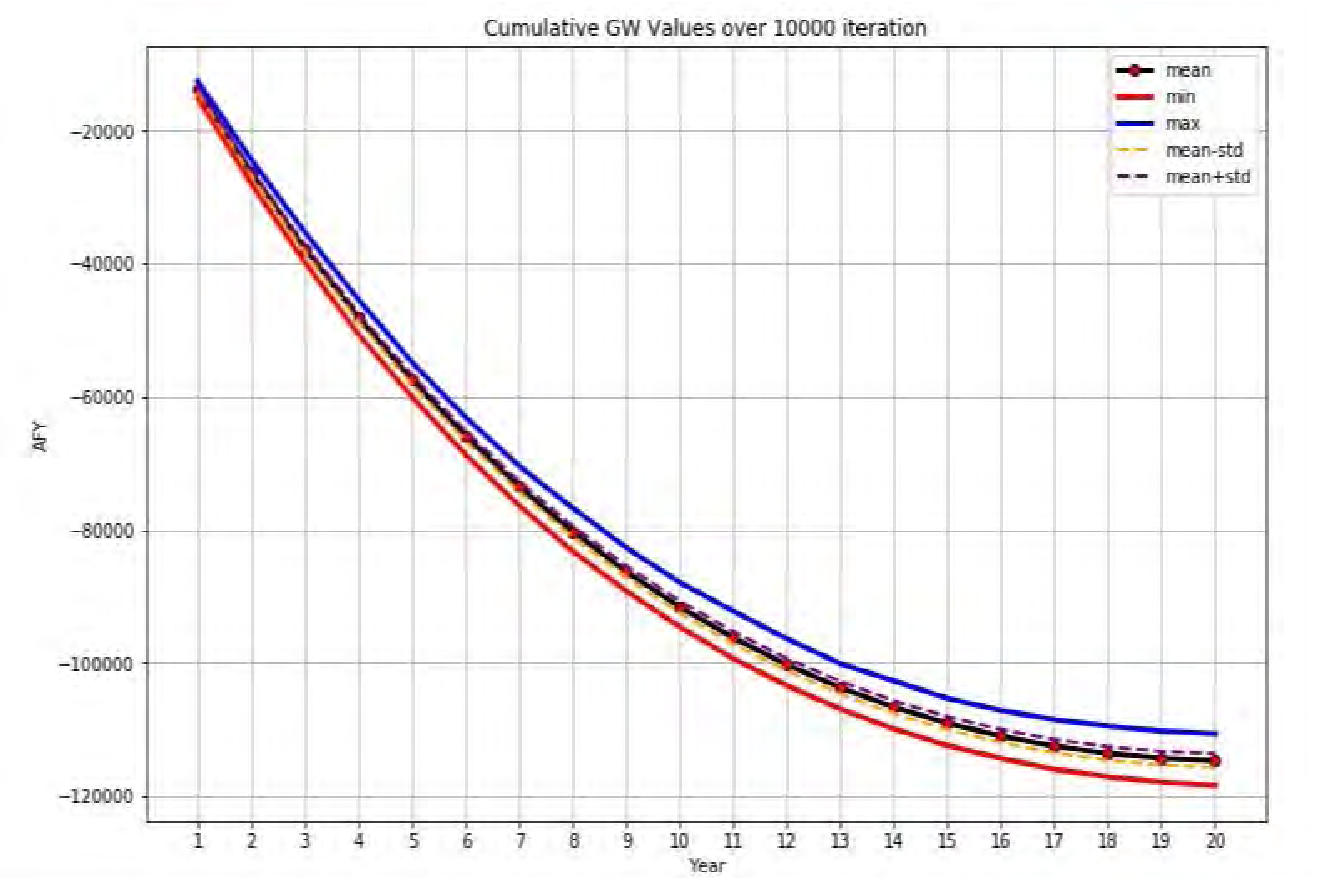
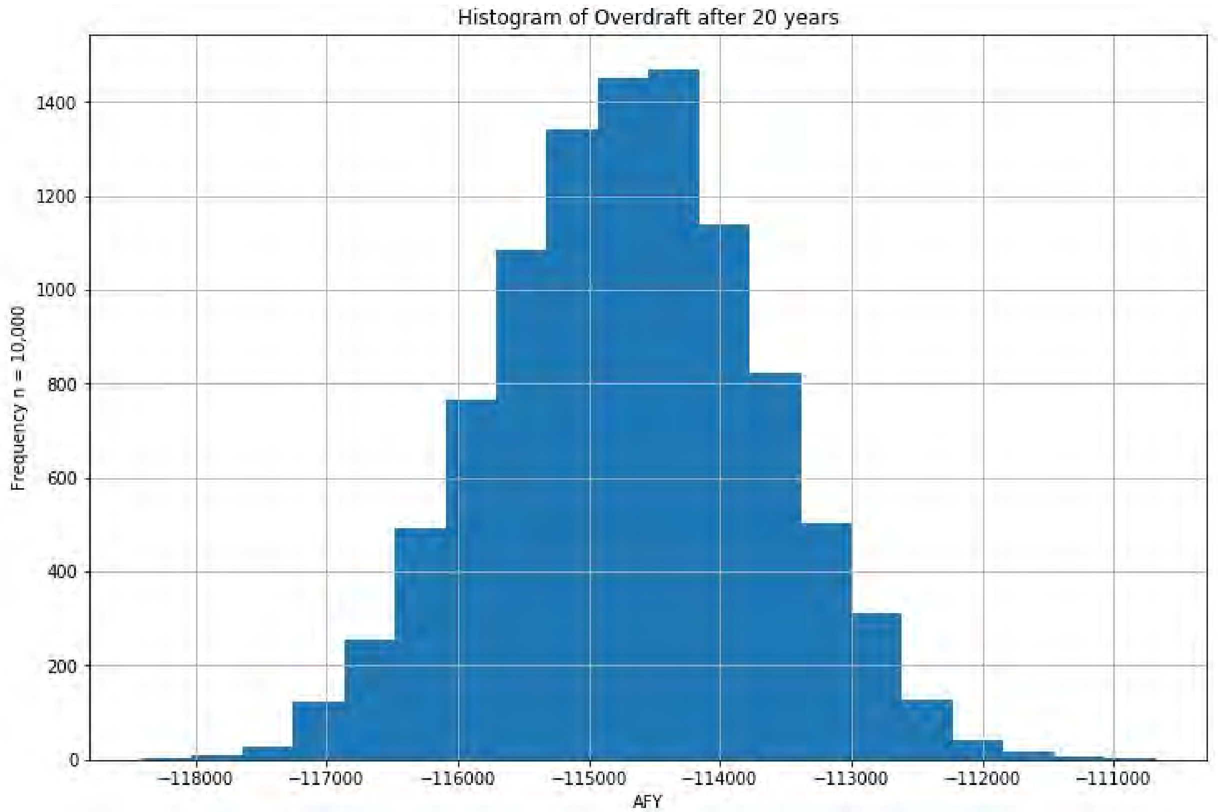


Figure 9 is a histogram showing the range of results after 20 years.



Review of the results show that when recharge is held constant the other parameters have relatively minor influence. The overdraft after 20 years in the MCS had a range of from approximately 110,500 to 118,500 AF, or +/- 4,000 AFY (3.5 percent), and has a Normal Distribution.

When **Figure 8** is compared to the extremes shown in **Figure 3** it is clear that the primary consideration for groundwater management is the potential variability in the recharge rate as driven by rainfall variability.

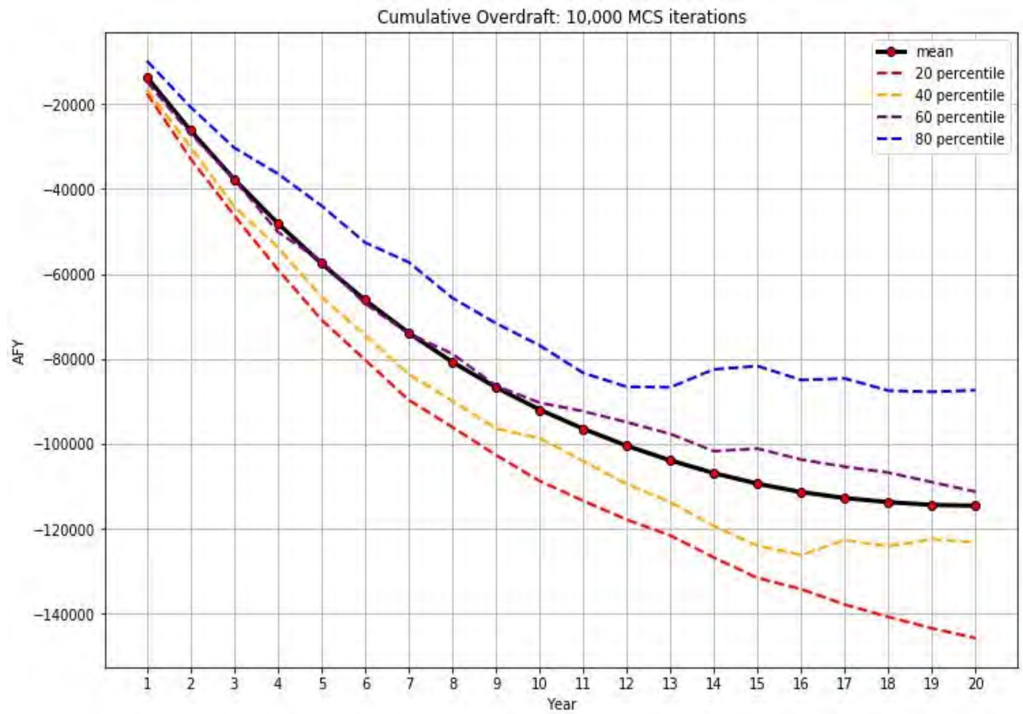
The next section expands the MCS calculation to include a range of recharge rates based on the USGS model results.

6.2 MCS Uncertainty Analysis: Time-varying Recharge Based on USGS Model History

The effect of time-varying recharge is evaluated using the MCS methodology based on the recharge values produced over the model period (as shown in **Figure 3)**. All of the simulations are based on the target pumping rate of 5700 AFY being achieved by year 20. Here, 20-year periods are selected at random from the time series. Alternatively, annual data could be randomly selected based on the distribution of values, but this was not done because review of the recharge values shows that there is periodicity within the time series. In effect the MCS provides for a series of 'what if' analyses where the 20-year SGMA attainment period could occur for any historical 20-year period and thus examine the potential variability in the water balance as exhibited by the model.

Fifty-three 20-year periods (from 1945 to 2016) are used in the MCS, together with the parameters presented in the previous section. **Figure 10** shows the MCS simulations in terms of the average and percentiles. Shown are the 20th through 80th percentiles. Percentiles group the data in order- a 20th percentile means that 20% of the values fall below the 20th percentile and 80% are above the 20th percentile. Since the simulations are looking at different time periods the values translate to rate of occurrence. For example, values below the 20th percentile occur 20% of the time.[10]

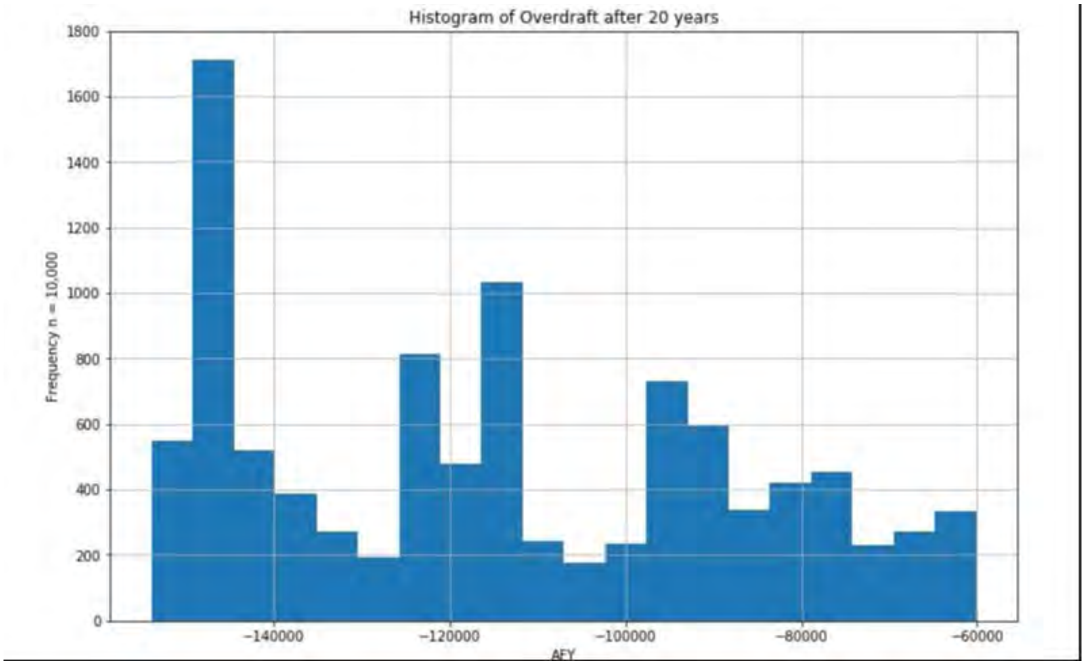
FIGURE 10 Cumulative Overdraft. 20th/40th/60th/80th percentiles



[10] Percentiles are used here to describe the results. Figure 11 shows that the results are not well described by simple statistics. For example, the average value is much different than the median since the values are 'skewed' towards lower recharge values.

The simulated overdraft at 20 years ranges between approximately 60,000 and 152,000 AF within the percentiles shown in **Figure 10**. The overdraft 'curve' that assumes a 5700 AFY average annual recharge is approximately equal to the 55th percentile- meaning sustainability occurs for 45% of the simulations. For reference calculations that use a constant annual recharge rate of 5700 AFY leads to an overdraft of 114,500 AF (approximately 115,000 AFY).

FIGURE 11.



The recharge variability is quite significant compared to the baseline case where a constant annual recharge rate is assumed. As calculated the cumulative groundwater extraction and degree of overdraft after 20 years is 54,000 to 37,000 AF above or below the mean of 114,500 AF. **Figure 10** shows the range of values at the end of the 20-year MCS period.

In contrast to the results shown in **Figure 8** where recharge uncertainty is not assessed, the histogram is asymmetric and shows that high recharge periods occur much less frequently than low recharge periods. This can also be seen in **Figure 2** by the 'spikes' in the annual data corresponding to high recharge years.

In essence the use of random 20-year periods to develop the MCS is equivalent to saying that the 20-year GSP period could begin any time from 1945 to 1996. Recharge is highly variable over the model period. It is noteworthy that an extreme low recharge period (1955 to 1974) was immediately followed by an extreme high recharge period (1975 to 1994). The MCS allows for additional analysis of the recharge variability between these extremes over the model period (1945 to 2016).

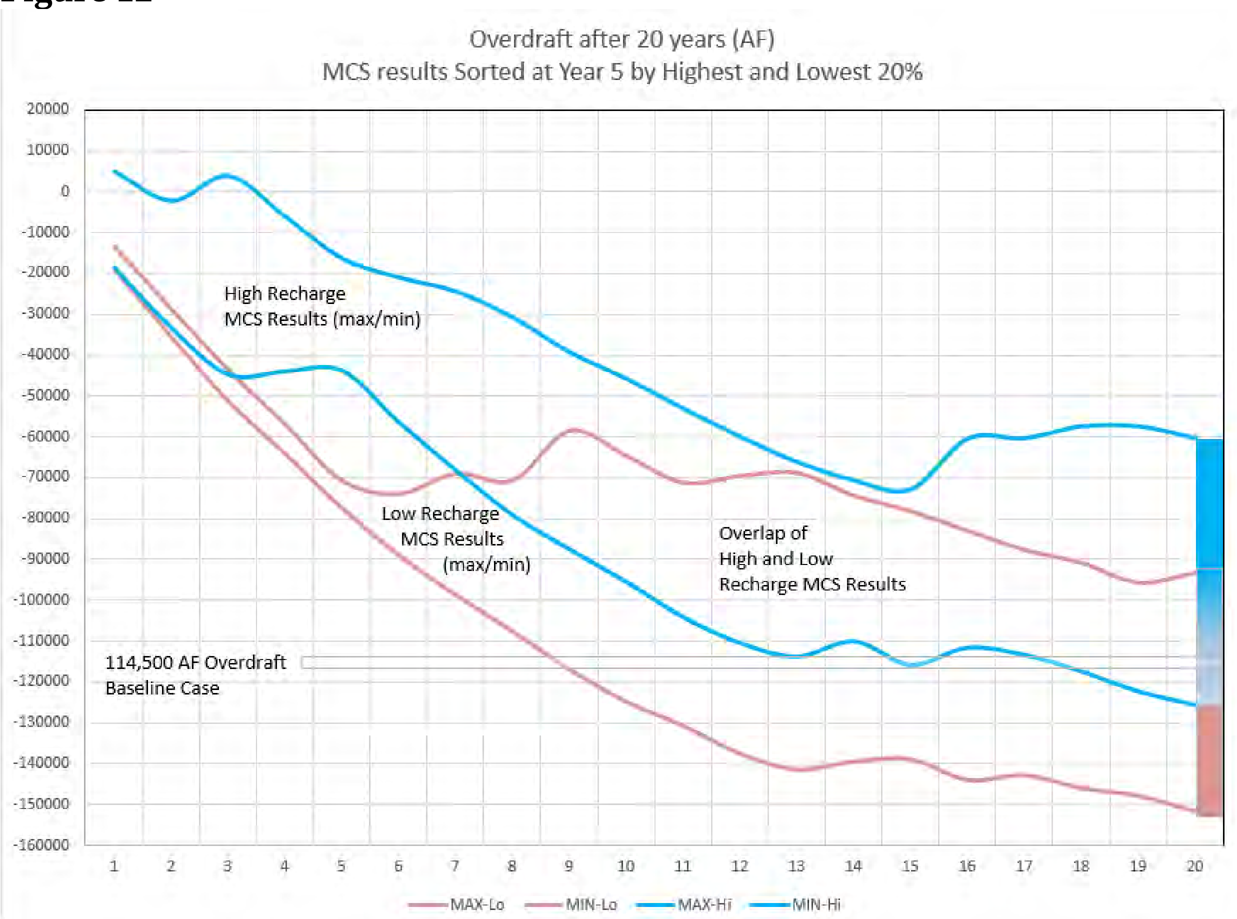
6.2 MCS-based Analysis: What happens after 5 years of low or high rainfall?

The MCS results can be used to examine 'what if' scenarios. In this case since the GSP is being proposed to be reviewed at 5-year intervals, the MCS is used to examine whether having 5 years of observations can allow for a prediction of the next 15 years. In other words, if there is an initial 5-year 'wet' or 'dry' period do the MCS results support revision to the target pumping rate? A 5-year period was used to correspond with the GSP review period.

For this example, the MCS results shown in Figure 9 were sorted in terms of 'wet' and 'dry' periods where the cumulative overdraft values after 5 years were sorted from high to low. The upper and lower 20% portions of the values were then separated for analysis.

The cumulative overdraft for the two sets of recharge values that correspond to initially 'wet' or 'dry' periods. Here the maximum and minimum values are used to show the range of values for the two cases in **Figure 12**. For reference the baseline sustainable pumping case results in an overdraft of approximately 115,000 AF after 20 years.

Figure 12



The values were sorted into two sets corresponding to the highest and lowest 20% of recharge after five years. Shown in the Figure are the full ranges of the two data sets described here as ‘wet’ and ‘dry’. Review of the MCS results shows that

- The 5700 AF target pumping rate will have a high likelihood of achieving sustainability after an initial ‘wet’ 5-year period. The lowest recharge rate after 20 years for this data set leads to an overdraft of approximately 126,000 AF (9% more than the baseline case).

- If ‘dry’ conditions occur over the initial 5-year period overdraft will not exceed the sustainability threshold approximately 40% of the time. However, an initial ‘dry’ period does not preclude the Borrego Basin from being sustainable after 20 years as 40% of the time there is sufficient recharge to meet the sustainability threshold.

- The MCS indicate that overdraft could range from approximately 60,000 AF to 152,000 AF due to the high level of variability in recharge rates over the 1945 to 2016 model period. This wide range creates a high level of uncertainty as indicated by the overlap between the two sets of data.

- Having 5 years of observations that demonstrate that ‘dry’ conditions occur does not substantially improve the MCS outcome of potential overdraft after 20 years. Here the range of outcomes after 5 ‘dry’ years is very wide and in years 12 to 14 can result in high recharge rates that are similar to the ‘wet’ data set. Comparison of the MCS results for all of the data shown in **Figure 9** shows that the threshold is met approximately 45% of the time versus 40% of the time after 5 years of ‘dry’ conditions.

7.0 BASELINE PUMPING AND MCS SUMMARY

The 5700 AFY pumping target has been evaluated based on water balance calculations for the Borrego Basin.

- Ongoing overdraft can be substantially controlled using the 5700 AFY pumping target. The water balance calculations include groundwater recharge, groundwater discharge, pumping, irrigation return flows, and evapotranspiration-related water demand from native vegetation (groundwater dependent ecosystems). An additional 115,000 AF of overdraft occurs over a 20-yr period as calculated in this Draft Report. For comparison the amount of overdraft was 520,000 AF as of 2016 (as reported in Chapters 2 and 3 of the Draft GSP).

- Projected overdraft over a 20-year period is greatly affected by variability in recharge rates. Instead of assuming an average annual recharge rate of 5700 AFY, the recharge rates are based on the results of the USGS Groundwater model for the period of 1945 to 2016. The long-term groundwater supply highly depends on 'wet' years with high recharge rates; however, these occur on a decadal scale and may not coincide with the 20-year GSP planning period.

  A clear example of the variability inherent in the recharge values is that the 20-year period from 1955 to 1974 was one of the 'driest' and it immediately preceded one of the 'wettest' periods from 1975 to 1994. The average annual recharge rates for these two periods of 'dry' and 'wet' precipitation were 3,975 and 11,907 AFY, respectively.

- Accelerated reduction periods, for example 10 to 15 years versus 20 years, can provide significant and proportional decreases in total overdraft (storage loss) and related water level decline. Because overdraft occurs cumulatively over the reduction period, the relative uncertainty associated with the overdraft also increases with time. Thus uncertainty is reduced with shorter reduction periods and a longer time is available to confirm that sustainability has been achieved within the 20-year GSP planning period,

- Uncertainty associated with the overdraft calculations is dominated by the historical variability of recharge rates. The other water balance components such as groundwater demand of native vegetation and irrigation return flows are of lesser importance. Additional uncertainty is associated with the time required for irrigation return flows to travel from the land surface to the underlying aquifer, the amount of return flows to application rates that may actually ever reach the water table, and the potential contaminants in such return flows.

- Overdraft, expressed as the total volume of water that is extracted from the aquifer, can be generally related to water levels when drawdown occurs within the upper and middle aquifers given the Sy and K values used in the USGS model. Here the USGS model predictions for water level decline (USGS Scenario 6) are reviewed for comparison to the calculated overdraft. Note that the USGS' scenario does not attain sustainable groundwater conditions and is not acceptable under SGMA.

With decreasing water levels water supply wells will necessarily be pumping relatively more water from the middle and lower aquifers. Because aquifer storage and permeability decreases with depth well yields are expected to decrease. Water level drawdown at the wells will also increase in order to extract similar amounts of water compared to wells screened in the upper aquifer.

- Statistically-based 'what if' Monte Carlo Simulations were used to look at what may be observed after 5 years of pumping reductions following 'wet' or 'dry' periods. A 5-year period was used that corresponds to the proposed GSP review cycle. Having 5 years of additional observations that demonstrate that 'dry' conditions occur does not substantially improve the projection of potential overdraft after 20 years. The percentage of the time that the simulations showed that percentage of time that sustainability was achieved decreased from 45% (for all of the data) to 40% after a 5-year 'dry' period, if this period was used to 'adjust' the target sustainable yield amount.

The draft report is limited to assessment of the volume of water associated with ongoing overdraft and pumping reduction necessary to balance groundwater use with groundwater replenishment by recharge. While the calculations presented in this report can provide insights towards quantification of overdraft and related changes in water levels calculations, it cannot replace ongoing observations and continued efforts to reduce groundwater pumping. Considerations going forward include:

- Are there changes in Water Quality related to overdraft that would necessitate additional pumping restrictions? The Borrego Basin is a relatively 'closed' groundwater system where minerals and contaminants will accumulate as water is used. The water balance analyses do not consider or account for changes in water quality related to natural or anthropogenic sources.

- The USGS model includes three layers for the upper, middle, and lower aquifers. Model-based projections of water level decline do not account for depth-dependent variations that may occur in the aquifer systems. It also assumes that unconfined conditions occur- should locally confined aquifer conditions occur more rapid drawdown is expected to occur in production wells than would be projected by the model.

- How to incorporate the effect of decadal recharge events given the 20-year SGMA planning period? Recharge variability occurs at a time scale greater than 20 years. A clear example is the two consecutive 'dry' and 'wet' periods- 1955 to 1974, and 1975 to 1994 as noted in the summary.

- How much of a 'miss' can be allowed during and after the 20-yr GSP planning and management period? Based on the MCS calculations (**Figure 10**) if overdraft is allowed to exceed by 20% (20% above the 114,500 AF mark or 137,400 AF) the MCS calculations support that the target pumping rate will succeed approximately 70 percent of the time.

- The MCS is based on recharge values from the model for the historical period of 1945 to 2016. The analysis assumes that the time series can be projected into the future and that the statistics (such as the mean and variance) don't change and can also be projected forward in time and are described as 'stationary'. The reasonability of this assumption must be considered by BWD when managing financial risk. One factor to consider is the potential for future recharge rates to decrease due to climate change. It is understood that the GSP will incorporate climate change projections when using the groundwater model to examine future overdraft conditions.

  The uncertainty associated with the magnitude of Irrigation return flows and time required for water to transit the vadose zone affects the water balance. While recharge variability is the dominant factor specific to the water balance, and inflow from adjacent watersheds provides the bulk of the water being recharged, irrigation return flows are a significant component of the current water balance during 'dry years'. This has the greatest impact early in the GSP process as the relative contribution of irrigation flows will decrease over time as pumping will be required to be reduced on the order of 70% to achieve sustainability.

- Should a factor of safety be applied to the target pumping rate or can revisions to the pumping rate be adaptively managed during a 20-year GSP period? Or should both be considered together? Or should a more aggressive reduction schedule be used to reduce the attainment period?

- Of concern is the relatively low resilience of BWD and its SDAC customer base to recover from miscalculations of initial GSP policy decisions. BWD is a relatively small municipal water district with limited borrowing capacity and small amount of cash reserves. Failure to include an adequate factor of safely into starting GSP policies could potentially place undue financial risk on the BWD and unrecoverable economic risk on its SDAC customer base. Based on the present analysis, an assumption that adaptive management by making policy changes every 5-year period, does not assure a means to recover from mistakes in initial GSP policy decisions based on 'better' future data.

Recommendations

- Additional analysis is needed as to the potential financial risk for the BWD and economic risk to the Borrego community from policy and starting assumptions in the GSP. Among the considerations include the impact of potential water quality changes and overdraft impacts on BWD production wells, potentially unexpected cost impacts to BWD, and the potential impact of costs and water reductions to the severely disadvantaged Borrego Springs community.

- Additional analysis and contingency planning are needed to determine how adaptive management will be used during implementation of the GSP to correct or modify initial policy assumptions, should the ongoing decrease in water levels exceed expectations either due to exceptionally low rainfall or other unexpected conditions. Among the factors necessary to implement effective adaptive management practices include sustainability agency governance, and enforcement, identification of potential funding methods, ongoing evaluation of pumping and water quality data, and ongoing review of monitoring and water quality standards.

8.0 WATER SUPPLY VARIABILITY AND UNCERTAINTY: WATER QUALITY

A detailed analysis of water quality data was developed to address the question of whether historical water quality data and ongoing water testing be used to predict future water quality. The work is included in its entirety as **Appendix B**, and was included in the Draft GSP as Appendix D2. The ENSI report is entitled *Water Quality Review and Assessment: Borrego Water District (BWD) Water Supply Wells*, dated 12/7/2018.

The 12/7/2018 water quality assessment report expanded on the water quality trend analyses conducted by Dudek prior to development of the GSP. The spatial variability of water quality within the Subbasin was organized by Dudek in terms of the Northern, Central, and Southern Management Areas (NMA, CMA, and SMA). The report also organizes the wells and data by these management areas.

A multi-parameter analysis of major anion and cation sampling data was conducted for historical and active BWD wells dating back in some instances to the 1970s. The results showed that systematic variations in groundwater quality occur within the Subbasin that generally follow pre-development groundwater conditions. The NMA and CMA waters are similar in nature and can be viewed from a groundwater perspective as having evolved along flowpaths that go from recharge areas into the central portion of the basin coincident with the Borrego Sink. The SMA differs due to having recharge waters from San Felipe Creek that originate from a different hydrologic regime. The aquifer sediment characteristics are also different.

Historical data, particularly when plotted on tri-linear (Piper) diagrams, reveal how dewatering of the upper aquifer has led to changes concentrations of naturally-occurring minerals, and show how overdraft has affected the quality of water. In general, the water that has been extracted from the upper aquifer system as a result of overdraft was of higher quality (specifically lower TDS and sulfate) that occurs deeper in the aquifer system.

Relationships among multiple water quality parameters were examined as a means to support trend analyses for the five primary chemicals of concern (COCs) that include arsenic, total dissolved solids (TDS), nitrate, sulfate, and fluoride (As, TDS, NO3, SO4, and F). A well-by-well analysis was performed for each of BWD's active water supply wells. Currently the wells produce potable water that meets drinking water standards without the need for treatment.

Inorganic water quality for naturally-occurring minerals (sulfate, TDS, sodium, and chloride) generally decreases with depth; however, there is a lack of depth-specific sampling data primarily because the production wells have relatively long screen sections and water samples represent a mixture of water derived from the wells. Exceptions include short-screened monitoring wells installed as part of the GSA's groundwater monitoring program, and limited profiling data from 2013 presented by the DWR (See Figure 10, **Appendix B**).

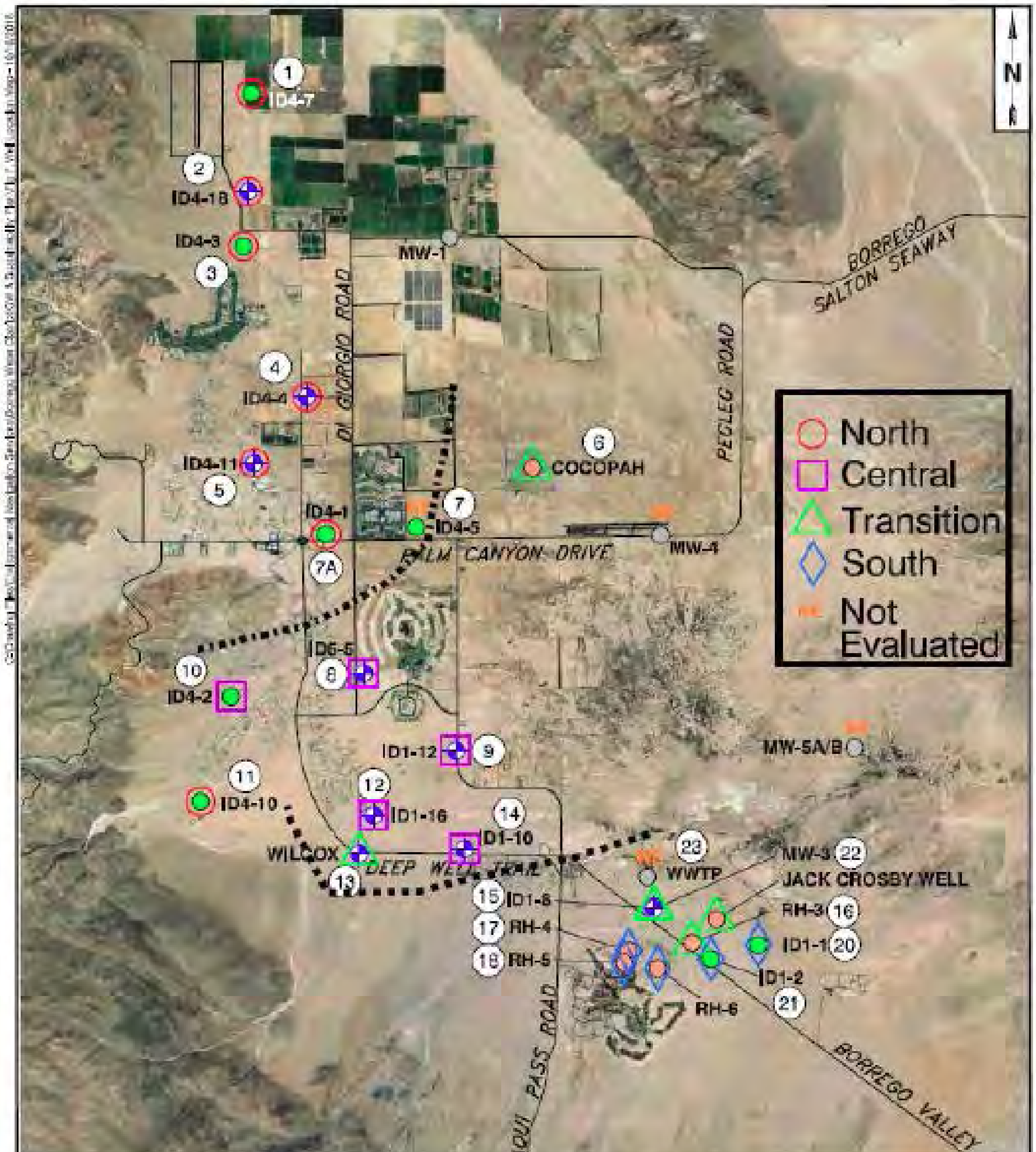
Sulfate in groundwater is increasingly becoming of concern as the upper aquifer system dewaters due to overdraft. Sulfate is shown in Appendix B to generally correlate with TDS. Electrical conductivity measurements are commonly used to assess TDS. In this case they can be used as a field-based monitoring tool for TDS, and in turn support tracking of sulfate. The TDS profiles presented by DWR (Figure 10 of **Appendix B**) are examples of electrical conductivity measurements used to evaluate TDS.

Nitrate in groundwater, as commonly noted in prior water quality studies referenced in Appendix B, has led to maximum contaminant level (MCL) exceedances and the primary sources of nitrate in the Subbasin include fertilizers associated with agriculture and turf grasses (golf courses), and septic systems. Nitrate concentrations are primarily related to land-based activities and do not correlate with inorganic water quality data. Overall determination of historical impacts and ongoing susceptibility of the aquifer to nitrate contamination will require review of prior, current, and future land use placed in a spatial context. Work done by DWR (for example as illustrated in Figure 11 [**Appendix B**]) is an example of how land use information can be used. Among the land use parameters that would go into a nitrate source analysis would the location and types of septic and sewer systems, current and historical agricultural activities, and current and historical irrigated turf/golf courses.

Arsenic in groundwater is of high concern because treatment to drinking water standards (MCLs) is relatively expensive. Arsenic concentrations above MCLs currently occur in groundwater in the South Management Area, primarily in wells installed for the Ram's Hill Golf Course. Historically, during the period of ~2010 to 2014, arsenic concentrations were at or near the MCL in multiple BWD production wells. Fortunately, the trends have reversed. The potential for MCLS to be exceeded is of high concern to BWD due to the potential cost of water treatment and/or well replacement. The MCL was temporarily exceeded in one well, ID1-10. Review of the data shows that there is a relationship between pH and arsenic where elevated arsenic concentrations occur under alkaline conditions with pH levels of approximately 8 and greater. Especially noteworthy is that peak arsenic concentrations can be observed to occur after the peak pH was observed in multiple wells (ID1-10, ID1-16, Wilcox, and ID1-8). The lag time is approximately 2 to 4 years. While additional data and observations are required to further assess the connection between arsenic and pH, this relationship could prove important toward the monitoring and management of BWD's water supply.

Overall, work to date has determined that well water quality trends can generally be identified spatially and with depth. Temporal trends for COCs in BWD production wells have been observed to be variable, and for example with arsenic, showed temporary increases that are not fully understood and will require further attention as BWD's water supply management and cost would be dramatically impacted by the need for water treatment, should that arise in the future.

Please refer to **Appendix B** for specific details and recommendations. The report summarizes the geochemical analysis of 22 historical and current BWD wells as depicted in Figure 7 of the report:



ENVIRONMENTAL NAVIGATION SERVICES, INC.

APPROXIMATE SCALE (FEET): 0 — 3,500 — 7,000

EXPLANATION BLOCK

- ID4-4 Active BWD Groundwater Well
- RH-4 Active Private Groundwater Well
- ID4 Inactive BWD Groundwater Well
- MW-1 Groundwater Monitoring Well

WELL LOCATION MAP

Borrego Valley Water District
Borrego Springs, California

JWJ	BWD		7
Project Manager: JWJ	Drafter: CM	Date: 10/18/2018	

The table of contents of the 12/7/2018 report follows for reference. **Section 1** of the report provides a summary overview of hydrologic conditions used to support the water quality review and assessment. The remaining sections present the data analysis as indicated.

9.0 WATER SUPPLY VARIABILITY AND UNCERTAINTY: BWD WATER PRODUCTION

A detailed analysis of hydrogeologic conditions and groundwater model results was developed to address the question of how will continued overdraft affect BWD water supply well production. The ENSI report is entitled *Assessment of Water Level Decline, Hydrogeologic Conditions, and Potential Overdraft Impacts for Active BWD Water Supply Wells*, dated 1/7/2019. The work is included in its entirety as Appendix C.

The 1/7/2019 Report is intended for use as the GSP is implemented as a means of evaluating well performance relative to the SGMA threshold criteria (see Section 3 of the Draft GSP). For example, the Draft GSP has established drawdown thresholds for BWD wells based on screen intervals (see Table 3-4 of the GSP) with the intent to establish a maximum allowable impact in support of the SGMA sustainability criteria. This is explained in the draft GSP (Section 3.3.1) as follows:

"*The GSP regulations provide that the "minimum threshold for chronic lowering of groundwater levels shall be the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results" (Title 23 CCR Section 354.28(c)(2)).*

*Chronic lowering of groundwater levels in the Subbasin, as discussed in Section 3.2.1, Chronic Lowering of Groundwater Levels – Undesirable Results, cause significant and unreasonable declines if they are sufficient in magnitude to lower the rate of production of pre-existing groundwater wells below that necessary to meet the minimum required to support the overlying beneficial use(s), where alternative means of obtaining sufficient groundwater resources are not technically or financially feasible. In addition, GWEs [*ed: groundwater elevations*] will be managed under the minimum thresholds to ensure the several aquifers in the Subbasin are not depleted in a manner to cause significant and unreasonable impacts to other sustainability indicators. At the same time, the GSA is mindful that groundwater levels are anticipated to fall below 2015 levels before they are stabilized by the end of the GSP implementation period. Thus, the minimum thresholds have been designed with that circumstance in mind.*

Maintaining groundwater levels above saturated screen intervals for pre-existing municipal wells during an anticipated multi-year drought circumstance was selected as the minimum desired threshold for GWEs that would be protective of beneficial uses in the Subbasin. This minimum threshold in most cases would also be protective of non-potable irrigation beneficial uses.

Explained as follows, these minimum thresholds are also intended to protect against significant and unreasonable impacts to groundwater storage volumes, water quality and the beneficial uses of interconnected surface water."

A key concept going forward is that ongoing overdraft is causing water levels to continue to drop and affect hydraulic conditions and well operation. In many cases sparse well-specific hydraulic test data are available, and the model developed to assess basin-wide hydrologic conditions is being used assess local, well-specific conditions. This gives rise to substantial uncertainty as the groundwater model is being used to predict future water level decline. The report, included as **Appendix C**, was developed as follows:

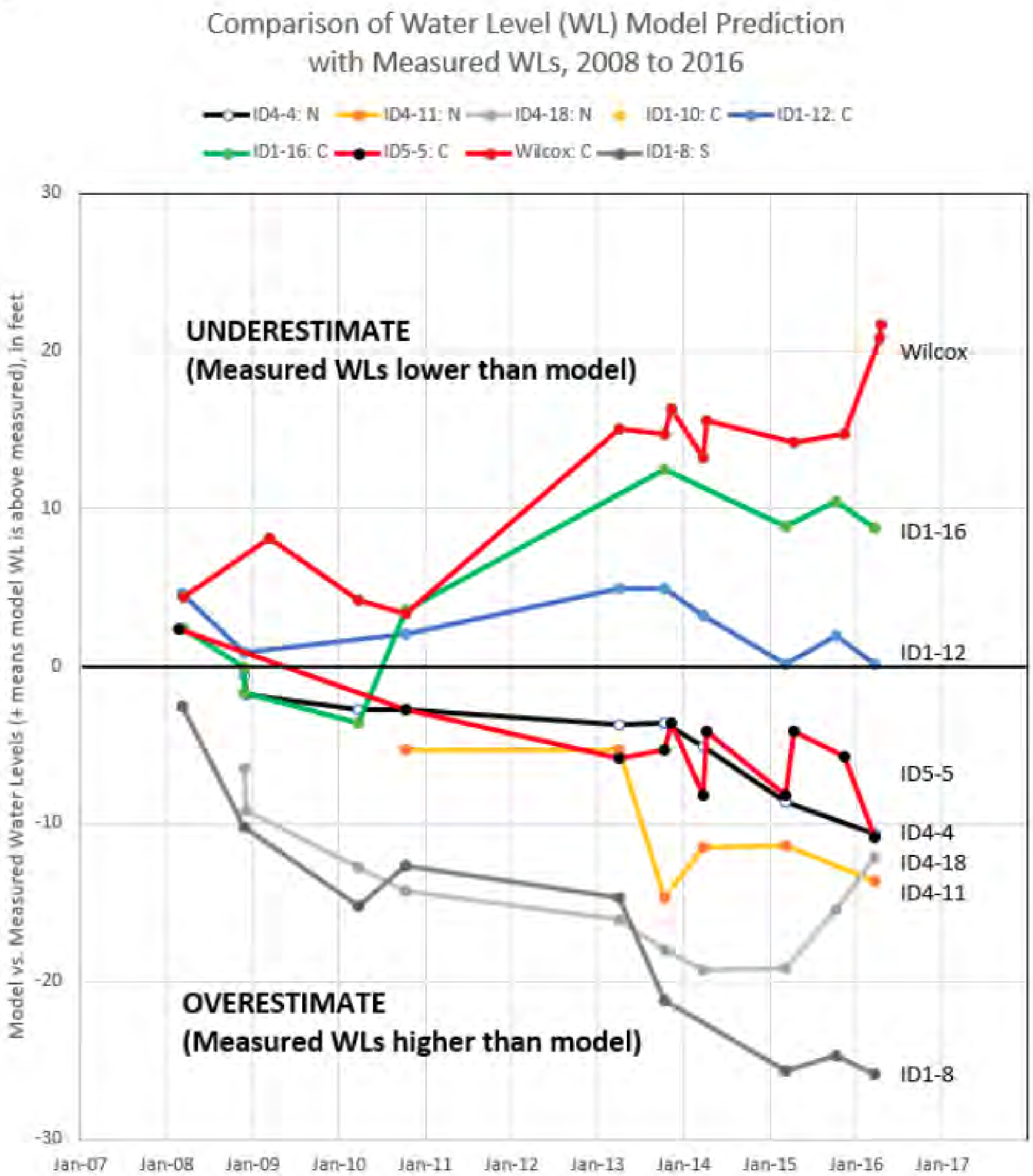
1) Construct and evaluate hydrographs depicting measured groundwater levels and model predicted groundwater levels at each well, and examine water level decline trends at each BWD water supply well. The hydrograph data were provided to ENSI by Dudek as the GSP was being developed. These data will be updated as part of the GSP process.

Observed groundwater elevations at the nine BWD wells and model-estimated groundwater elevations calculated as part of the Groundwater Model Update by Dudek are presented in hydrograph plots (Figures 3 to 12 [**Appendix C**]). Dudek's update used the calibrated USGS model (1945 to 2005) and incorporated additional hydrologic data to extend the model period through 2016. (Their model update report is included in Appendix D of the Draft GSP).

In the larger perspective the groundwater model generally replicates the overall decrease in water levels and loss of groundwater from storage that has been and continues to occur in the Subbasin due to overdraft. Groundwater elevation decline observed at each of the BWD wells has ranged from 20 to 89 feet for each of the wells. The water level elevation decline rates observed in eight of the nine wells over the past decade range from 0.6 to 4.5 feet/year based on linear trends fitted to the water level data (Table 3 of Appendix C). Well ID1-10 is an exception and has exhibited a rise in groundwater elevation over the past 10 years. Note that ID4-4 is scheduled to be replaced in 2019.

The differences between the observed and modeled groundwater elevations over time are depicted for eight of the nine BWD water supply wells (Figure 3, included below). Figure 3, further described in Appendix C, clearly illustrates how the model calibration process provide a large-scale statistical fit that results in both over- and under-estimates of water level elevation and that the differences can vary over time. Future work done in support of the 20-year GSP process will likely include review and revision of the groundwater model.

FIGURE 3



Notes:

1. Overestimates mean that the model calculations lead to more overdraft than is being observed. This may provide a factor of safety for the well operation.
2. ID1-10 is not shown because results show the model water levels are higher than observed by 60 to 40 ft (See **Figure 4**)

2) Develop lithologic logs for each of the BWD wells as derived from driller's logs and available detailed geologic cross-sections and related studies. Use the interpreted logs to compare local well conditions to the larger-scale hydrogeologic parameters used in the USGS Model [USGS Model Report, 2015[11]].

Here the driller's logs are the only available subsurface data for each of the wells. Driller observation can vary significantly in terms of detail and quality so the logs presented in **Appendix C** are based on professional experience and a high level of interpretation was employed, including the review of underlying hydrogeologic reports.

3) Compare the hydrographs and model-based water level predictions to the lithologic logs to provide an understanding of well-specific hydrogeologic conditions at BWD's nine water supply wells.

Comparison of the observed and model-calculated water level elevations can be used to support the use of the groundwater model at BWD well locations. The model works to provide a statistically-based 'fit' of observed and predicted water levels and tends to average conditions across the Subbasin. As a result, while the model provides a Subbasin-wide assessment of hydrologic conditions, local water level elevations calculated by the model can be higher or lower than those observed by water level elevations obtained by measurements at the wells. If the water level elevations calculated by the model are lower than observed, the model is said here to overestimate water level declines and thus overestimate overdraft. From a BWD management perspective this means that the use of the model is protectively conservative and allows for a margin of error. Conversely, if the model-calculated water levels are higher than those observed at a well the model is said to underestimate water level decline and overdraft. In both cases the understanding of model behavior can be used to support the localized use of the model.

[11] [USGS Model Report, 2015] Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed, Michelle, Brandt, Justin, Martin, Peter, and Coes, A.L., 2015, Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California: U.S. Geological Survey Scientific Investigations Report 2015–5150, 135 p., http://dx.doi.org/10.3133/sir20155150

4) Use the model aquifer geometry and local hydraulic conductivity values to calculate aquifer transmissivity, a measure of aquifer productivity, for each BWD well location. Based on observed water level decline, calculate the change in transmissivity as a function of aquifer saturation to assess how overdraft will potentially affect BWD water supply well production.

FIGURE 22

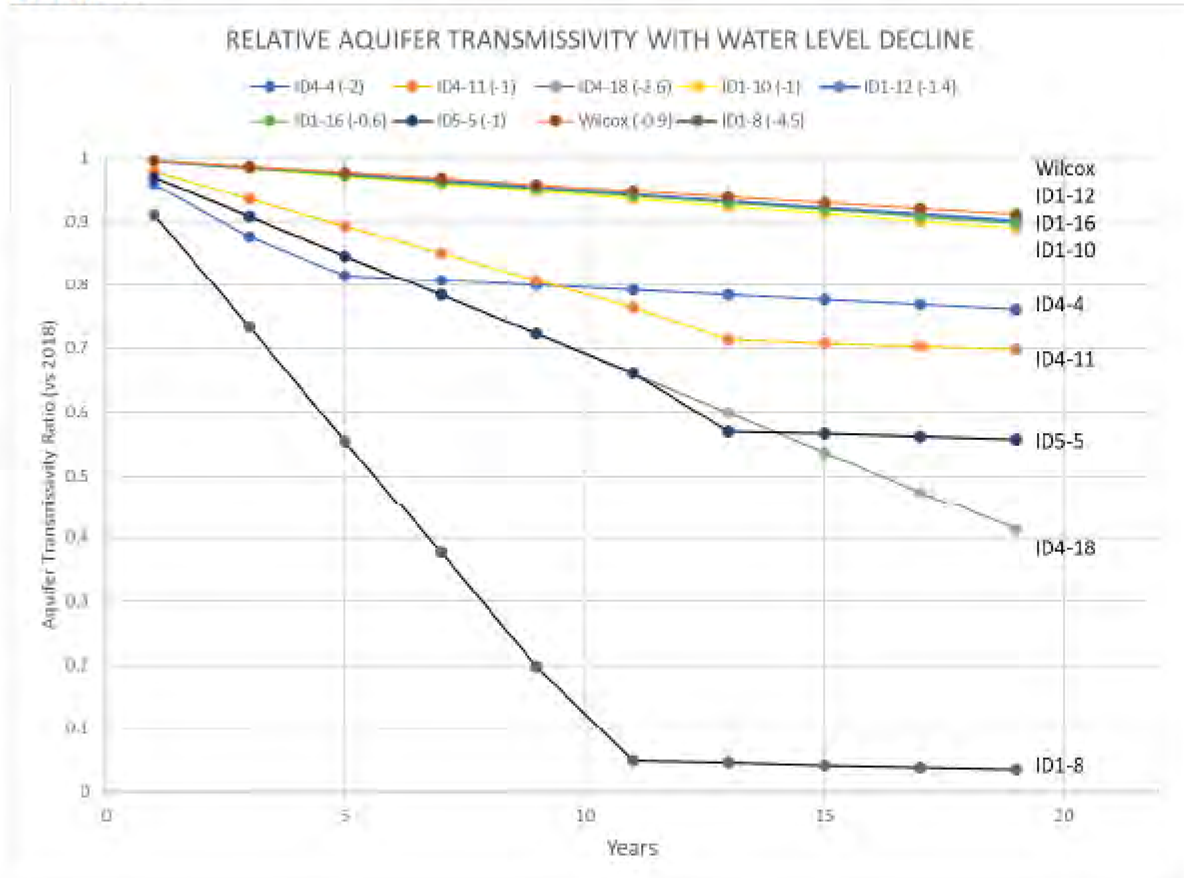


Figure 22, further explained in **Appendix C**, depicts the change in transmissivity over time expressed as a ratio, starting at a value of 1 and decreasing. The annual rate of water level decline is noted for each well in the chart labels, was assumed constant, and ranges from 0.6 to 4.5 ft/year. A future water level decline rate of 1.0 ft/year is provisionally assumed for the ID1-10 replacement well.

Transmissivity is a parameter the is equal to the hydraulic conductivity of the sediment encountered by the well multiplied by the saturated thickness. As water levels decline due to overdraft so does the ability of the well to produce water as flow is proportional to the transmissivity. Wells where large declines in transmissivity occur, such as ID5-5, ID4-18, and ID1-8, will be the most vulnerable to continued overdraft.

Overdraft will affect all of the wells, with the most significant loss in production occurring in a subset of the wells when the upper aquifer is dewatered. As water production shifts to the middle aquifer the well capacities decrease and production rates are expected to generally decrease to varying degrees as a function of water level.

The table of contents of the 1/7/2019 report follows for reference. Section 1 of the 12/7/2018 report (Appendix B) provide a summary overview of hydrologic conditions.

10.0 SUMMARY

Three aspects of the effect of chronic overdraft are reviewed and assessed in this Report:

- Uncertainty associated with the long-term aquifer water balance (water budget) due to decadal variability of groundwater recharge. This variability occurs on a time-scale longer than the 20-year GSP compliance period. **Sections 3, 4, and 5** present an overview analysis of the aquifer water balance components. The goal of SGMA is to attain a sustainable water supply condition where groundwater used is replaced by recharge. Monte Carlo simulations (**Section 6**) were developed based on water balance components determined by the groundwater model that are being used in the GSP to support minimum thresholds for groundwater elevation. As noted in the Draft GSP (page 3-21) "[T]*he minimum threshold is based on the estimated degree of groundwater level decline that would occur in each indicator well if the 20th percentile scenario for groundwater recharge were to be realized*."

- Changes in groundwater quality (**Appendix B**) have occurred and will continue to occur as a result of chronic overdraft. A multi-parameter analysis of water quality data was conducted for 22 wells located across the Subbasin. Sulfate, nitrate, and arsenic are the primary chemicals of concern specific to drinking water. Overdraft has affected water quality, particularly where the upper aquifer system has been extensively or completely dewatered. Groundwater quality decreases with depth and distance away from recharge areas where surface waters enter the Subbasin. The lack of depth-specific data represents a significant data gap and source of uncertainty; however, existing data clearly establish the relationship between overdraft and water quality.

- Decreases well productivity have been and will continue to be associated with dewatering of the most prolific portion of the aquifer system. Further well yields are expected to decrease with time due to decreasing transmissivity (relative rate of inflow) with depth. **Appendix C** provides an assessment based on the aquifer characteristic included in the groundwater model together with a hydrogeologic interpretation of driller's well logs. A review of the impact of overdraft and comparison of model-predicted and observed water levels was conducted for BWD water supply wells that can be used to guide future GSP work.

The GSP provides for a maximum 20-year time frame for the ~75% water use reductions to be accomplished and additional overdraft will occur that has the potential to adversely affect the groundwater supply. An overall framework for the water supply management process has been developed that will revised and updated as the actions outlined in the GSP are implemented. Going forward, the information and analyses included in this Report provide tools and a methodology framework to allow the Borrego Water District (BWD) and others to look at potential water supply situations that may directly impact groundwater users in Borrego Springs, assess the probability of the water supply situations occurring, and make decisions accordingly.

11.0 ACKNOWLEDGEMENTS

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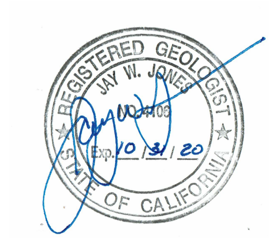
Matthew Wiedlin, PG, CHG
Charlie Monahan (Graphics)



Peer Review was provided by:
Matthew Wiedlin, PG, CHG
Shlomo Orr, PE, Ph.D.
Trey Driscoll, PG, ChG

This work was done under Task 3 of the Proposition 1 Grant Agreement. It is based on work done by Dudek and Geosyntec to develop the Groundwater Sustainability Plan (GSP). Much of the underlying data used in this Report was provided by Dudek staff during development of the GSP

In closing we would like to thank the County of San Diego and the Borrego Water District for their facilitation and support of this work conducted under the Proposition 1 Grant. We also fully appreciate the professional support and cooperation of the people working with the multiple companies that are support the GSA including LeSar Development Consultants, Dudek, Geosyntec Consultants, and Raftelis Financial Consultants.

Appendix A:
Grant Agreement Scope

EXHIBIT A
WORK PLAN

Project Title: San Diego County GSP Development (Project)

Project Description: The Grantee's Project shall: 1) identify vulnerabilities and potential impacts from the GSP process on the SDAC in Borrego Valley; 2) assess programmatic level environmental impacts from implementation actions identified in the GSP; and 3) prepare a GSP. Although, the Project will cover the entire Borrego Valley Groundwater Basin (BVGB), the focus will be the Borrego Springs Subbasin (Subbasin) rather than the Ocotillo Wells Subbasin since the latter is not overdrafted and minimally developed.

Component 1: Grant Administration
Category (a): Grant Management, Invoicing, and Reporting
Manage and administer the Project. Prepare and submit invoices to DWR, track progress and schedule, and manage contracts and budgets associated with the Grant Agreement. Administer and track contracts with consultants or other agencies that are necessary to complete tasks in the Work Plan and compile the required invoice back-up information. Conduct administrative responsibilities associated with the Project such as coordinating with partnering agencies and managing consultants/contractors including coordination of conference calls/meetings as needed.

Compile quarterly Progress Reports and invoices for submittal to DWR. Progress Reports will be prepared in accordance with Exhibit F. Invoices will include backup documentation. For each component, backup documentation will be collected and organized by category, along with an Excel compatible summary document detailing the contents of the backup documentation.

Prepare draft Component Completion Reports for Components 2 and 3 and submit to DWR for the Project Manager's comment and review no later than 90 days after work completion. Prepare a draft Grant Completion Report and submit to DWR for the Project Manager's comment and review no later than 90 days after work completion. Prepare the final Component Completion Reports and Grant Completion Report addressing the Project Manager's comments and submit to DWR in accordance with the provisions of Exhibit F.

<u>Deliverables:</u>

- Environmental Information Form (EIF)
- Progress Reports
- Invoices and associated backup documentation
- Final Component 2 and 3 Grant Completion Reports
- Final Grant Completion Report

Component 2: Borrego Valley SDAC Impact Assessment/Environmental Planning
Provide support for the GSP and projects in the Subbasin by identifying vulnerabilities and potential impacts from the GSP process on water supply, accessibility, and usage, as well as assessing environmental, economic, cost, governance, and infrastructure concerns. The deliverables produced support the GSA's work by providing reference materials that will aid GSP planning and implementation outreach and decision-making efforts.

Category (a): Planning/Environmental Documentation
Task 1: SDAC Engagement
Establish community characteristics baseline data on SDAC rate payers and the economic structure of Borrego Valley and provide an overview of GSP planning activities to date and an update on engagement efforts.

Deliverables:

- Summary Report: Community Characteristics
- Summary Report: SDAC Engagement
- Summary of activities included in Progress Report(s)

Task 2: SDAC Impact/Vulnerability Analysis
Understand implications that the implementation of SGMA will have on the SDAC including impacts based on potential water reduction scenarios by analyzing baseline data and identifying the primary vulnerabilities of the SDACs within each subarea.

Deliverables:

- Summary Report: Baseline Water Use
- Summary Report: Water Supply Impact/SDAC Vulnerability/SGMA Impacts Analysis

Task 3: Decision Management Analysis
Develop tools to allow the Borrego Water District (BWD) to look at potential water supply situations that may directly impact groundwater users in Borrego Springs, assess the probability of the water supply situations occurring, and make decisions accordingly. Assess the potential range of outcomes of the groundwater extraction restrictions that will allow the BWD to look at water supply situations, such as the potential need for water treatment, or loss of individual supply wells due to ongoing groundwater overdraft and be able to assess its probability of occurring. Assessment of the potential range of outcomes of the groundwater extraction restrictions using Monte Carlo simulation methods and alike. Analyses will be performed of the potential impacts of various water reduction scenarios on the SDAC, rate payers, and BWD infrastructure. A larger scale impact assessment (SGMA/Environmental/Societal/Government Impacts) will be developed that examines community-wide socioeconomic impacts and changes that will result from the GSP.

Deliverables:

- Summary Report: Water Supply Uncertainties
- Summary Report: Monte Carlo simulation model
- Summary Report: Cost and Rate Structure Uncertainty and Impact Analysis
- Summary Report: SGMA/Environmental/Societal/Government Impacts

Task 4: Well Metering
Refine groundwater extraction data, particularly for agricultural use, that is being pumped within the Subbasin. Well meters will be installed on non-de minimis production wells within the Subbasin of the BVGB.

Deliverables:

- Meter Installation and Calibration Report

Task 5: Water Vulnerability/New Well Site Feasibility Study
Assess water supply vulnerability and determine a new well site to provide potable water to the SDAC in Borrego Springs via the BWD. Once alternative well locations are identified and prioritized, a test well will be drilled to identify geologic and hydrogeologic conditions of the selected location including lithology and borehole geophysics. The test well will be drilled to the depth of optimal supply quantity expected (possibly up to 1,000 feet) and evaluated for production capacity, aquifer properties, and water quality parameters. Upon completion of the evaluation, the test well may be utilized as a production well for BWD, if appropriate. Complete environmental review pursuant to CEQA and procure necessary permits as set forth in Paragraphs 14 and D.7 of this Agreement.

Deliverables:

- Summary Report: Well Ranking System
- Summary Report: Updates on WaterCAD hydraulic modeling files
- Well Installation Report

- Monitoring Plan for the newly installed well
- EIF, all necessary California Environmental Quality Act (CEQA) documents, permits, and access agreements to construct test well as applicable

Category (b): Environmental Planning
Prepare the appropriate CEQA analysis and programmatic documentation, anticipated to be an EIR, for the tasks identified in the GSP that will aid GSP planning. No costs to be reimbursed with grant funds for Component 2, Category (b) may be incurred prior to the adoption of the GSP by the GSA.

Task 6. Project Description, Initial Study, Notice of Preparation, and Scoping
Prepare a project description, which forms the basis of analysis of potential impacts in the EIR. The Notice of Preparation (NOP) will be prepared consistent with CEQA Guidelines and include a completed Initial Study checklist attached to the NOP.

Deliverables:

- Project Description
- Initial Study and NOP

Task 7. Draft EIR, Notice of Availability, and Notice of Completion
Prepare a Draft EIR, Notice of Availability, and Notice of Completion. The EIR will focus on the issues that are identified to have potentially significant impacts in the Initial Study. The EIR will include all contents required by County requirements, the CEQA statute, and State CEQA Guidelines.

Deliverables:

- Draft EIR
- Notice of Availability
- Notice of Completion

Task 8. Final EIR
Review and respond to comments received on the Draft EIR. This task will also include preparation of CEQA Findings of Fact (Finding), Mitigation Monitoring and Reporting Program (MMRP), Notice of Determination (NOD) and, if necessary, a Statement of Overriding Considerations (SOC).

Deliverables:

- Final EIR
- CEQA Findings
- Mitigation Monitoring and Reporting Program
- Notice of Determination
- Statement of Overriding Considerations (if necessary)
- Environmental Information Form for subsequent implementation actions identified in an adopted GSP

Component 3: Borrego Valley GSP Development
Category (a): Planning Activities
Task 1: Advisory Committee Meetings and Public Hearings
Participate in advisory committee meetings throughout GSP development and attend public hearings at key milestones in the process.

Deliverables:

- Summary of activities and meetings included in Progress Report(s)

Task 2: GSA Coordination Meetings
Coordinate GSA activities with consultants and partner agencies to develop GSP components and collaborate on appropriate projects and management actions to achieve sustainability within the Subbasin.

Deliverables:
- Summary of activities and meetings included in Progress Report(s)

Category (b): GSP Development
Task 3: Data Management System, Data Collection and Analysis
Develop a data management system (DMS) that can store information to support development and implementation of the GSP, as well as continued monitoring of the Subbasin and sustainability tracking. Conduct semi-annual water level monitoring and groundwater quality sampling of wells located in areas where pumping and water-level decline are greatest.

Deliverables:
- Summary of the DMS

Task 4: GSP Development
Prepare a GSP for the BVGB that meets SGMA regulations and DWR requirements. Provide summaries of GSP development activities within the Progress Reports. The GSP will include, at a minimum, the sections outlined below:

1. Administrative Information
   Prepare the Introduction section of the GSP. Components of this task includes defining the Purpose of GSP, establishing Sustainability Goal, providing Agency Information, and discussing GSP Organization.

2. Plan Area and Basin Setting
   Identify the geographic area covered by GSP and develop a description of the area. Evaluate the existing monitoring network and providing recommendations on expanding the network and developing an ongoing monitoring program to include water level monitoring and water quality sampling throughout the GSP implementation phase.

3. Water Budget and Hydrogeologic Model
   Develop a water budget and create a hydrogeologic conceptual model to be included in the GSP. Update the United States Geological Survey Numerical Model for the basin.

4. Sustainable Management Criteria
   Prepare the Sustainable Management Criteria section of the GSP. Components of this task include establishing a Sustainability Goal, defining Undesirable Results, determining Minimum Thresholds, establishing Measurable Objectives, and preparing a section on Monitoring Network.

5. Project and Management Actions to Achieve Sustainability Goal
   Prepare the Projects and Management Actions to achieve the identified Sustainability Goal and interim goals. Projects and management actions will be identified and Project Descriptions will be provided.

6. Plan Implementation
   Prepare the Plan Implementation section of the GSP. Components of this task include the Estimate of GSP Implementation Costs, Schedule for Implementation, Annual Reporting, and Periodic Evaluations.

7. Final GSP
   Review public comments, drafting responses to public comments, and finalizing the GSP.

Deliverables:

- Summaries of activities included as attachments in the Progress Reports
- Final GSP
- Proof of final GSP submittal to DWR

Task 5: Well Permitting
Perform adequate revisions to the County's well permitting process for Borrego Valley.

Deliverables:

- Revised Well Permitting Requirements

Appendix B:

Water Quality Review and Assessment:
Borrego Water District (BWD) Water Supply Wells.
ENSI Draft dated 12/7/2018
(Included as Appendix D2 of the Draft GSP)

December 7, 2018

Mr. Geoff Poole
General Manager, Borrego Water District
806 Palm Canyon Drive,
Borrego Springs, CA 92004

RE: Water Quality Review and Assessment:
Borrego Water District (BWD) Water Supply Wells

Dear Geoff,

The following draft Report was produced under our existing contract to provide technical support to BWD for to the Borrego Valley Groundwater Basin Groundwater Sustainability Plan Proposition 1 Grant Project.   It addresses portions of Tasks 2.1 and 2.2, and will support Tasks 3.1 and 3.2 specific to water quality changes related to groundwater overdraft.

Subsequent analyses are in process that will build from this Report to examine the effect of overdraft on BWD's long-term water supply.

Thank you for your time and attention.

Sincerely,

Jay W. Jones
CA PG#4106
Environmental Navigation Services Inc.

WATER QUALITY REVIEW AND ASSESSMENT: BORREGO WATER DISTRICT (BWD) WATER SUPPLY WELLS

OVERVIEW

The purpose of this Report is to review water quality data for active Borrego Water District (BWD) water supply production wells to

1) Provide an overview of water quality conditions among the wells and assess spatial variations;
2) Examine how water quality has changed over time due to overdraft;
3) Evaluate the potential relationships among multiple water quality parameters as a means to support trend analyses for the five primary chemicals of concern (COCs) that include arsenic, total dissolved solids (TDS), nitrate, sulfate, and fluoride (As, TDS, NO_3, SO_4, and F);
4) Determine how well water quality trends may (or may not) be able to be identified among BWD water supply wells; and,

The Borrego Springs Subbasin (Subbasin) of the Borrego Valley Groundwater Basin is in a state of critical overdraft and subject to the Sustainable Groundwater Management Act (SGMA). As defined under SGMA[1] "A basin is subject to critical overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts."

Pursuant to SGMA a Groundwater Sustainability Plan (GSP) is currently under development for the Subbasin. This work updates and extends beyond prior work done by Dudek to assess water quality trends for BWD wells as described in the Draft Borrego Springs Subbasin Groundwater Quality Risk Assessment presented to the BWD Board on 6/28/2017.[2]

The analyses included herein will be used in subsequent ENSI reports to examine potential BWD water supply impacts and costs associated with current and future water quality conditions.

[1] See: https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118/Critically-Overdrafted-Basins

[2] The data used in the Report were located and compiled by Dudek staff as part of the GSP preparation process. The analyses presented in this Report would not have been possible without their support.

Preparation of the GSP is underway and it is understood that the draft GSP will be available for public review by January 2019[3]. The GSP will include a range of potential options for Projects and Managements Actions (PMAs), including PMAs to address water quality and water quality optimization. Among the direct impacts of degraded groundwater quality to BWD include:

- Need for Water Treatment to achieve drinking water standards (on a per well basis)
- Impact of water quality on the choice and design of replacement wells at existing well locations
- Potential need for Intra-Subbasin Transfer of Potable water from new or existing wells due to degraded water quality due to natural or anthropogenic sources

Groundwater quality data also have a role in the assessment of potential water management options that include but are not limited to:

- Options for Enhanced Natural Recharge (understood to be limited)[4]
- Artificial Recharge using Treated Wastewater

Of primary concern to BWD is the ability of historical data combined with ongoing water quality monitoring program to assess water quality trends. The data are needed to support management of their water system, for example to assess the probability of MCL (maximum contaminant level) exceedances and to plan for water treatment, if needed.

[3] The GSP is being developed by the Groundwater Sustainability Agency (GSA) that consists of the County of San Diego and the Borrego Water District. See overview at: https://www.sandiegocounty.gov/pds/SGMA.html
[4] It is understood that that recharge basins within the floodplains where much of Borrego Springs' residential population is located are likely not permittable due to County Flood Control Management concerns. Similarly managed artificial recharge areas located along mountain fronts within or nearby to the Anza Borrego State Park are also not likely permittable given their potential impact on the State Park.

This report includes the following sections:

1.0 HYDROLOGIC CONDITIONS

A brief summary of the hydrologic conditions of the Subbasin is provided here to support review of the water chemistry data. Included is a description of groundwater recharge, pre- and post-development groundwater levels, and aquifer conditions. Many of the figures and much of the discussion included in this section was derived from the USGS Model Report prepared in 2015 entitled *Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California*: U.S. Geological Survey Scientific Investigations Report 2015–5150[5]. For reference the *simulation of groundwater flow* refers to the use of a numerical model (in this case the USGS Modflow Model as described in the 2015 report) to examine the groundwater levels, recharge, and overall hydrologic conditions for the period of 1945 to 2010. The GSP contains additional detailed hydrologic information, and updates the USGS modeling work.

1.1 Basin Location and Setting: Contributory Watersheds

The Borrego Springs Subbasin (Subbasin) of the Borrego Valley Groundwater Basin is located at the western-most extent of the Sonoran Desert. The primary source of water to the Subbasin is surface water (storm water and ephemeral stream flow) that flows into the valley from adjacent mountain watersheds and infiltrates within the valley. The contributory watersheds are approximately 400 square miles (mi^2) and much larger in area than the approximately 98mi^2 Subbasin as illustrated in **Figure 1**.

Direct recharge by rainfall within the valley is very low compared to surface water inflows as the annual rainfall averages 5.8 inches per year (in/yr.) [USGS Model Report, page 43]. Stream and flood flows from the adjacent watersheds provide the bulk of the water that enters the Subbasin.

[5] Referenced herein as the "USGS Model Report": Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed, Michelle, Brandt, Justin, Martin, Peter, and Coes, A.L., 2015, Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California: U.S. Geological Survey Scientific Investigations Report 2015–5150, 135 p.
See: http://dx.doi.org/10.3133/sir20155150

FIGURE 1 (from USGS Model Report)

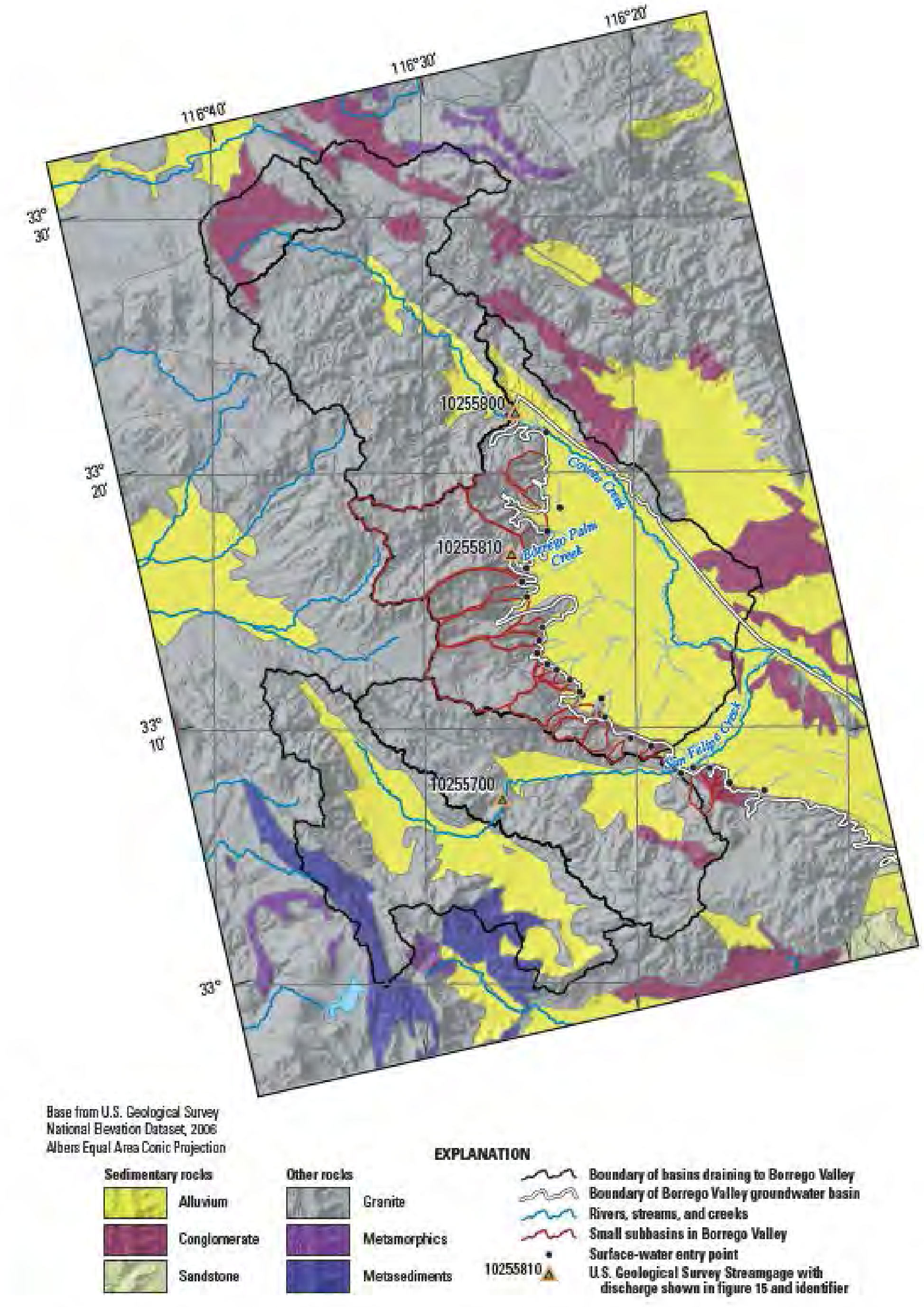


Figure 16. Drainage basin boundaries and geology used in the Basin Characterization Model to estimate climate-driven natural recharge in the Borrego Valley, California.

Note: The Subbasin lies within the area defined by alluvium. The tributary watersheds (e.g. that support Coyote Creek, Borrego Palm Creek, and San Felipe Creek) are outside of the Subbasin.

1.2 Historical Groundwater Conditions

The Subbasin receives recharge waters from the adjacent watersheds that include Coyote Creek, watersheds along the northwestern edge of the valley such as Borrego Palm Canyon, and San Felipe Creek that enters the south side of the valley (**Figure 1**).

Two water level maps from the USGS Model Report are included in **Figures 2A** and **2B** that depict pre- and post- development water levels (1945 and 2010). In both cases the Subbasin can be generally described as "closed" where surface water flows typically do not discharge from the valley but instead, if sufficient flows occur, terminate at the Borrego Sink.

Prior to development (**Figure 2A**) groundwater flow within the northern and central portions of the valley can generally be described as moving from northwest to southeast towards the Borrego Sink. Flow in the southern portion of the Subbasin is directed northeast towards the Borrego Sink. Pumping since 1945 has lowered groundwater levels and led the development of significant depressions of the water table associated with 'pumping centers' (see **Figure 2B**). From a groundwater perspective the overall flow patterns in the northern and central areas of the valley have changed from a roughly uniform flow (generally towards the Borrego Sink) to a condition where groundwater flow is reversed in some areas and now flows toward the pumping centers. The rate of pumping has greatly exceeded groundwater recharge rates and water levels have dropped well over 100 feet in some areas. Because the current rate of groundwater use continues to cause significant water level decline and loss of water from subsurface storage the Subbasin is now classified as being in critical overdraft.

Further description of historical and current groundwater conditions is included in the GSP.

FIGURE 2A (from USGS Model Report)

44 Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley

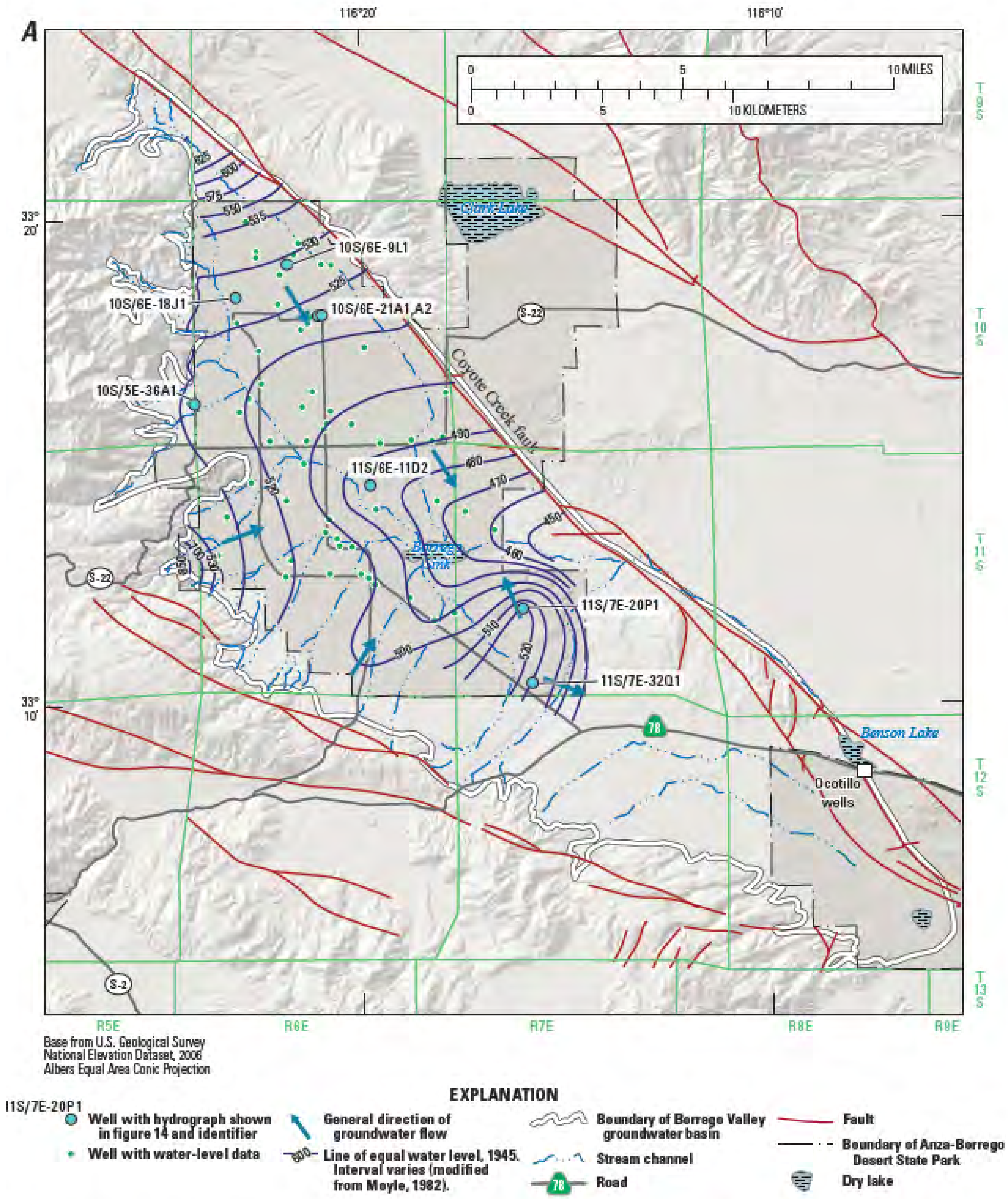


Figure 13. Water-level elevations and direction of groundwater flow in Borrego Valley, California, for *A*, 1945, approximately predevelopment, and *B*, 2010. (2010 data are modified from http://www.dpla.water.ca.gov/sd/groundwater/basin_assessment/basin_asssment.html).

Note: The arrows indicating groundwater flow are roughly coincident with intermittent surface water channels (dashed blue lines) that enter from adjacent watersheds and flow towards the Borrego Sink.

FIGURE 2B (from USGS Model Report)

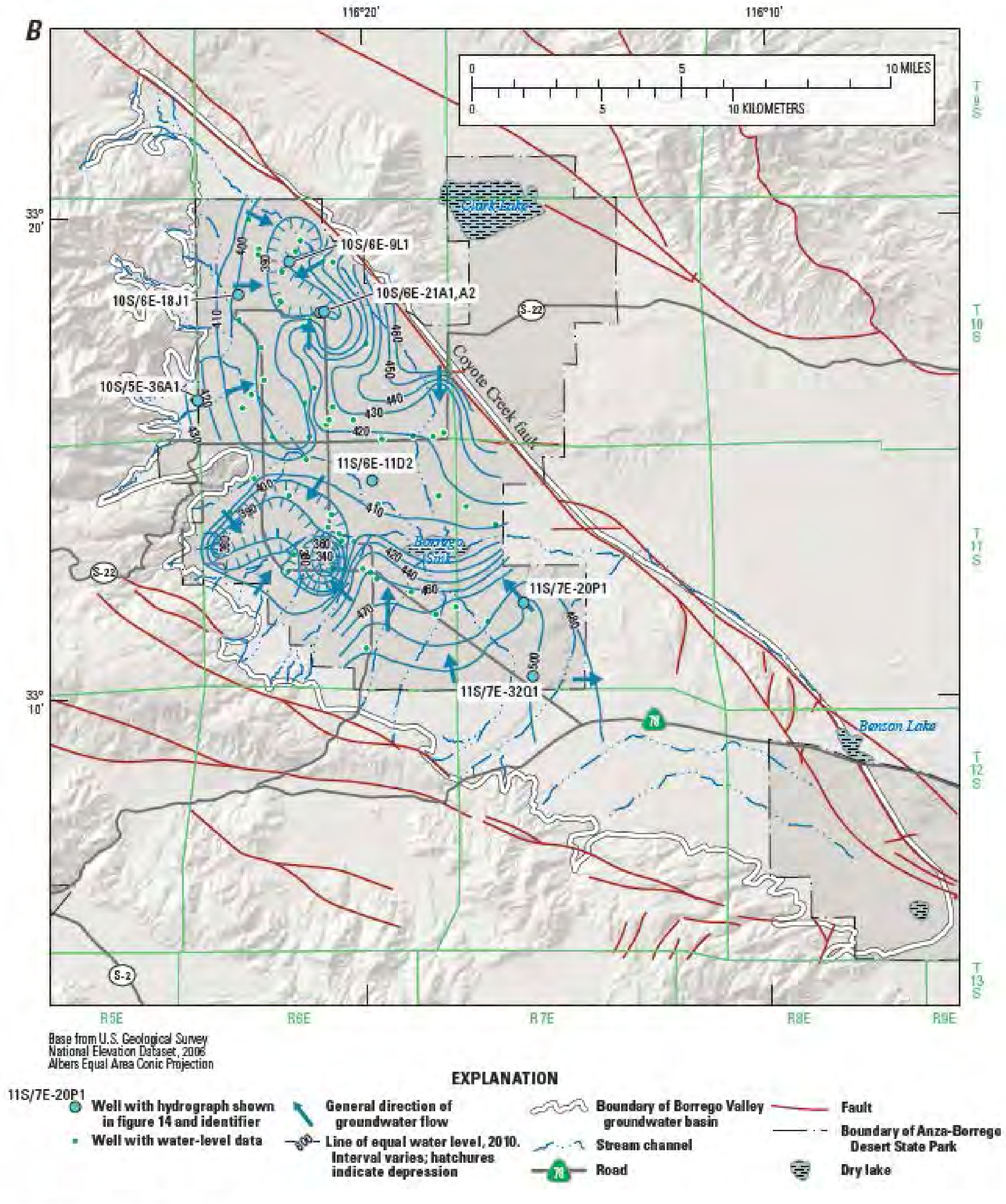


Figure 13. —Continued

NOTE: Hachured areas show the two major pumping centers in the Subbasin. The influence of northern pumping center has caused groundwater to reverse flow direction (see arrow at well 10S/6E-21A1). The central pumping center captures groundwater that was previously flowing south and southeastward towards the Borrego Sink.

1.3 Stratigraphy and Aquifer Conceptual Model

The current conceptual model for the aquifer system as incorporated in the USGS Model is that it consists of three unconfined aquifers named the upper, middle and lower aquifers. The upper and middle aquifers are the primary sources of water currently and are typically comprised of unconsolidated sediments. However, with time, the upper aquifer has become or is expected to become dewatered and the lower aquifer will become a more important source of water as overdraft continues.

The lower aquifer sediments become consolidated with depth and have been subject to folding and faulting. The lower aquifer provides water supply for some pumpers, especially in the southern area of the Subbasin. **Figure 3** (Figure 7 of the USGS Model Report) depicts the Borrego Valley Groundwater Basin as described by Moyle, 1982.[6] Additional work has been done by Mitten et al (1989),[7] and by Netto (2001).[8] Of these, Netto (2001) provides the most detailed analysis of basin stratigraphy based on well log review and interpretation. Review of their work supports that locally confined aquifer conditions are expected to occur.

In brief there are a number of geologic features relevant to groundwater conditions and water quality:

- The Subbasin, as exemplified by the flow of water and sediment toward the current-day Borrego Sink, has historically been the locus of sediment deposition. Sedimentation initially occurred in a marine environment (with sediment sources located to the east) and transitioned to terrestrial environments as seen today.[9]
- The Borrego Sink, similar to dry lake beds that occur in the desert, is a location where water evaporates and minerals will accumulate and can form evaporite deposits. Historically similar conditions occurred as sediments were deposited. Thus, the middle and upper aquifers have the potential to include evaporite deposits that can re-dissolve and lead to elevated concentrations of sulfates and carbonates that result in corresponding increase in TDS.

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[6] Moyle, W. R., 1982, Water resources of Borrego Valley and vicinity, California; Phase 1, Definition of geologic and hydrologic characteristics of basin: U.S. Geological Survey Open-File Report 82–855, 39 p.

[7] Mitten, H.T., Lines, G.C., Berenbrock, Charles., and Durbin, T.J., 1988, Water resources of Borrego Valley and vicinity, California, San Diego County, California; Phase 2, Development of a groundwater flow model: U.S. Geological Survey Water-Resources Investigation Report 87–4199, 27 p.

[8] Netto, S.P., 2001, Water Resources of Borrego Valley San Diego County, California: Master's Thesis, San Diego State University, 143 p.

[9] See GSP. For general reference see: Dorsey, R.J., 2005. Stratigraphy, Tectonics, and Basin Evolution in the Anza-Borrego Desert Region. In "Fossil Treasures of the Anza-Borrego Desert", George T. Jefferson and Lowell Lindsay, editors, Sunbelt Publications, San Diego California, 2006
https://pages.uoregon.edu/rdorsey/Downloads/DorseyChaperNov05.pdf

- Structural features such as the Coyote Creek Fault, the Desert Lodge anticline, and the effect of basement uplift and exposure of lower aquifer sediments along the southeastern portion of the Subbasin (cross-section A-A' in **Figure 3**) limit groundwater flow within and out of the basin. The Coyote Creek Fault is assumed to be a 'no flow' boundary condition in the USGS Groundwater Model and as such serves to contain groundwater within the basin and direct flow to the southeast towards the Borrego Sink. The current-day topography combined with the geologic structure creates a 'closed' groundwater condition where ongoing evaporation of water will lead to the long-term accumulation of minerals (often referred to as 'salts') in soil and groundwater.
- While the lower aquifer is quite deep and contains a significant volume of groundwater, the sediments have less storage capacity than the upper and middle aquifers as quantified in the USGS Model by lower specific storage and specific yield. The lower aquifer is also expected to have poor water quality with depth.
- Waters that flow into the Subbasin from the adjacent watersheds will have varying chemistry depending on the geologic and hydrologic conditions encountered in the watersheds. For example, water that flows in Borrego Palm Creek from nearby crystalline rock of the San Ysidro Mountains (see **Figure 1**) will be different than the waters of San Felipe Creek that drain from an alluvial desert valley and more likely to accumulate dissolved minerals.

Please refer to the GSP for additional details.

FIGURE 3

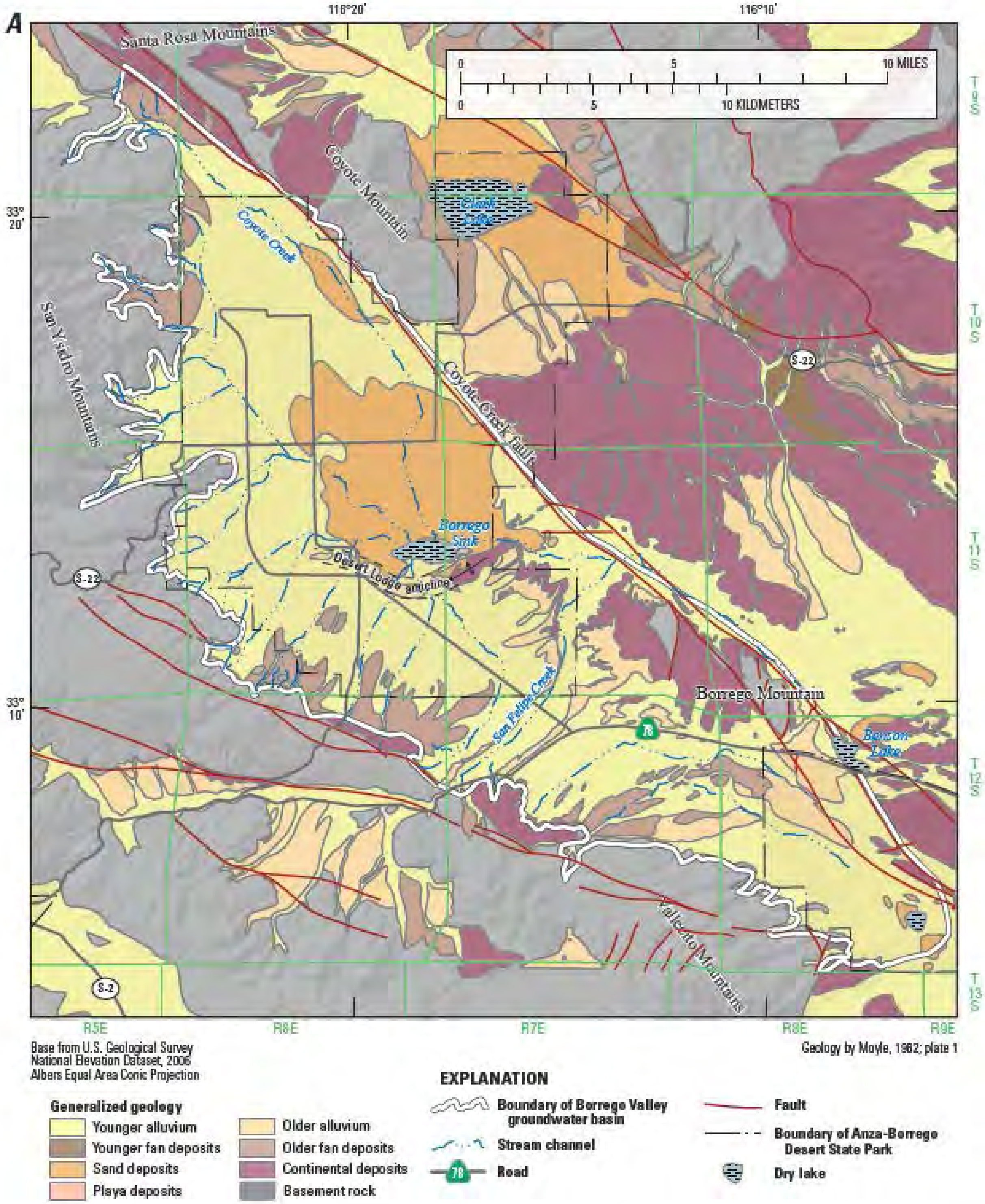


Figure 7. Maps showing Borrego Valley, California, showing *A*, geology; *B*, hydrogeology; and *C*, generalized hydrogeologic cross sections A-A′ and B-B′. (Lines of section are shown in figure 7B.)

FIGURE 3, continued

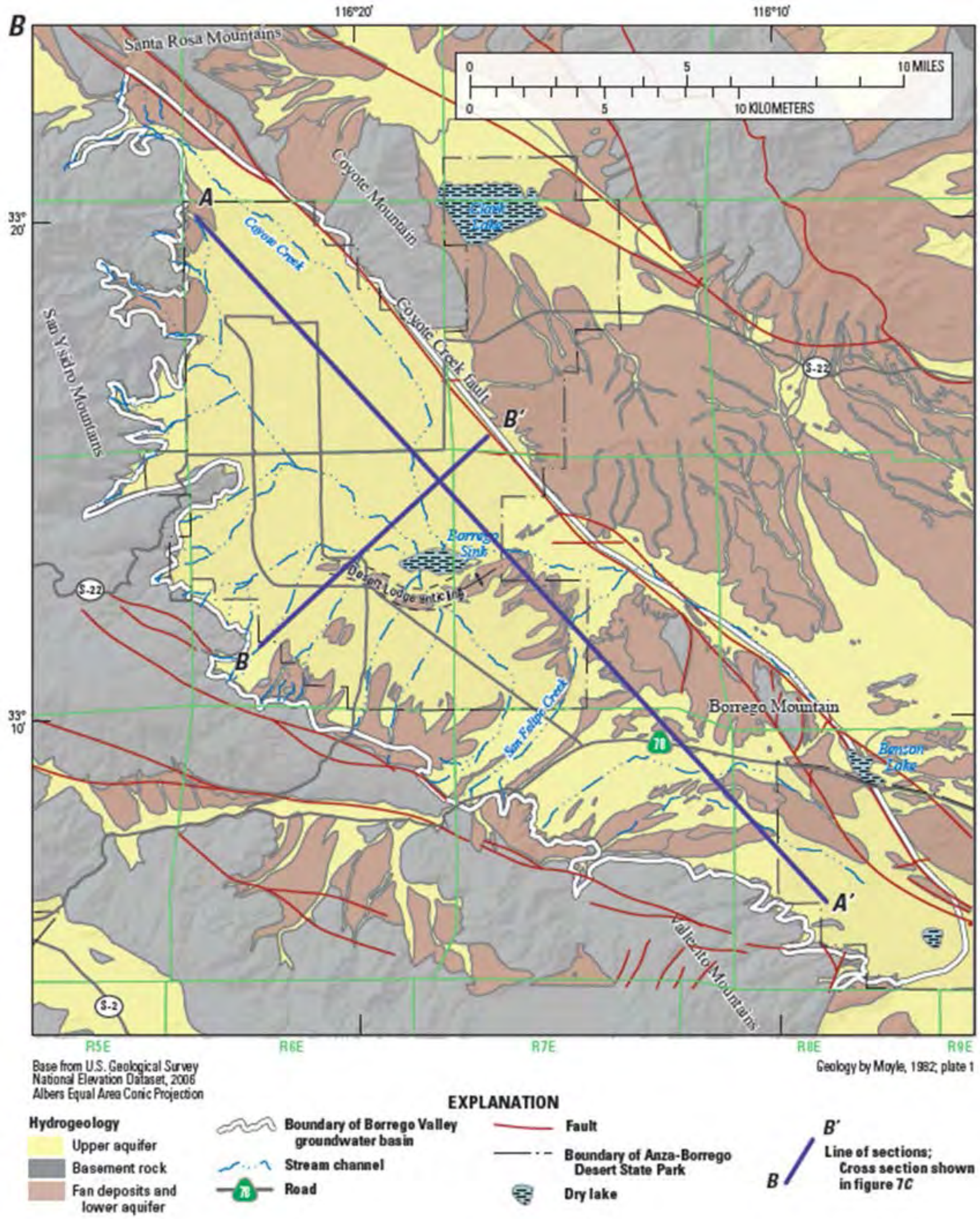
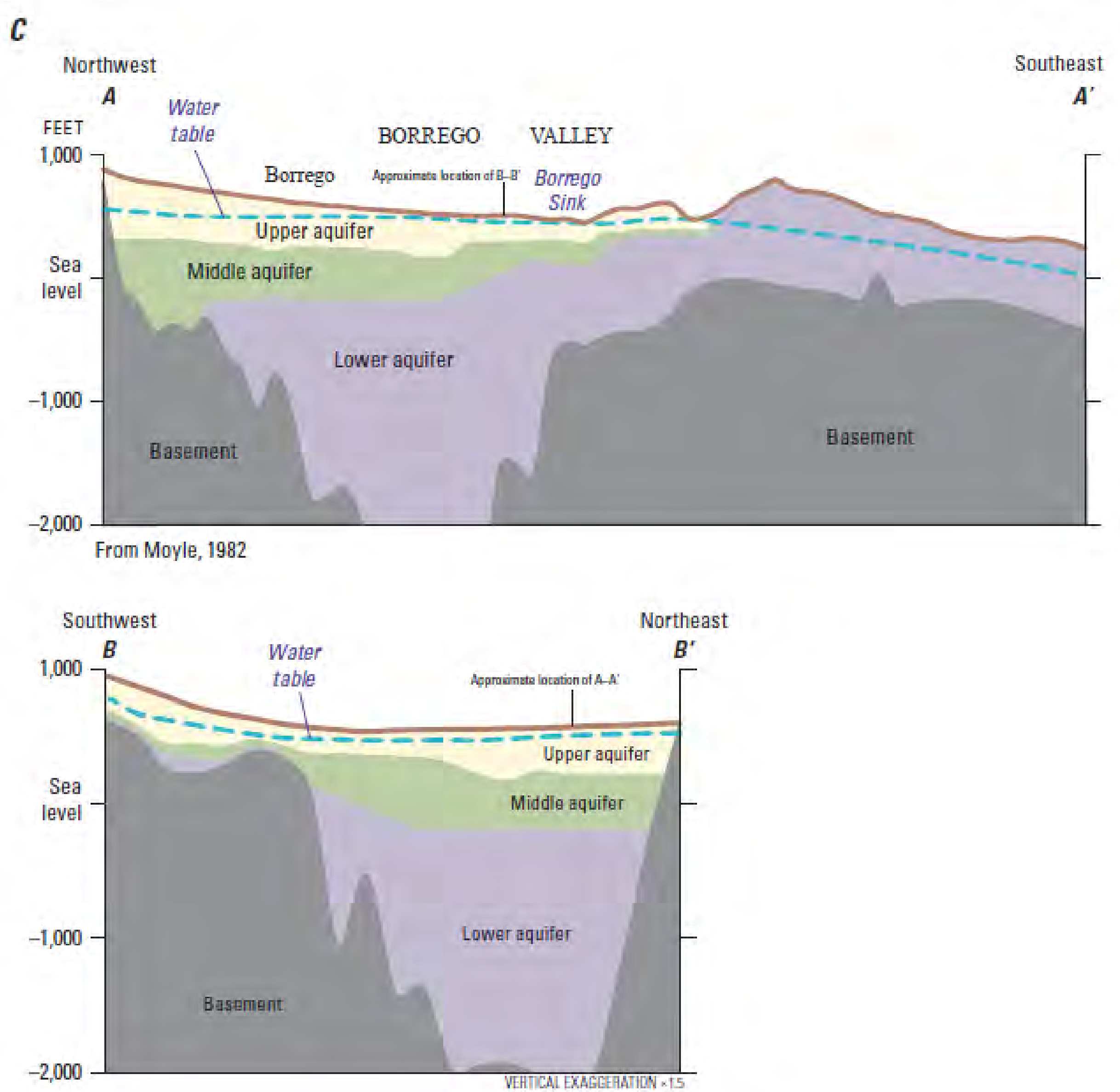


Figure 7. —Continued

FIGURE 3, continued



2.0 WELLS AND DATA USED IN THIS ANALYSIS

A total of 23 wells were included in this water quality analysis. Of these eight are active BWD supply wells and a ninth is used for emergency supply. The data for the wells were compiled and tabulated by Dudek staff as part of the GSP preparation process.

It is important to note that the wells were typically completed with long screened sections and can be open to flow from the upper, middle, and/or lower aquifers depending on the well construction, current groundwater levels, and well hydraulics. As a result, the data were not segregated by aquifer or depth.

Table 1A lists the active BWD wells and indicates the time periods when general minerals data were obtained. The wells have been segregated into three management areas (North, Central, and South) as established in prior work by Dudek.

TABLE 1A: BWD Water Supply Wells

Plot ID	Area	Well Name	GSA GWM Well	Year Inst.	gpm	Static Water Level (ft)	Draw Down (ft)	gpm/ft ***	Plant Eff.****	Well Depth (ft)	Sampling Period	
											start	end
4	North	**ID4-4***	Yes	1979**	365	205.4	63.5	6	71	802	1954**	2017
5		**ID4-11**	Yes	1995	620	223.2	5.8	107	73	770	1995	2017
2		**ID4-18***	Yes	1982	130	311.2	7.6	17	50	570	1984	2017
14	Central	**ID1-10***	Yes	1972	317	213.9	11.5	28	54	392	1972	2017
9		**ID1-12**	No	1984	890	145.5	10.4	86	72	580	1988	2018
12		**ID1-16**	Yes	1989	848	230.9	24.3	35	71	550	1993	2016
8		**ID5-5**	Yes	2000	542	182.1	16.1	34	62	700	2004	2016
13		**Wilcox**	Yes	1981	205	305.2	5.8	35	NA	502	2000	2017
15	South	**ID1-8**	Yes	1972	448	71.2	47.7	9	51	830	1972	2018

Notes: Data from 2018 Pump Check Results (in Dudek New Wellsite Feasibility Report, in process)
*, wells being considered for replacement (3)
**, ID4-4 was redrilled in 1979.
***, gpm/ft calculated from Pump Check data
****, Plant Efficiency from Pump Check, in percent. Values less than 60% are viewed to be of concern.

The 'plot ID' listed in **Tables 1A and 1B** supports the map-based location of the wells and roughly proceeds from north to south.

TABLE 1B

Plot ID (Figure 7)	Management Area	in GWM program?	Water Quality: 2Q 2018 (MCL as indicated) TDS (500/1000 mg/L)	F (2 mg/L)	NO3 (as N, 10 mg/L)	SO4 (250/500 mg/L)	As (10 ug/L)	Well Name		gpm	TD (msl)	Year Inst.	notes	anion/cation trend over time (see Piper Diagram)
3	**North**	.					<2	ID4-3	IA	no data			last tested 2007	Percent Sulfate Increased, may be stable; Calcium has been variable
4		yes	330	0.16	0.5	110	2.2	ID4-4	A*	365	-204	1979	(redrilled 1979)	Fairly stable (new well),
1		.					0	ID4-7/ Anza#4	IA	no data			last tested 1983	Percent Sulfate Increased (1973 to 1983)
5		yes	380	0.23	0.56	90	1.2J	ID4-11	A	620	-156	1995		Fairly stable
2		yes	**630**	0.87	0.54	**270**	<1.2	ID4-18	A*	130	-121	1982		Percent Sulfate Increasing
14	**Central**	yes	340	0.48	1.3	67	2.8	ID1-10	A*	317	-203	1972		Variable over time, no clear trend
9		yes	300	0.35	0.34	95	2.5	ID1-12	A	890	-48	1984		Fairly stable
12		yes	300	0.44	1	58	2.0	ID1-16	A	848	40	1989		Fairly stable
7A		.					<3	ID4-1	IA	no data			last tested 1980	Becoming more Calcium dominant (last gen min data 1980)
10		.					2.3	ID4-2	IA	no data			last tested 2010	Large change in 2010 (dec Sodium), no recent data to assess trend
7		.					2	ID4-5	IA	no data			last tested 1994	Limited data to assess trend
11		.					<2	ID4-10	IA	69?	200	1989	last tested 2012	Fairly stable
8		yes	330	0.8	0.39	100	2.1	ID5-5	A	542	-124	2000		Percent Sulfate Increased (2001 to 2013), may now be stable
6		.					6.4	Cocopah	A	1166	-393	2005	last tested 2013	Limited data to assess trend
13		yes	230	0.64	1.00	19	3.8	Wilcox	(A)	205	198	1981		Increasing bicarbonate, decreasing Calcium
20	**South**	yes	**1600**	0.18	0.76	**700**	<1.2	ID1-1	IA	200	-75	1972		Major changes 1972 to 2017: Increasing sulfate and Calcium; dec bicarbonate
21		yes	320	0.49	2.9	36	5.5	ID1-2	IA	200	-157	1972		Major changes 1972 to 2017: Increasing bicarbonate
15		yes	490	0.62	1.6	86	4	ID1-8	A	448	-335	1972		Increasing Sulfate and Chloride, Increasing Calcium
22		yes	**830**	0.56	0.5	**350**	**15**	Jack Crosby	(A)	10	194	2004		Limited data to assess trend
-		yes	640	0.37	**20**	100	2.5	WWTP	mw	mw	404	2009		Gen min data failed QA/ not assessed
16		yes	nm	nm	nm	nm	**15**	RH-3 (2017 data)	A	230	-323	2014		Limited data to assess trend
17		yes	400	1	0.49	110	6.3	RH-4	A	260	-147	2014		Limited data to assess trend
18		yes	480	1.3	3.6	100	**15**	RH-5	A	350	-169	2015		Increasing Bicarbonate
19		yes	330	1.2	3.3	31	**13**	RH-6	A	350	-312	2015		Limited data to assess trend
-		yes	450	0.51	1.2	76	2.8	MW-3	mw	mw	197	2005		Limited data to assess trend

xx exceeds the MCL

note: Secondary MCLs apply to TDS and Sulfate

Reccomended and maximum values are listed for TDS and Sulfate

A* active BWD Production Well, * indicates wells cuurently slate for replacement due to condition

A active non-BWD Production Well

IA Inactive BWD Well

mw Monitoring Well

Figure 4 shows the well locations and names used in this Report. Review of **Figure 4** shows that the well locations are spatially biased along the western portion of the valley and the Subbasin. This is because the BWD wells are located in populated areas within their historical service areas (or Improvement Districts [ID] as indicated by the well names).

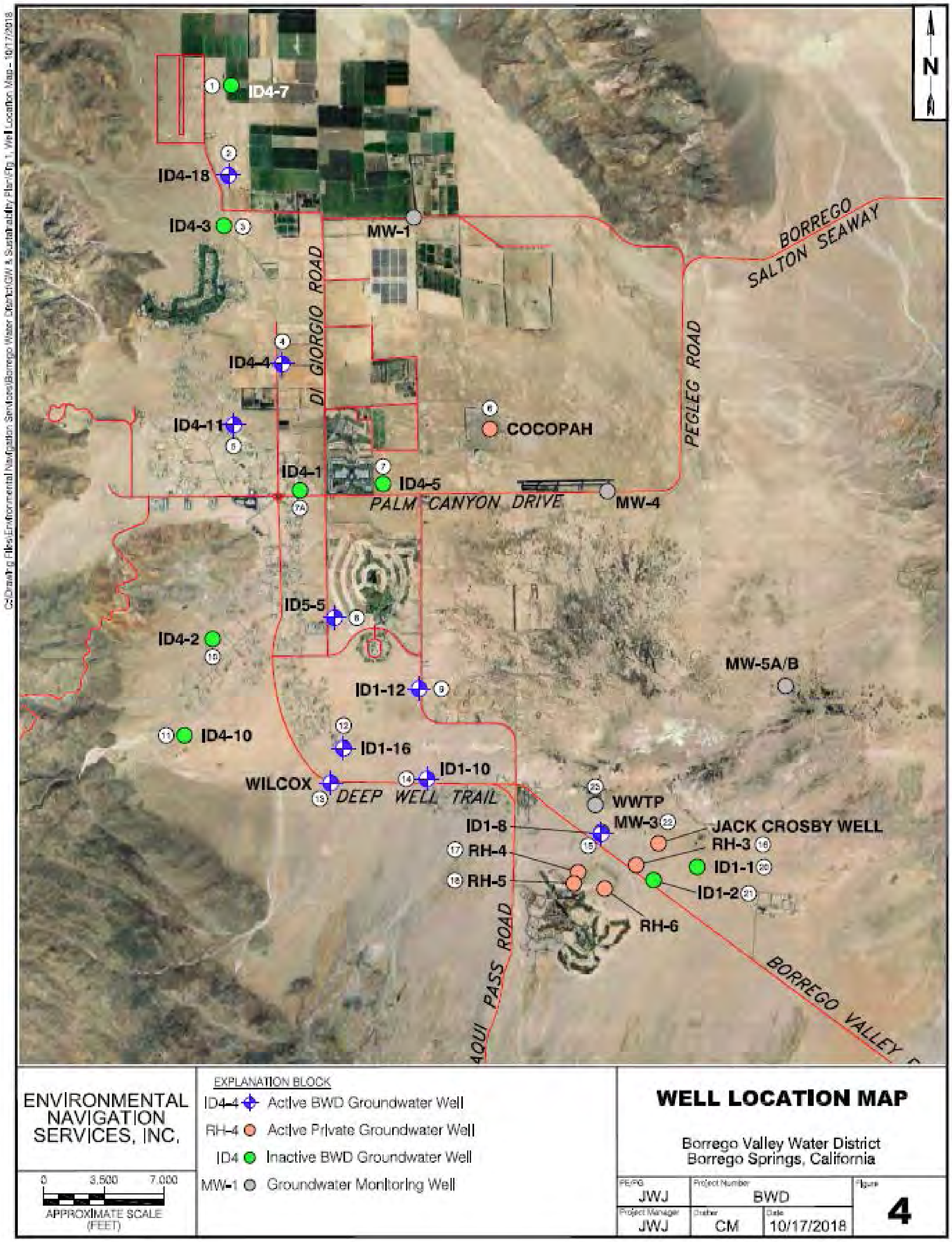
The analytical data used in the Report were located and compiled by Dudek staff from multiple sources as part of the GSP preparation process. The data base used here is from July 2018- the GSP data base is updated and revised on an ongoing basis. This Report focuses on:

- Chemicals of Concern (COCs) that include arsenic, TDS, nitrate, sulfate, and fluoride (As, TDS, NO_3, SO_4, and F).
- General Minerals: comprised of four cations- calcium (Ca^{+2}), sodium (Na^{+}), magnesium (Mg^{+2}), and potassium (K^{+}); and four anions- sulfate (SO_4^{-2} [also a COC]), chloride (Cl^{-}), carbonate (CO_3^{-2}) and bicarbonate (HCO_3^{-}).
- Hardness and pH.

The overall intent of this Report is to assess the use of multiple water quality parameters to examine how the primary COCs at BWD wells vary over time and to examine the likelihood that drinking water quality criteria will be exceeded. Of primary concern are arsenic and nitrate. Sulfate is also of concern.

Other COCs not examined in this Report include pesticides, herbicides, naturally-occurring radionuclides, and unregulated contaminants for which monitoring is required. Per State Law the Borrego Water District tests their water supply wells in accordance with California Code of Regulations Title 22 for a wide variety of potential contaminants because they operate a publicly-regulated water system. For additional information refer to their Consumer Confidence Report (CCR, available at http://www.bvgsp.org/sgma-blank.html).

FIGURE 4


ID4-7
ID4-18
ID4-3
MW-1
BORREGO SALTON SEAWAY
DI GIORGIO ROAD
ID4-4
PEGLEG ROAD
ID4-11
COCOPAH
ID4-1
ID4-5
PALM CANYON DRIVE
MW-4
ID5-5
ID4-2
MW-5A/B
ID1-12
ID4-10
ID1-16
ID1-10
WILCOX
DEEP WELL TRAIL
WWTP
MW-3
JACK CROSBY WELL
ID1-8
RH-3
RH-4
ID1-1
RH-5
ID1-2
RH-6
AQUI PASS ROAD
BORREGO VALLEY
N
ENVIRONMENTAL NAVIGATION SERVICES, INC.
0 3,500 7,000
APPROXIMATE SCALE (FEET)
EXPLANATION BLOCK
ID4-4 Active BWD Groundwater Well
RH-4 Active Private Groundwater Well
ID4 Inactive BWD Groundwater Well
MW-1 Groundwater Monitoring Well
WELL LOCATION MAP
Borrego Valley Water District
Borrego Springs, California
JWJ
Project Number BWD
Figure 4
Project Manager JWJ
Drafter CM
Date 10/17/2018

3.0 SUBBASIN-WIDE WATER QUALITY: GENERAL MINERALS, ARSENIC, AND NITRATE

The term "general minerals" is a descriptor that includes the eight anions and cations that typically comprise most of the minerals, by mass, dissolved in groundwater. Anions are negatively charged and cations are positively charged. The eight dominant ions include four cations- calcium (Ca^{+2}), sodium (Na^{+}), magnesium (Mg^{+2}), and potassium (K^{+}); and four anions- sulfate ($SO4^{-2}$), chloride (Cl^{-}), carbonate ($CO3^{-2}$) and bicarbonate ($HCO3^{-}$). Of these, sulfate is a COC. TDS is also a COC and represents the sum all of the anions and cations in solution.

Table 2. Common Cations and Anions Analyzed in the Subbasin

Common Cations	Common Anions
calcium (Ca^{+2})	sulfate (SO_4^{-2})
sodium (Na^{+})	chloride (Cl^{-})
magnesium (Mg^{+2})	carbonate (CO_3^{-2})
potassium (K^{+})	bicarbonate (HCO_3^{-})

The dominant anions and cations can be used to examine how the chemistry of groundwater varies in time at a well, or spatially among wells. Because they occur as a result of rock and mineral dissolution, they can also be diagnostic of minerals such as sulfates and carbonates that occur in the subsurface, or that occur in water being recharged to the aquifer system.

Graphical methods used to depict multiple anions and cations include Stiff Diagrams and Trilinear or Piper Diagrams.[10] Both are used in this Report and will be explained in more detail in Sections 3.1 and 3.2, respectively.

3.1 Spatial Overview (DWR, 2014; Stiff Diagrams)

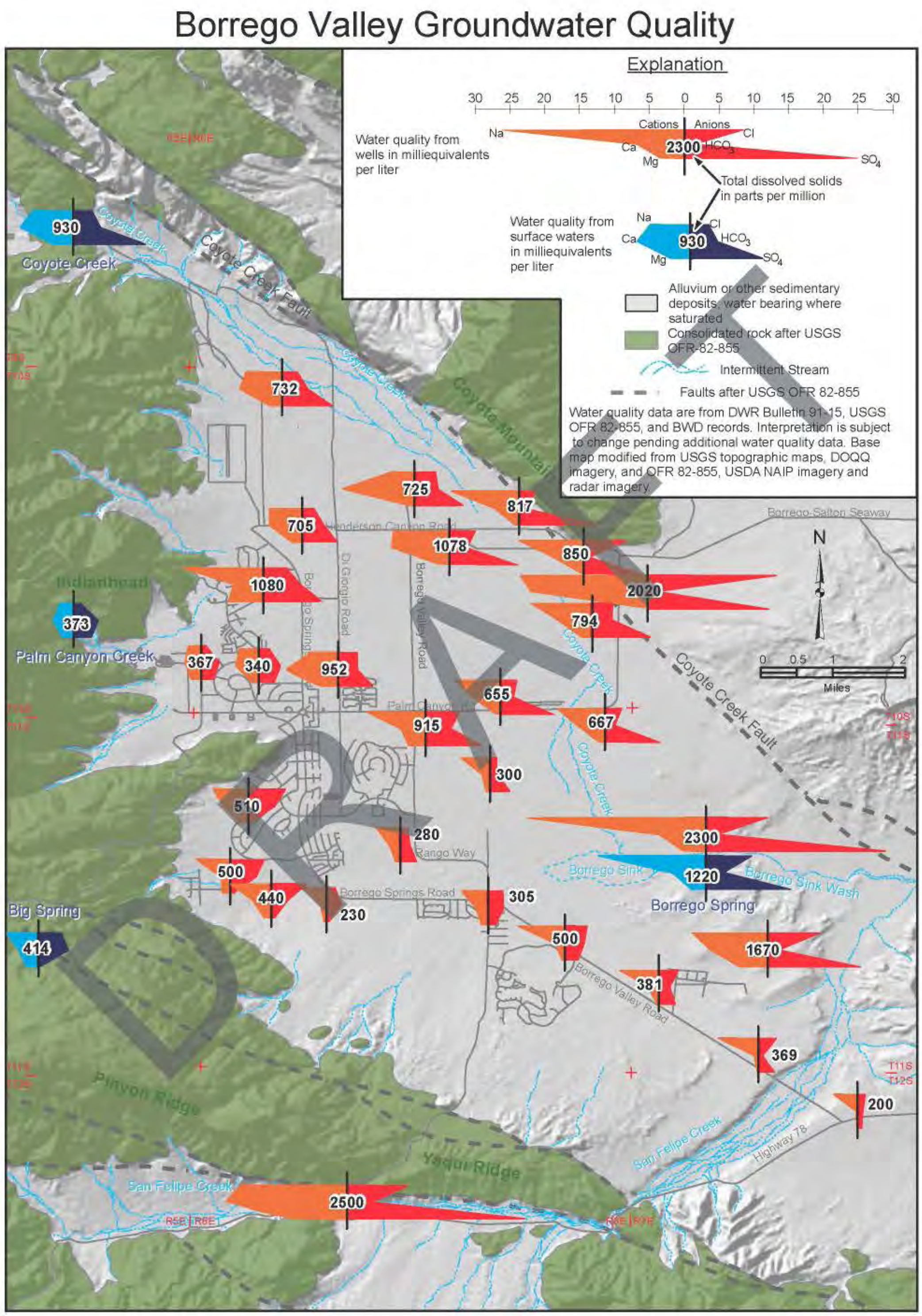
Stiff diagrams graphically depict the relative concentrations of three dominant anions (Cl, HCO3, and SO4) together with three dominant cations (Na, Ca, and Mg) determined from water samples.[11] A 2014 groundwater quality study was conducted by the California Department of Water Resources (DWR)[12] based on the compilation of DWR, BWD, and USGS water quality data generally obtained between 1950 and 2014. A map depicting Stiff Diagrams of water quality is depicted in **Figure 5**.

[10] An overview summary is provided by: Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water: U.S.
Geological Survey Water-Supply Paper 2254, 3rd edition, Washington D.C., 263 p.

[11] Stiff, H.A., Jr., 1951, The interpretation of chemical water analysis by means of patterns: Journal of Petroleum Technology, v. 3, no. 10, p. 15-17.

[12] DWR, 2014. Powerpoint presentation by Dr. Tim Ross dated May 2014. A copy is included for reference in **Appendix A**.

FIGURE 5


Borrego Valley Groundwater Quality
Explanation
Water quality from wells in milliequivalents per liter
Cations
Anions
Total dissolved solids in parts per million
Water quality from surface waters in milliequivalents per liter
Alluvium or other sedimentary deposits, water bearing where saturated
Consolidated rock after USGS OFR-82-855
Intermittent Stream
Faults after USGS OFR 82-855
Water quality data are from DWR Bulletin 91-15, USGS OFR 82-855, and BWD records. Interpretation is subject to change pending additional water quality data. Base map modified from USGS topographic maps, DOQQ imagery, and OFR 82-855, USDA NAIP imagery and radar imagery.
Coyote Creek
Coyote Creek Fault
Coyote Mountain
Indianhead
Palm Canyon Creek
Big Spring
Pinyon Ridge
Yaqui Ridge
San Felipe Creek
Borrego Sink
Borrego Sink Wash
Borrego Spring
Borrego-Salton Seaway
Borrego Valley Road
Di Giorgio Road
Henderson Canyon Road
Borrego Springs Road
Rango Way
Highway 78
Miles
N

An explanation of how the analytes are depicted using Stiff Diagrams is also included in **Figure 5**. The 'legs' and overall size of the diagrams increase as the analytes increase in concentration and allow visual comparison of each of the sample results. Also included in the diagrams is the TDS in milligrams per liter. For reference the TDS of drinking water should be no more than 1,000 mg/L and ideally less than 500 mg/L (the recommended and maximum secondary MCLs, respectively).

DWR noted based on comparison of surface water and groundwater chemistry that "*The high proportion of Sulfate in the surface water of Coyote Creek appears to dominate the character of groundwater in the northern and eastern parts of the basin. The more Bicarbonate waters of Borrego Palm Canyon and Big Spring influence the groundwater along the western and southern parts of the basin.*" For reference, the surface water watersheds are shown in **Figure 1**.

Additional observations that can be made from the Stiff Diagrams include:

- Surface water inflows that enter the along the edges of the valley are the primary source of recharge. The highest quality groundwater (TDS < 500 mg/L) generally occurs near recharge areas.
- Groundwater quality tends to increase in TDS towards the Borrego Sink with distance from the recharge areas. Ongoing evaporation and accumulation of minerals is occurring within the Subbasin. The Subbasin is effectively a closed basin and has been a closed basin during much of the time that alluvial sediments have been deposited from current watersheds. (Please refer to the GSP for a detailed description of the Subbasin geology and sedimentology.)
- Elevated concentrations of sulfate in surface waters are of concern from a water quality standpoint. Groundwater within the San Felipe Creek watershed that potentially recharges the South Management Area contains relatively high concentrations of sulfate, calcium and sodium.
- The Stiff Diagrams highlight the dominance of sulfate in groundwater (lower right portion of the diagrams). Sodium and chloride (upper right and upper left 'legs') also occur at significant concentrations in many samples.

The DWR presentation also reviewed TDS trends with time and depth at selected wells. No consistent trends were identified. The data were not evaluated in terms of the upper, middle, or lower aquifer.

DWR also assessed nitrate. Review of their results is included in **Section 3.5**.

3.2 General Minerals: Spatial Variability Based on Piper Diagrams

The eight dominant anions and cations can also be analyzed using Piper trilinear diagrams (Piper, 1944).[13] In brief, the Piper plot is a visualization technique for groundwater chemistry data. It is based on a combination of ternary diagrams for the major anions and cations that are then projected onto a central diamond. The concentration data on (milligrams/liter) are converted to milliequivalent (meq/L), a measure of the number of electrochemically active ions in the solution.[14] The analytes are plotted as relative proportions in order to examine the relative percentages of each of the dissolved minerals, primarily to show clustering or patterns of samples. The diagrams also support interpretation of trends and potential mixing of waters that have different chemistry.

Figure 6A provides a brief explanation of the Piper diagram. The methodology is explained in more detail in **Appendix B**, together with the Piper trilinear diagrams for all of the wells as noted in **Table 1B**. Ternary diagrams present a combination of three values that add up to 100 percent. The three values are 'picked off of' the sides of triangle by projection along a triangular grid. Please refer to **Appendix B** as needed for additional explanation.

Recent general minerals data, dating from 2004 to present, were used to represent the water chemistry at each of the wells. Review of the data supported the use of two data subsets. The North and Central Management Area wells have been combined and the South Management Area wells are presented as a second set. **Figure 6** depicts the data. Each of the wells are numbered per **Figure 4** and **Table 1** to simplify the data presentation. The numbering generally follows from north to south along the axis of the valley.

3.2.1 Data Quality Review: General Minerals

The data presented in the Piper diagrams underwent a data quality review based on the ion chemistry. Groundwater under natural conditions should be at or near electrochemical equilibrium. Here the sum of the negatively charged anions (in meq/L) was checked versus the sum of the positively charged cations. The sums should be similar (within ~5%) for a solution that is in equilibrium. Not all of the data were used because in some cases not all of the eight general minerals data were analyzed and in other cases the anion/cation balance test failed. As explained above, the anion/cation balance test may fail as a result of less common anions or cations being present within the water quality sample that were not analyzed. Charge imbalance may also indicate laboratory error.

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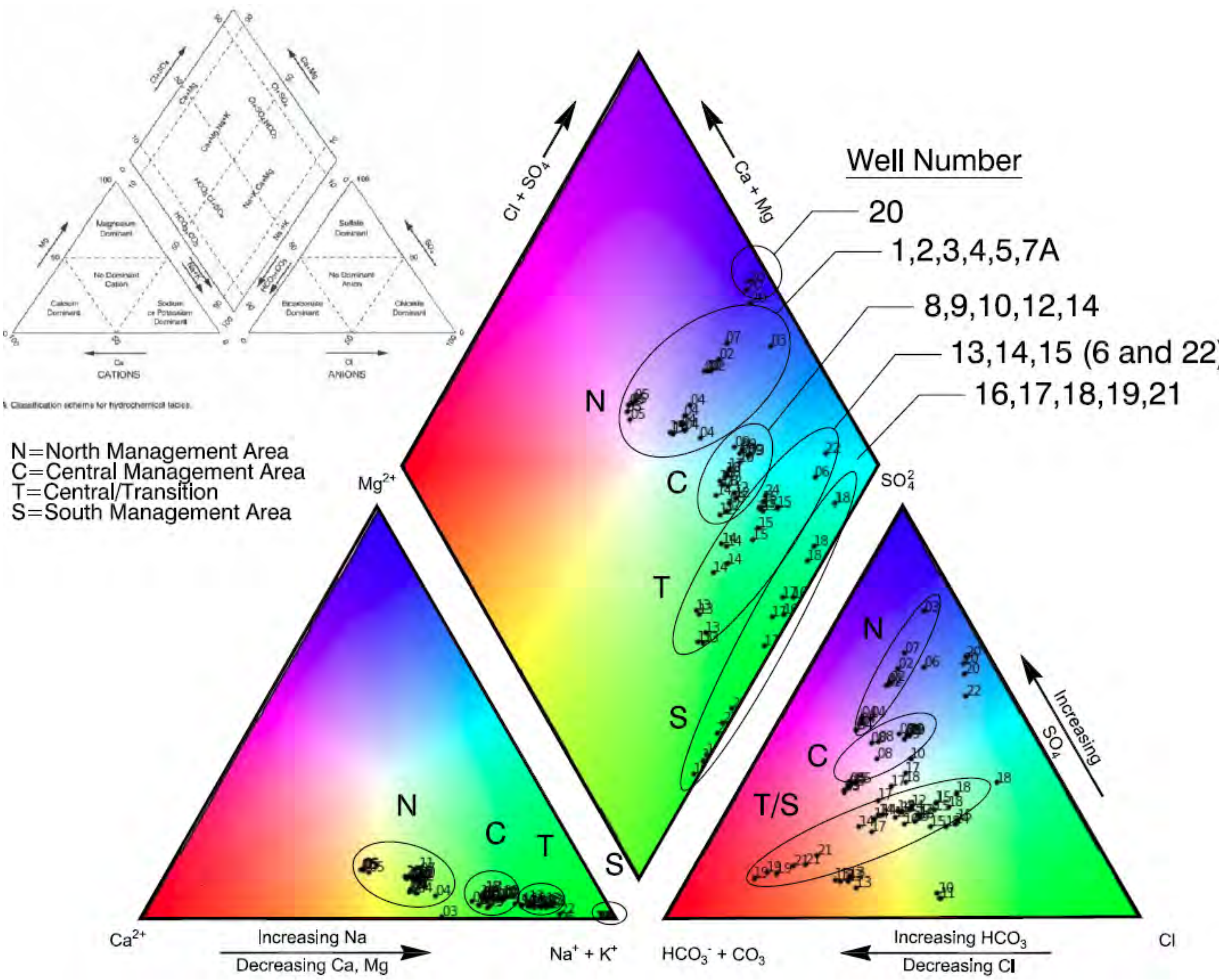
[13] Piper, A.M. 1944. A graphic procedure in the geochemical interpretation of water-analyses. Transactions- American Geophysical Union 25, no. 6: 914–923

[14] The number of ions in a solution is expressed in terms of moles, a unit widely used in chemistry as a convenient way to express amounts of reactants and products of chemical reactions. An equivalent is the number of moles of an ion in a solution, multiplied by the valence of that ion. For example, if 1 mole of NaCl and 1 mole of $CaCl_2$ are dissolved in a solution, there is 1 equivalent of Na, 2 equivalents of Ca, and 3 equivalents of Cl in that solution. The calculation is based on: mEq/L = (mg/L × valence) ÷ molecular weight.

The eight anions and cations generally comprise the bulk of the minerals that comprise TDS. Sodium and calcium are the dominant cations; bicarbonate, sulfate, and chloride are the dominant anions. The long-term average concentrations, in mg/L, for the nine BWD wells were TDS (378), calcium (39), sodium (82), magnesium (5.4), and potassium (5), sulfate (112), chloride (56), carbonate (0.6) and bicarbonate (124). Nitrate averaged 1.8 mg/L.

A calculation of TDS was made by summing the concentrations of the eight anions and cations and comparing it to the TDS for all samples that met a 5% or less charge imbalance criteria. On average the sum was less than the TDS by 40 mg/L, where the mass of cations exceeded the mass of anions. Other anionic COCs not included in the calculation include fluoride and nitrate, but when these were added into the calculations the mass of anions remained lower than the mass of cations. While the mass balances remained within tolerance, the results suggest that additional anions occur in groundwater that have not been tested. Phosphates are one type of anion that may occur but have not been included in the analytical program.

FIGURE 6: Piper Diagram, recent data for all wells (2004 to 2018)



Notes:

1. Numbers correspond to IDs shown in Figure 4. These generally increase from north to south.

2. The wells by management area include:

North Management Area: Wells # 1 to 5, #7, and #11

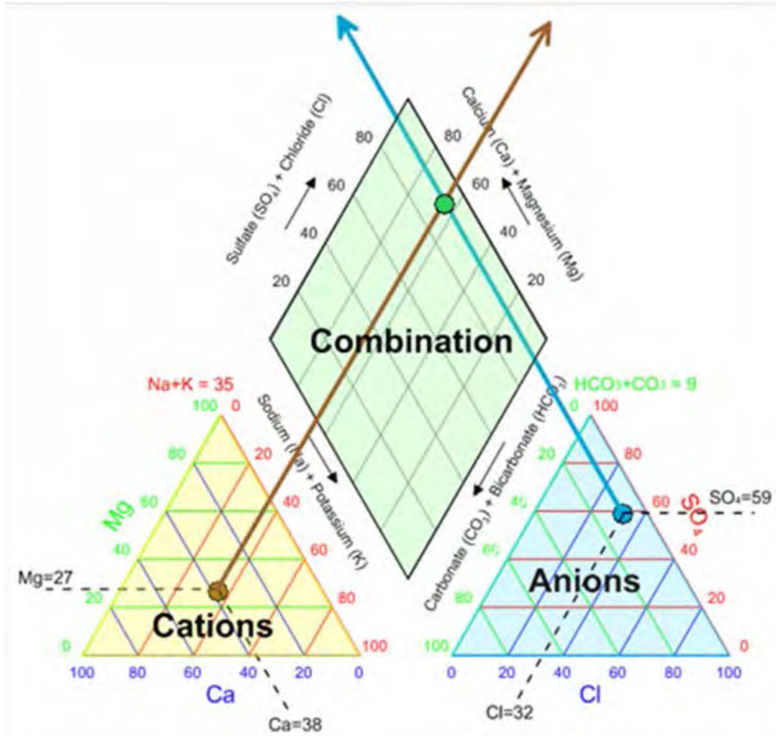
Central Management Area: Wells #8, #9, #10, and 12

"Transitional": Wells #6, #13, #15, #16, #22

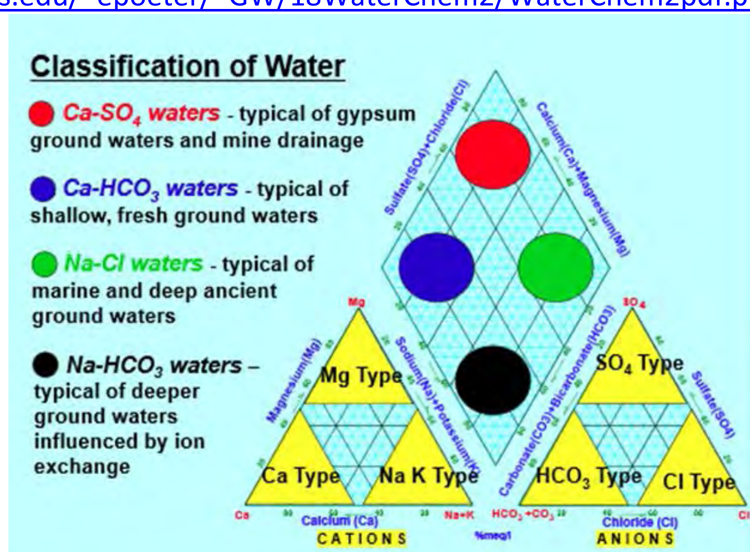
South Management Area: Wells #17 to 21, #23

FIGURE 6A

The Piper diagram is used to plot the 8 general minerals based on two ternary diagrams (triangles, at the base) that are projected onto a central diamond area. From (www.goldensoftware.com)



Where the subregions generally depict the chemical characteristics of the water (from http://inside.mines.edu/~epoeter/_GW/18WaterChem2/WaterChem2pdf.pdf)



Here colors are used to show subareas following a methodology presented by Peeters, 2014. (A Background Color Scheme for Piper Plots to Spatially Visualize Hydrochemical Patterns by Luk Peeters, Vol. 52, No. 1–Groundwater–January-February 2014). Also see **Appendix B**.

No distinction was made regarding well completion by aquifer because of a lack of water quality data as a function of depth. However, while the wells include a range of ell completions, the data do not indicate that any differentiation can be made among wells based on recent data (2004 to present). Review of the Piper Diagrams indicates that a systematic variation of water quality can be observed from north to south, and that the water quality in the South Management Area is sufficiently different to support segregation of the data into two data sets. Inorganic water quality depicted in the central Piper diagrams (**Figure 7**) indicates the data generally group by management area (MA): North MA (Wells # 1 to 7, and 11), Central MA (Wells #8, #9, #10, and 12), "Transitional" between the Central and South MAs (#13, #15, #16, #22), and South MA (#17 to 21, #23). Data from sets of wells align on the Piper diagram (**Figure 6**) indicative of waters that are mixing. Some general observations follow:

North and Central Management Areas

- A subset of the wells in the northern part of the basin (#1, #2, #3, and #4) occur along a line of anion data where high sulfate occurs.
- The North and Central Management Areas subdivide into two groups within the Piper diagram. With distance towards the south a general trend occurs where chloride decreases, bicarbonate increases, and sulfate decreases. Two mixing lines may occur where the waters go from sulfate dominant to a mixed condition (no dominant anion).

South Management Area

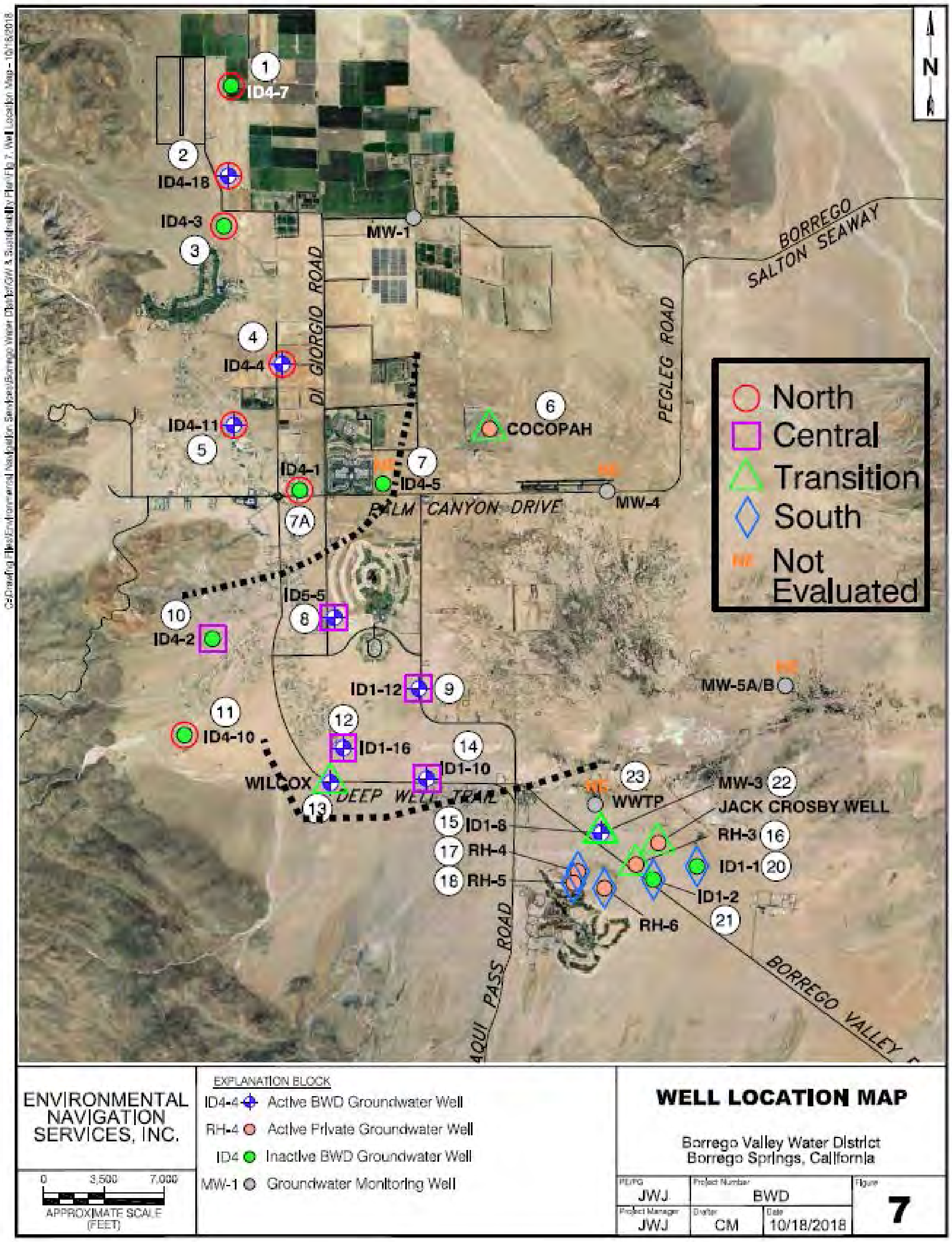
- A transitional zone occurs roughly coincident with the location of the Desert Lodge anticline (as depicted in **Figure 3**). The anticline is regarded as a structure that influences groundwater flow (refer to the GSP for further details).
- Mixing lines are observed for both cations and anions. For anions: as chloride decreases, bicarbonate increases, and sulfate decreases. For cations: as calcium decreases, sodium and magnesium increase.
- As also noted by the Stiff diagrams, the North Management Area has high sulfate as indicated by points that occur in the upper part of the cation ternary diagram. In contrast the South Management Area wells either have no dominant anion or become bicarbonate dominant (the lower left portion of the ternary diagram for anions).

Overall the Piper diagrams support that the inorganic water chemistry systematically varies across the Subbasin. The primary observations are summarized in **Figure 7**:

- Water quality gradually changes from north to south within the North and Central Management Areas, consistent with pre-development groundwater flow patterns.
- For both areas the cation relationships (calcium, magnesium, and sodium) are similar and are generally sodium dominant. In both cases the water quality is characterized by decreasing calcium and increasing percentages of sodium and magnesium.
- The South Management Area anionic water chemistry is different than the North and Central Management Areas, likely due to the difference in the San Felipe Creek recharge water and potential differences in aquifer mineralogy.

FIGURE 7

Shows water chemistry classified into the three Management Areas North, Central, and South. Also notes Transition (between central and south)



3.3 General Minerals: Variations Over Time at Wells, Piper Trilinear Diagrams

Of central concern to BWD and all other users of groundwater within the Subbasin is water quality degradation over time due to ongoing overdraft, irrigation and septic-related return flows, and loss of higher quality water due to dewatering of the upper aquifer. Piper trilinear diagrams were constructed for each of the wells using available historical data (compiled in **Appendix B**). Two examples are included as **Figures 8** and **9** where one well has had significant changes in water quality over time versus another that has been relatively stable.

The Piper diagrams depict relative ratios of the anions and cations, not the total concentrations. Also included in the figures are graphs of the anions and cations that present the measured concentrations (in mg/L).

ID1-8 (South Management Area, Well#15 on **Figure 7**)
Water chemistry has significantly changed over time at ID1-8. This well is in the South Management Area as depicted as Well #15 on **Figure 7**. It has been sampled since 1972. **Figure 8** includes a Piper Diagram and charts depicting TDS, cations, and anion concentrations over time.

Observed is historically decreasing bicarbonate, increasing chloride, and increasing calcium. Recent data indicates that water quality may be stabilizing.

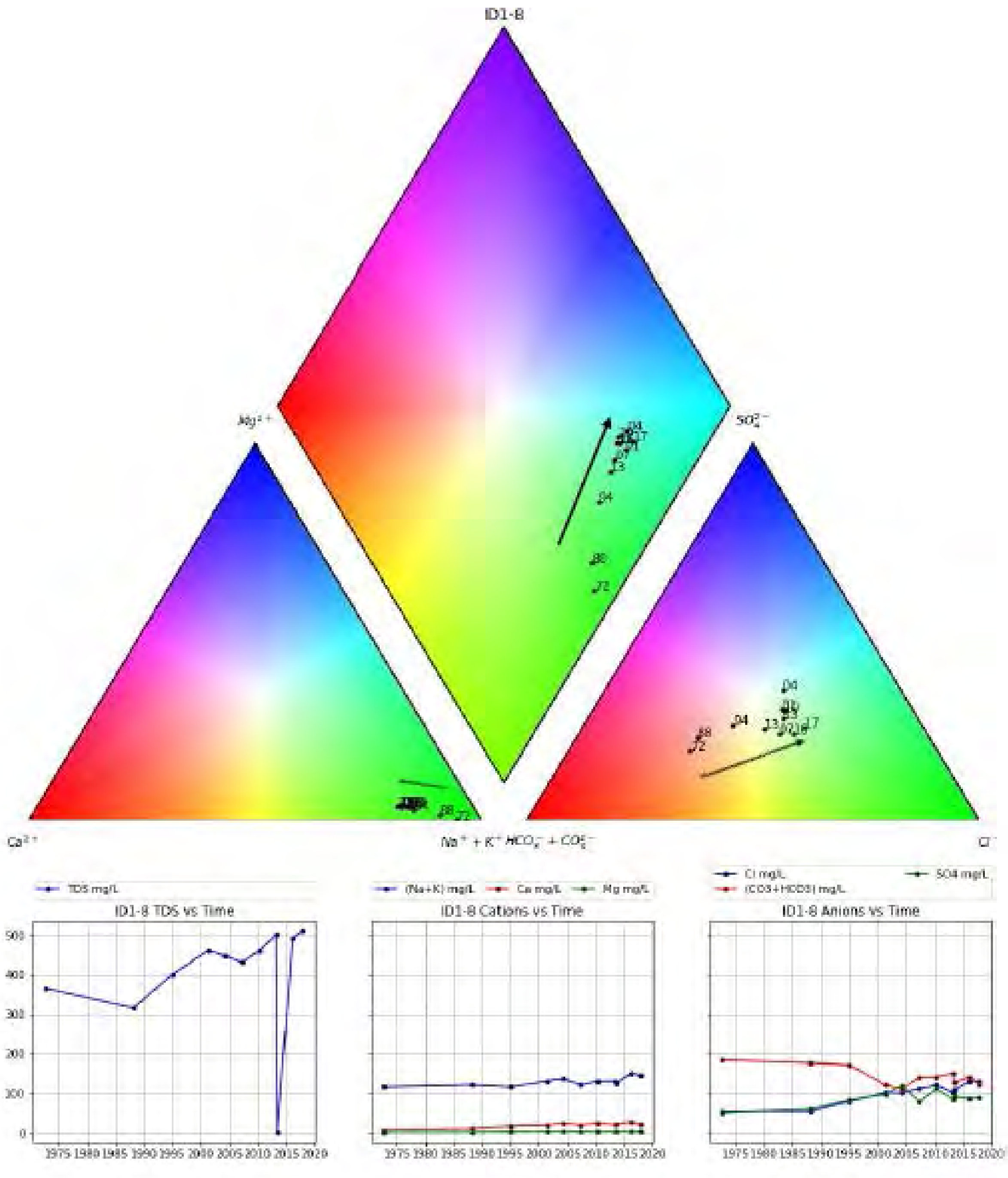
In terms of overall chemistry (see **Figure 6A**) the water in this well in now described as sodium chloride dominant, typical of marine and deep ancient groundwater.

ID4-18 (North Management Area, Well #2 on **Figure 7**)
This well is in the North Management Area as depicted as Well #2 on **Figure 7**. It also has been sampled since 1972. **Figure 9** includes a Piper Diagram and charts depicting TDS, cations, and anion concentrations over time.

There is much less overall change with time compared to ID1-8, but the sampling data do show sulfate is increasing. The change is subtle change but significant since concentrations are above the recommended secondary MCL of 250 mg/L, but do remain below the upper MCL of 500 mg/L. Sulfate is increasing as bicarbonate decreases over time. The points in the anion portion of the diagram (lower right triangle) occur along a line indicative of increasing sulfate.

In terms of anion chemistry (see Figure 6A) the water in this well in now described as sulfate dominant. Sulfate is a COC.

FIGURE 8: ID1-8 (see Figure 8A for explanation of the diagram and axes)

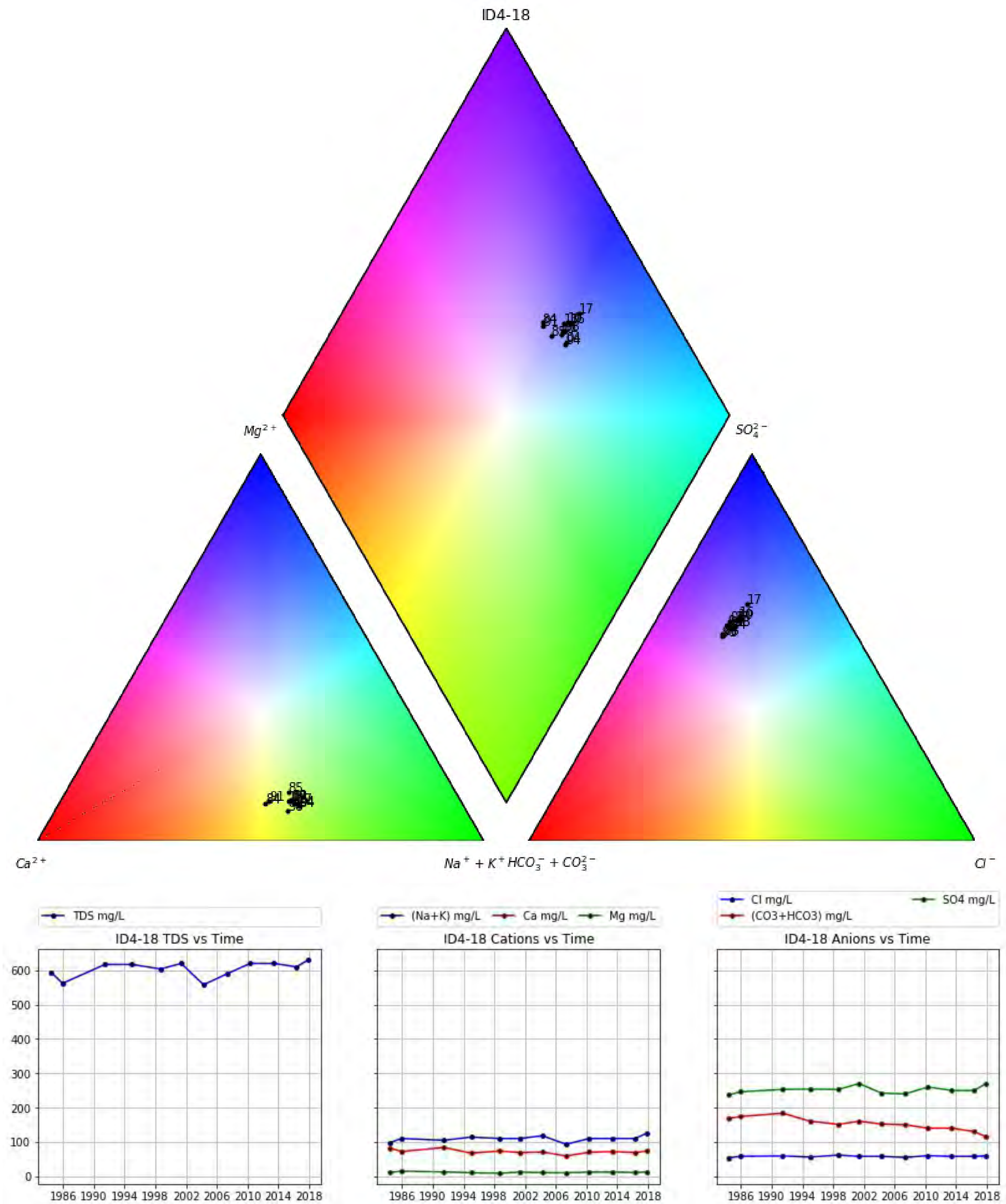


Notes:

1. The last two digits of the year the samples were taken are shown in the Piper diagram.

2. Chemistry has changed due to increases in sulfate, chloride, and sodium; and decreased bicarbonate. The change from 1970s to the 2000s is evident. TDS is also increasing.

FIGURE 9: ID4-18



Note:

1. The last two digits of the year the samples were taken are shown in the Piper diagram.

2. Water chemistry is fairly stable with a slow increase in sulfate and decrease in bicarbonate.

3.4 TDS with Depth

Well profiles based on TDS and temperature were presented by the DWR in a 2014 presentation (as referenced in footnote #11, a copy is included in **Appendix A**). **Figure 10** presents the profile data obtained from eleven wells that ranged in depth from 280 to 900 feet. For reference BWD water supply wells currently range in depth from 392 to 830 feet (Table 1).

Review of **Figure 10** supports the following:

- TDS varied by well, with linear increase with depth at each well. The exception is well ID4-3 where a step-wise increase in TDS was observed at a depth of approximately 350 feet.
- Groundwater temperature was relatively warm, ranging from approximately 80 to 90 ^{o}F. All wells exhibited increasing temperature with depth.

Geologic conditions and lithologies do change with depth, and it is generally expected that water quality change will decrease with depth. While quite important towards understanding the effect of overdraft on water quality, relatively few depth-specific groundwater chemistry data have been obtained in the Subbasin. The data presented in **Figure 10** are obtained by lowering measurement probes into the wells and are relatively inexpensive to collect provided there are no obstructions in the well. Additional discussion of well profiling methods is included in the report recommendations.

FIGURE 10

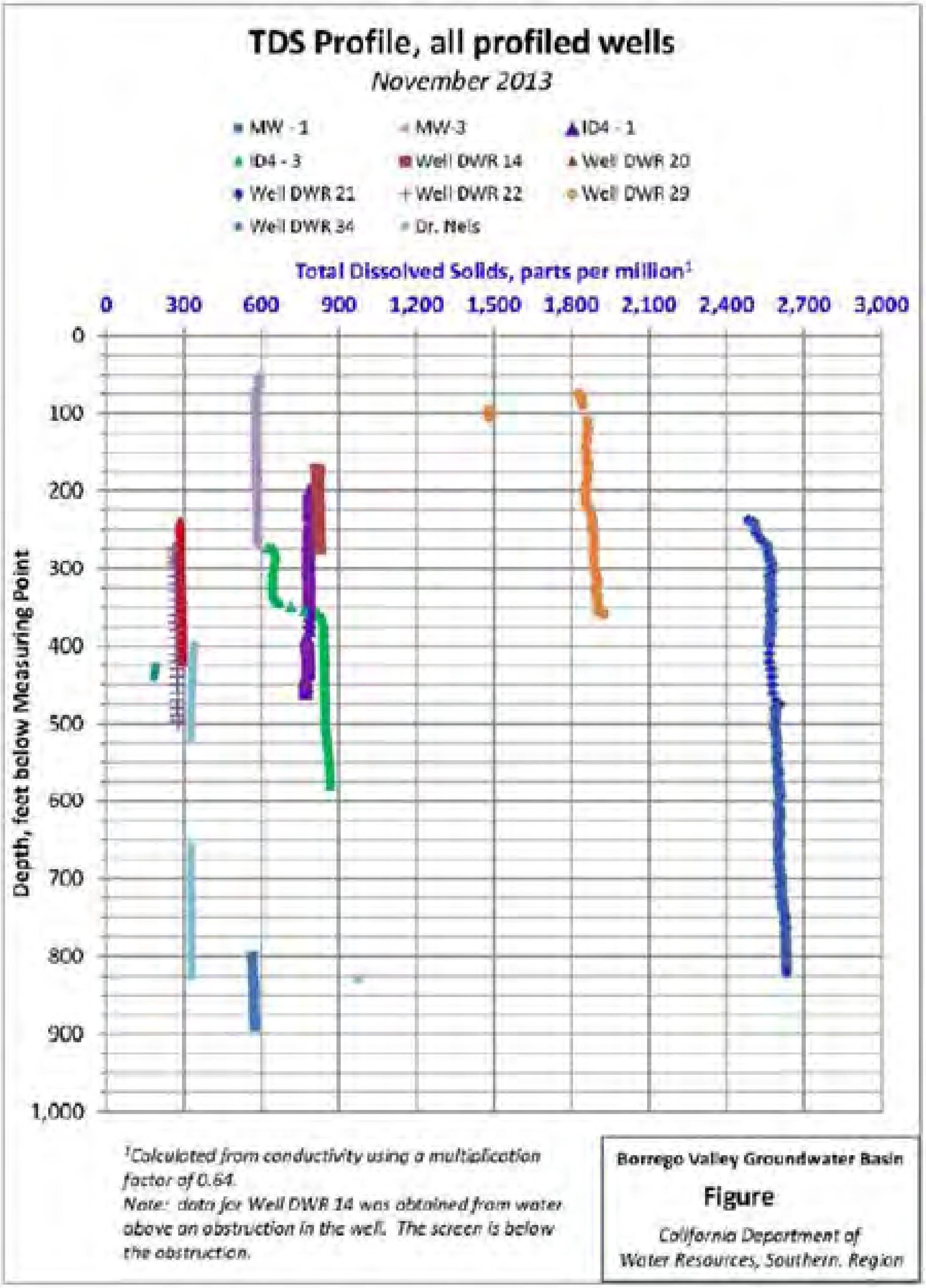
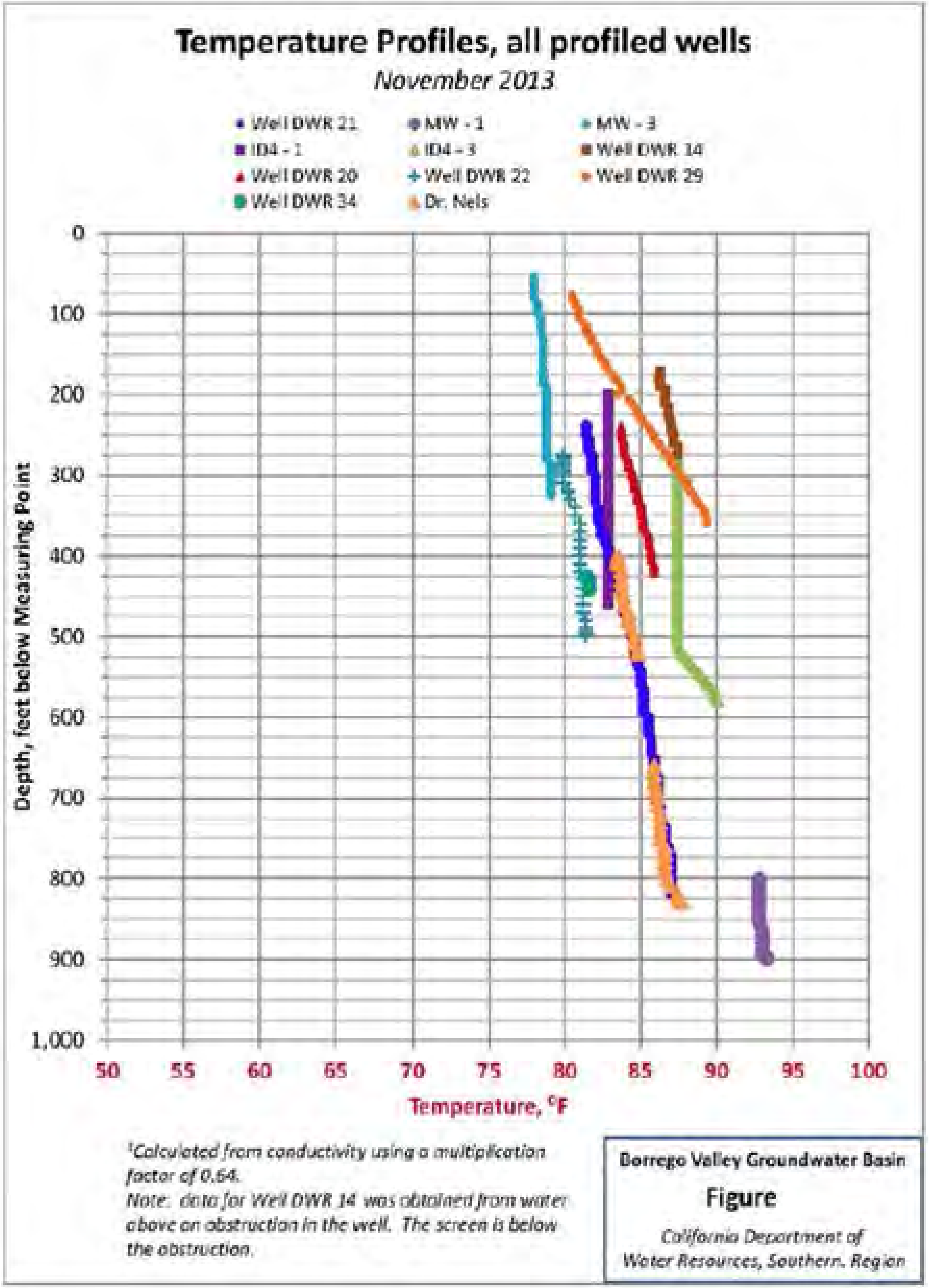

TDS Profile, all profiled wells
November 2013
MW - 1
MW-3
ID4 - 1
ID4 - 3
Well DWR 14
Well DWR 20
Well DWR 21
Well DWR 22
Well DWR 29
Well DWR 34
Dr. Nels
Total Dissolved Solids, parts per million[1]
0
300
600
900
1,200
1,500
1,800
2,100
2,400
2,700
3,000
Depth, feet below Measuring Point
0
100
200
300
400
500
600
700
800
900
1,000
[1]Calculated from conductivity using a multiplication factor of 0.64.
Note: data for Well DWR 14 was obtained from water above an obstruction in the well. The screen is below the obstruction.
Borrego Valley Groundwater Basin
Figure
California Department of Water Resources, Southern Region

FIGURE 10, continued



3.5 Nitrate

Nitrate (NO_3) is a groundwater contaminant that is commonly detected in drinking water supplies obtained from alluvial basins throughout the southwestern US (see, for example, USGS NAWQA[15], CA SWRCB GAMA[16], and others). Nitrate in groundwater has many natural sources, but nitrate concentrations in groundwater underlying agricultural and urban areas are commonly higher than in other areas. The primary sources of nitrate in the Subbasin include fertilizers associated with agriculture and turf grasses (golf courses), and septic systems.

The relationship between groundwater quality and overlying land uses was examined by DWR (DWR, 2014; in **Appendix A**). **Figure 11** shows "*the distribution of nitrate analyses for the Borrego Basin. Maximum content is shown per section and sections are colored according to the number of analyses in the section. Sections where the maximum contaminant level (MCL) are exceeded are shown in hatched patterns.*" The DWR analysis shows that nitrates occur above MCLs in multiple wells.

The USGS reviewed nitrate data and stated that "*TDS and nitrate concentrations were generally highest in the upper aquifer and in the northern part of the Borrego Valley where agricultural activities are primarily concentrated." (USGS Model Report, p.2) … "Water-quality samples from wells distributed throughout the valley show that NO_3-N concentrations ranged from less than 1 mg/L to almost 67 mg/L. NO_3-N concentrations were highest in the shallow aquifer and exceeded the CA-MCL of 10 mg/L in some samples from the shallow and middle aquifers in the northwestern part of the basin (fig. 26). NO_3-N concentrations in samples from the lower aquifer did not exceed 6.7 mg/L.*" (USGS Model Report p.64)

Further spatial analysis of the occurrence of nitrate relative to land use is not included in this report. Additional review of nitrate data is included in **Section 3.7**, and in the GSP.

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[15] Thiros, S.A., Paul, A.P., Bexfield, L.M., and Anning, D.W., 2014, The quality of our Nation's waters—Water quality in basin-fill aquifers of the southwestern United States: Arizona, California, Colorado, Nevada, New Mexico, and Utah, 1993–2009: U.S. Geological Survey Circular 1358, 113 p., http://dx.doi.org/10.3133/cir1358. National Ambient Water Quality Assessment (NAWQA)

[16] Groundwater Ambient Monitoring and Assessment Program (GAMA
See:)https://www.waterboards.ca.gov/gama/

3.5.1 Supporting Information Regarding Nitrate

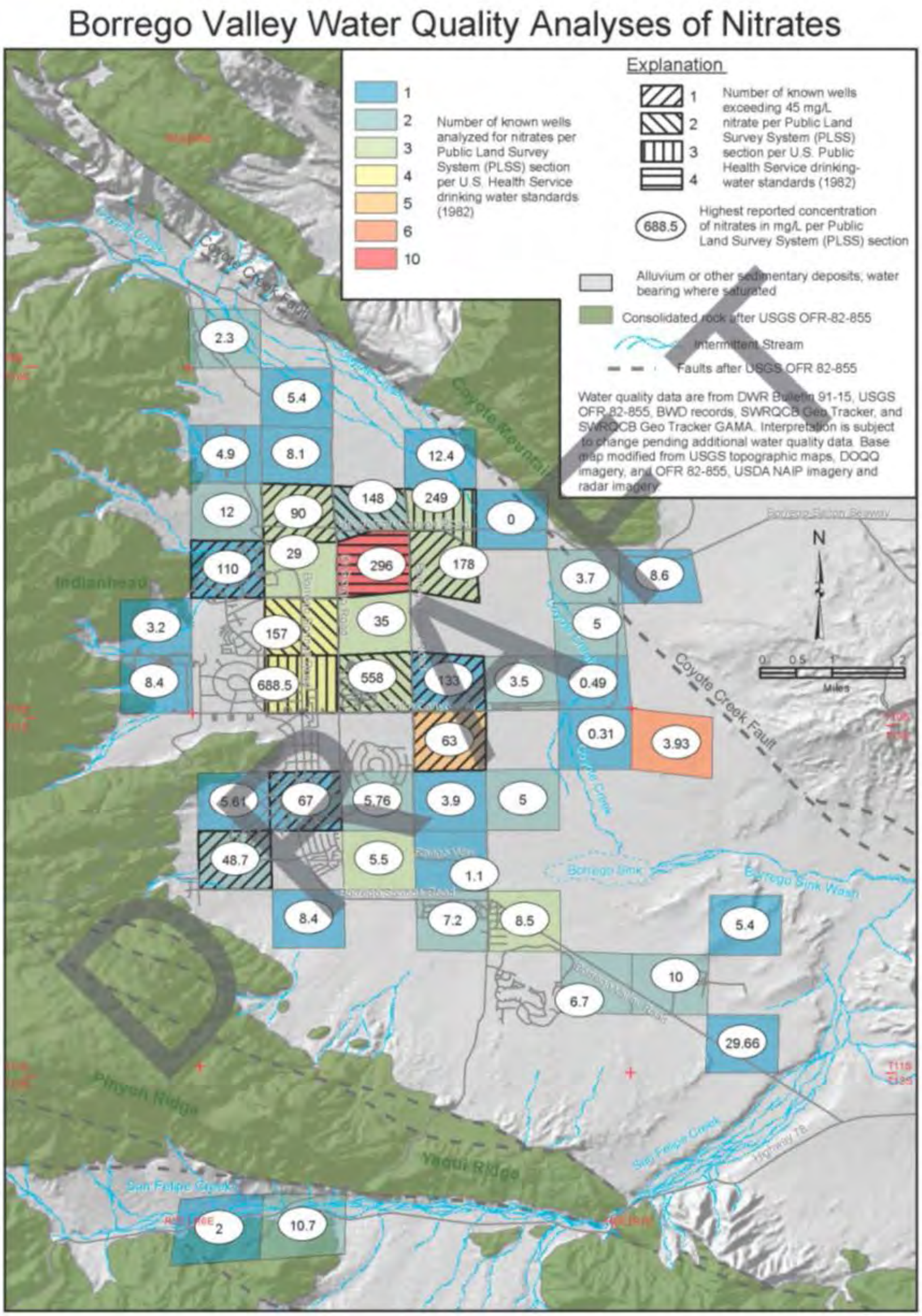
Historical groundwater quality impairment for nitrates is noted in the GSP to predominantly occur in the upper aquifer of the North Management Area underlying the agricultural areas, and near areas with a high density of septic point sources. The primary source of nitrates is likely associated with either fertilizer applications.

Information provided by Dudek in the GSP supports that nitrates have historically impacted multiple wells as follows. It is understood that the BWD Improvement District 4 (ID4) well 1 and 4, Borrego Springs Water Company Well No. 1 (located at the BWD office), the Roadrunner Mobile Home Park, and Santiago Estates wells were all taken out of potable service due to elevated nitrate. The latter two developments were connected to municipal wells operated by the BWD as an alternative source of supply. Well ID4-4 was re-drilled and screened deeper at the same location and successfully accessed good water quality not impacted by nitrates. The DiGiorgio wells 11, 14 and 15 located north of Henderson Road have historical detections of nitrate and TDS above drinking water standards. The existing groundwater network indicates elevated nitrate currently occurs at the Fortiner well No.1 in the North Management Area and at the BWD's WWTP monitoring well (see map, **Figure 4**).

Nitrate contamination enters the unconfined aquifer system via irrigation return flows and septic system discharge. An unconfined aquifer is directly open to the downward percolation of water. Thus, the uppermost portion of the aquifer is the most susceptible to nitrate impacts. However, as noted in **Table 1B**, nitrate impacts have been observed at low concentrations in all of the active BWD water supply wells.

There are two factors that can facilitate the downward migration of nitrates within the aquifer system- both caused by wells. The first is that ongoing pumping from deeper portions of the aquifer can actively draw shallow groundwater deeper into the aquifer system. The second is that inactive wells can act as conduits for groundwater flow and facilitate the drainage of water from the upper aquifer into deeper aquifers because of downward hydraulic gradients induced by ongoing pumping and overdraft (see Recommendations, Section 5.2, for additional discussion).

FIGURE 11



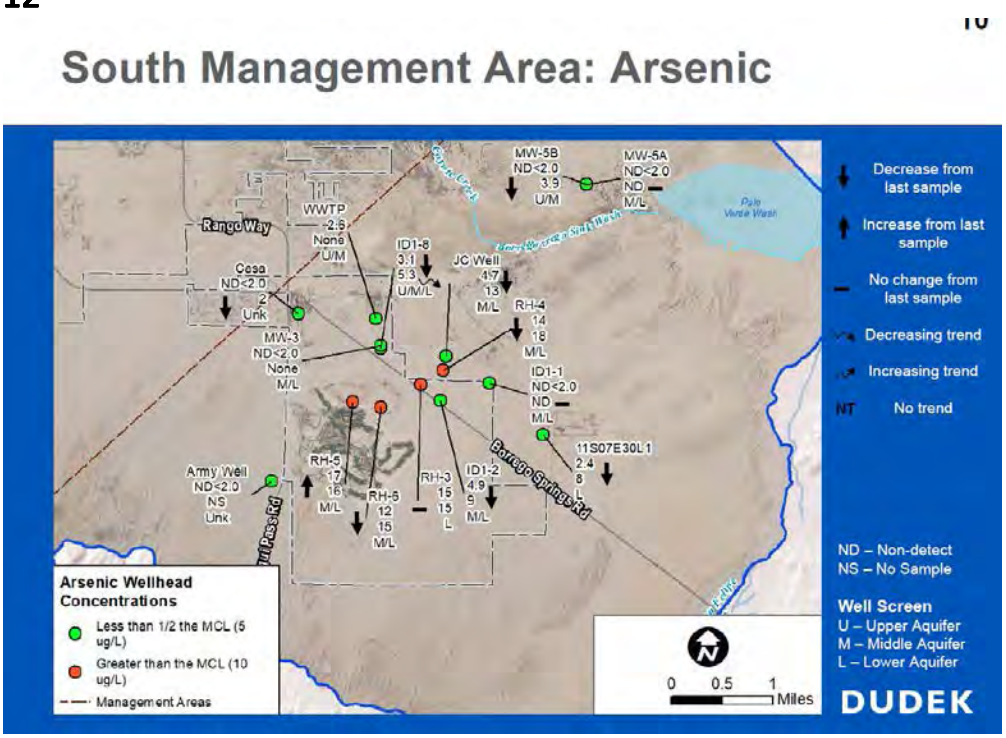
Borrego Valley Water Quality Analyses of Nitrates
Explanation
1
2
3
4
5
6
10
Number of known wells analyzed for nitrates per Public Land Survey System (PLSS) section per U.S. Health Service drinking water standards (1982)
Number of known wells exceeding 45 mg/L nitrate per Public Land Survey System (PLSS) section per U.S. Public Health Service drinking-water standards (1982)
688.5
Highest reported concentration of nitrates in mg/L per Public Land Survey System (PLSS) section
Alluvium or other sedimentary deposits; water bearing where saturated
Consolidated rock after USGS OFR-82-855
Intermittent Stream
Faults after USGS OFR 82-855
Water quality data are from DWR Bulletin 91-15, USGS OFR 82-855, BWD records, SWRQCB Geo Tracker, and SWRQCB Geo Tracker GAMA. Interpretation is subject to change pending additional water quality data. Base map modified from USGS topographic maps, DOQQ imagery, and OFR 82-855, USDA NAIP imagery and radar imagery.
Coyote Creek Fault
Coyote Mountain
Indianhead
Pinyon Ridge
Yaqui Ridge
San Felipe Creek
Borrego Sink
Borrego Sink Wash
N
Miles
DRAFT

3.6 Arsenic

Arsenic is the primary drinking water COC identified throughout alluvial basins across the desert southwest (see, for example, previously cited USGS NWQA Report, 2014). The fate and transport of arsenic highly depends on the hadrochemical environment. Chemical conditions control the chemical state (valence) of the ion in solution- here arsenic can occur as either arsenate (As^{+3}) or arsenate (As^{+5}). The chemical behavior of arsenic in groundwater depends on multiple factors including the pH and the relative state of oxidation (i.e., chemically oxidizing or reducing, or 'redox' state). Arsenate (As^{+5}) for example, tends to become more soluble as pH increases. Microbial processes are also known to be involved in the oxidation and mobility of arsenic.[17]

Arsenic concentrations above MCLs currently occur in groundwater in the South Management Area, primarily in wells installed for the Ram's Hill Golf Course. **Figure 12**, from BWD Board presentation by Dudek dated 1/25/2018, shows prior sampling results. Sampling results for the remainder of the Subbasin indicate arsenic to occur at less than half the MCL (5 micrograms per liter [µg/L]). The sampling results for active BWD wells are summarized in **Section 4**.

FIGURE 12



[17] Sun 2010. The Role of Denitrification on Arsenite Oxidation and Arsenic Mobility in An Anoxic Sediment Column Model with Activated Alumina. In Bioengineering and Biotechnology. https://onlinelibrary.wiley.com/doi/abs/10.1002/bit.22883 This work is cited because it supports that Nitrate, an alternative electron acceptor, can support oxidation of As^{+3} to As^{+5} (arsenate) by denitrifying bacteria in the absence of oxygen. Arsenate is generally considered to be mobile in groundwater at pH levels greater than 8.

3.6.1 Supporting Information Regarding Arsenic

To date all water quality testing has reported 'total arsenic'. While this is consistent with the reporting requirements for drinking water testing, the current monitoring program does not speciate arsenic by valence. The species that occur in groundwater can generally be inferred based on knowledge of water conditions- specifically the pH and Eh (or redox state).

A study of arsenic and nitrate in the Subbasin done in cooperation with the BWD was published by Rezaie-Boroon et al, in 2014.[18] The study was based on data from six BWD wells (ID4-18, ID4-11, ID1-12, ID4-10, ID1-10, and Wilcox) for the period of 2006 to 2014. Their trend analyses are not summarized here because four more years of data have since been collected and the trends have changed. Their work emphasized the following:

- The chemical environment as determined by pH and Eh is important. Both pH and Eh conditions control how dissolved arsenic occurs in aqueous environment (see reference).[19] Arsenic is more soluble in an alkaline (high pH) and anoxic environments. The relative mobility of arsenic depends on its valence, typically occurring as either arsenite (As^{+3}) or arsenate (As^{+5}). As^{+3} is typically more mobile than As^{+5} in anoxic groundwater.
- The presence of iron oxide coatings on soil and sediment particles supports arsenic adsorbtion and can cause the concentration of arsenic in solution to decrease. This will typically occur under oxidizing conditions where As^{+5} will generally occur versus As^{+3}, and where iron oxides will occur.
- *"The most common forms of arsenic in groundwater are their oxy-anions, arsenite (As+3) and arsenate (As^{+5}). Both cations are capable of adsorbing to various subsurface materials, such as iron oxides and clay particles. Iron oxides are particularly important to arsenate fate and transport"* because…*"arsenate [ed: As+5] strongly adsorbs to these surfaces in acidic to neutral waters."* Thus, increases in pH will support the desorption or release of arsenate into groundwater.

The interaction of arsenic with soil and aquifer material containing iron oxide is summarized in a 2015 report by the Water Research Foundation.[20] This study is potentially relevant to the use of arsenic-bearing irrigation water, because it shows that arsenic can be removed from water when passed through soil. The Water Research Foundation report concluded that "Results of this study provide an inexpensive arsenic treatment method for water utilities", while

[18] Rezaie-Boroon et al, 2014. The Source of Arsenic and Nitrate in Borrego Valley Groundwater Aquifer. Journal of Water Resource and Protection, 5, p1589-1602.
https://www.scirp.org/journal/PaperInformation.aspx?PaperID=51944

[19] Stein, C.L., Brandon, W.C. and McTigue, D.F. (2005) Arsenic Behavior under Sulfate-Reducing Conditions: Beware of the "Danger Zone". EPA Science Forum 2005: Collaborative Science for Environmental Solutions, 16-18 May 2005, Washington DC.

[20] Water Research Foundation, 2015. In-situ Arsenic Removal During Groundwater Recharge Through Unsaturated Alluvium. Web Report #4299.

recognizing that the work was a pilot study and that a good understanding of site conditions is necessary to achieve similar results.

Arsenic may also be released from the dewatering or release of water in from clays. A recent study published in 2018 for the San Joaquin Valley of California examined the potential release of arsenic from the Corcoran Clay, a regionally extensive clay deposit that is being compressed as a result of land subsidence due to groundwater overdraft.[21] Their results "support the premise that arsenic can reside within pore water of clay strata within aquifers and is released due to overpumping".

Four factors were seen to contribute to the occurrence of arsenic in groundwater that included clay thickness, dissolved manganese (Mn) concentrations, elevation (depth), and recent subsidence. As stated in their report "We highlighted four of the most important variables describing arsenic concentration within the Tulare Basin in the recent model, shown in Fig. 2a-d [of their report]. Of these, the thickness of the Corcoran Clay (a confining unit that overlies a lower aquifer) shows a positive correlation with arsenic concentrations due to increased clay content. Elevation has a negative correlation, as lower areas are more likely to have been water-saturated and thus anaerobic. A positive correlation was found between $\log_{10}$(Mn) and arsenic concentrations, as the presence of manganese indicates an anoxic environment, in which arsenic tends to be more soluble. Significantly, recent subsidence from InSAR[22] [ed: land surface elevation data] showed a positive correlation, as over-pumping leads to increased pore water drainage from clays. The first three variables are well-known from the literature and not related to human activity. The quantitative link between pumping-induced subsidence and arsenic concentrations has not been shown before, and is directly related to human activity."

Their analysis supports that geochemical data that include measurements of oxidation-reduction potential (redox) and oxygen content, and testing for minerals that are indicative of geochemical conditions (such as ferrous and ferric iron, and manganese) can support assessment of the potential for arsenic to become mobile in the aquifer system. A recent USGS publication provides further explanation of the role of iron oxides under varying pH and redox conditions (USGS Scientific Investigations Report 2012–5065[23]). A key point made by the USGS is that arsenic becomes mobile at a pH greater than 8 under oxidizing and neutral/transitional

[21] Overpumping leads to California groundwater arsenic threat. By Ryan Smith, Rosemary Knight, and Scott Fendorf. June 2018. In Nature Communications (2018) 9:2089, DOI: 10.1038/s41467-018-04475, www.nature.com/naturecommunications. or at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5988660/pdf/41467_2018_Article_4475.pdf

[22] "InSAR (Interferometric Synthetic Aperture Radar) is a technique for mapping ground deformation using radar images of the Earth's surface that are collected from orbiting satellites". see https://volcanoes.usgs.gov/vhp/insar.html

[23] Predicted Nitrate and Arsenic Concentrations in Basin-Fill Aquifers of the Southwestern United States, by David W. Anning, Angela P. Paul, Tim S. McKinney, Jena M. Huntington, Laura M. Bexfield, and Susan A. Thiros; https://pubs.usgs.gov/sir/2012/5065/pdf/sir20125065.pdf

redox conditions, and is potentially mobile under strongly reducing conditions where both arsenite and iron can be in solution.

The USGS Model Report evaluated land subsidence in the Subbasin for the period of the 1960s to 2010 (page 70 of their report) and concluded that "…land subsidence attributed to aquifer-system compaction is not currently a problem in the Borrego Valley and is unlikely to be a significant problem in the future". However, this does not preclude the potential release or extraction of arsenic from clay-rich portions of the aquifer system that may occur under current or future pumping absent subsidence, or as a result of changes in geochemical conditions that could mobilize arsenic from clay-rich sediments that may contain arsenic.

Overall the occurrence, nature, and extent of arsenic in the Subbasin is not well understood. It is more prevalent in South Management Area wells. While currently water quality conditions are good relative to arsenic, it was observed to be at or near drinking water MCLs in multiple BWD water supply wells during the last decade and could affect BWD's water supply in the future.

3.7 Correlations Among Water Quality Parameters (Combined Data Assessment)

One of the goals of this Report is to evaluate whether multiple chemical parameters can be used to better define and predict COC trends at BWD water supply wells. Piper diagrams presented in **Section 3.2** were used to examine spatial trends and also illustrate that there are definable relationships among the general minerals seen in the trilinear diagrams. In this section the water chemistry data are combined for all wells to examine general relationships and correlations. The data set also includes pH, hardness. Other potentially important geochemical parameters such as iron and manganese were not included because they were not uniformly obtained for the water quality samples historically collected.

3.7.1 Water Quality Data Correlations

Water quality data obtained since 2004 were used to examine potential correlations and relationships. The recent data were selected to represent current conditions as water quality has changed over time in many wells. Among the parameters that were tested include anions (HCO_3, Cl, SO_4), cations (Ca, Mg, and Na [potassium was not included as less data were collected]), pH, TDS, Ca+ Na, Cl+HCO_3, As, F, and NO_3. Also included in the correlation analysis were two parameters named Midst and Low Sat that represented the percentage of well screen open to flow per aquifer unit as described in each of the wells (for example if a well is completed with the same amount of screen length per aquifer then both values would be 50 percent).

Correlations greater than 0.5 or less than -0.5 are highlighted in **Table 3**. Values between 0.5 and 0.7 are underlined, and values greater than 0.7 are in bold. The South Management Area data have been separated from the North and Central Management Areas.

Selected data are shown in graphical form in this section. The data set used in the correlations was limited to those samples where the general minerals charge balance was within 10 percent. The graphs further restrict the data to only include higher quality data with a +/- 5 % charge balance. Hem (1985) considers data with 5% charge balance to be of good quality[24].

[24] John Hem, 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. USGS Water-Supply Paper 2254. From page 163: "Under optimum conditions, the analytical results for major constituents of water have an accuracy of +/-2 - +/- 10 percent. That is, the difference between the reported result and the actual concentration in the sample at the time of analysis should be between 2 and 10 percent of the actual value. Solutes present in concentrations above 100 mg/L generally can be determined with an accuracy of better than +/- 5 percent. Limits of precision (reproducibility) are similar."

Table 3

NORTH and CENTRAL

	Bicarbonate	Chloride	Sulfate	Fluoride	Calcium	Magnesium	Sodium			cation	anion	pct middle	pct lower	Arsenic	Nitrate
	HCO3	**Cl**	**SO4**	**F**	**Ca**	**Mg**	**Na**	**pH**	**TDS**	**Ca+Na**	**Cl+HCO3**	**MidSat**	**LowSat**	**As**	**NO3**
HCO3	1.00	**0.73**	-0.38	-0.30	0.46	**0.76**	-0.10	-0.69	0.27	0.18	**0.94**	-0.48	0.30	-0.28	0.49
Cl		1.00	-0.26	-0.09	0.28	0.54	0.31	-0.53	0.43	0.36	**0.92**	-0.40	0.15	-0.13	**0.72**
SO4			1.00	0.26	0.46	0.07	0.67	0.16	**0.70**	**0.70**	-0.35	0.01	0.09	0.23	-0.43
F				1.00	-0.30	-0.23	0.54	0.48	0.15	0.21	-0.21	-0.43	0.47	0.66	-0.14
Ca					1.00	**0.79**	0.34	-0.60	**0.72**	**0.77**	0.40	-0.31	0.25	-0.32	0.14
Mg						1.00	0.23	**-0.75**	0.57	0.58	**0.70**	-0.48	0.40	-0.33	0.37
Na							1.00	0.03	**0.83**	**0.86**	0.10	-0.39	0.38	0.31	0.22
pH								1.00	-0.31	-0.30	-0.65	0.24	-0.12	0.68	-0.46
TDS									1.00	**0.95**	0.37	-0.41	0.33	0.04	0.21
Ca+Na										1.00	0.28	-0.43	0.39	0.04	0.23
Cl+HCO3											1.00	-0.47	0.24	-0.23	0.65
MidSat												1.00	**-0.86**	-0.30	-0.43
LowSat													1.00	0.30	0.22
As														1.00	-0.18
NO3															1.00

SOUTH

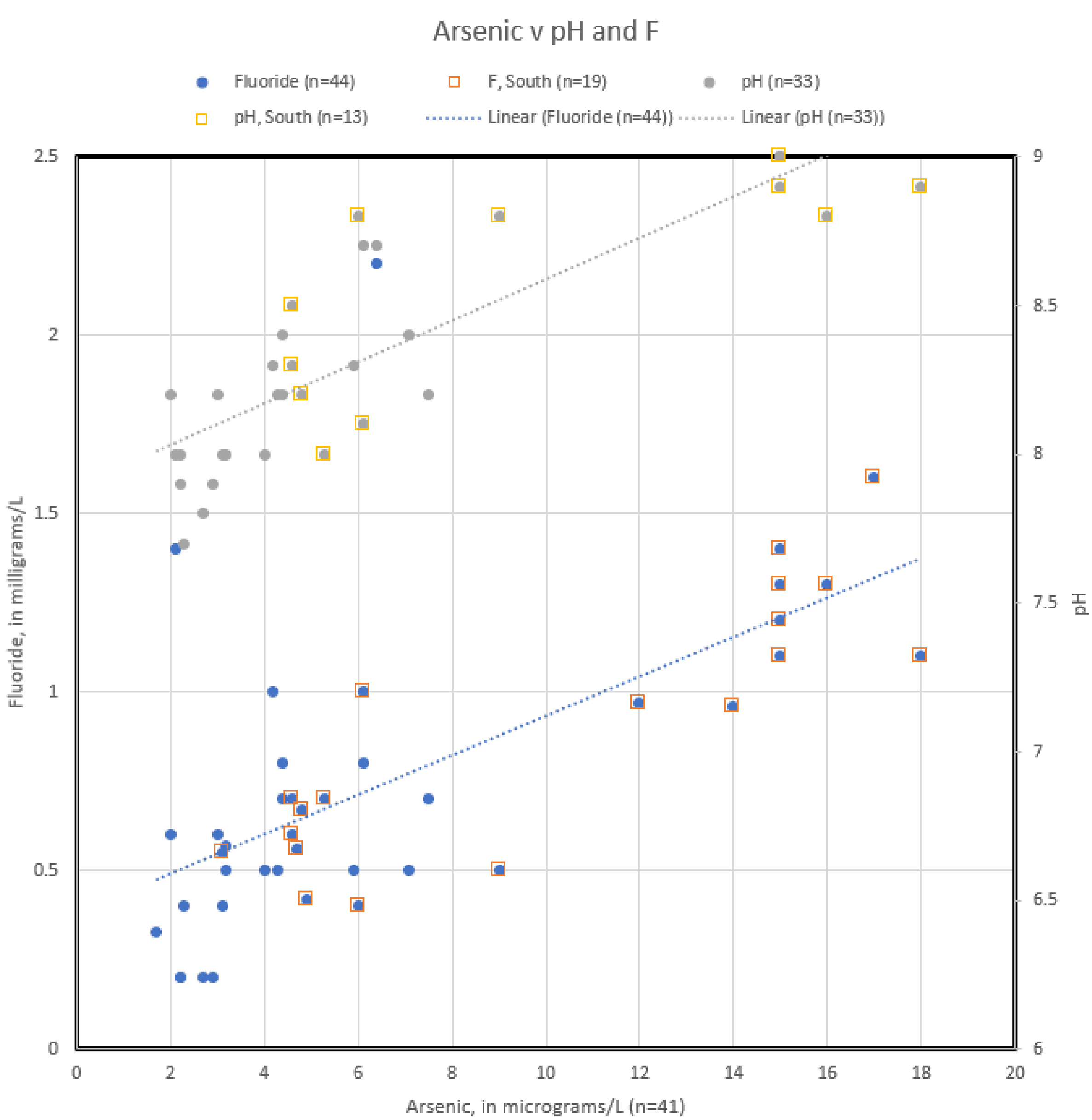
	Bicarbonate	Chloride	Sulfate	Fluoride	Calcium	Magnesium	Sodium					pct middle	pct lower	Arsenic	Nitrate
	HCO3	**Cl**	**SO4**	**F**	**Ca**	**Mg**	**Na**	**pH**	**TDS**	**Ca+Na**	**Cl+HCO3**	**MidSat**	**LowSat**	**As**	**NO3**
HCO3	1.00	-0.45	-0.44	0.14	-0.37	**-0.31**	-0.16	0.27	-0.33	-0.25	0.14	0.31	-0.33	0.10	0.19
Cl		1.00	**0.87**	-0.31	**0.80**	0.36	**0.83**	-0.34	**0.92**	**0.84**	0.47	0.17	-0.19	-0.08	0.11
SO4			1.00	-0.37	**0.95**	0.46	**0.73**	-0.31	**0.96**	**0.86**	0.37	-0.03	0.04	-0.01	0.01
F				1.00	-0.48	-0.16	-0.14	0.56	-0.40	-0.41	-0.33	-0.23	0.23	**0.73**	-0.22
Ca					1.00	0.42	0.60	-0.46	**0.92**	**0.78**	0.29	0.05	-0.05	-0.13	0.08
Mg						1.00	-0.03	**-0.13**	0.42	0.16	0.07	-0.11	0.11	0.06	-0.05
Na							1.00	-0.10	**0.81**	**0.86**	0.49	0.24	-0.24	0.09	0.19
pH								1.00	-0.35	-0.25	-0.13	-0.18	0.19	0.55	-0.30
TDS									1.00	**0.89**	0.44	0.14	-0.14	-0.03	0.18
Ca+Na										1.00	**0.70**	0.18	-0.19	-0.06	0.15
Cl+HCO3											1.00	0.27	-0.30	-0.14	0.05
MidSat												1.00	-1.00	-0.15	0.46
LowSat													1.00	0.17	-0.45
As														1.00	-0.06
NO3															1.00

COC	North and Central	South
Arsenic	pH (.68), F (.66)	F (.73), pH (.55)
Nitrate	Cl (.72)	-none-
Sulfate	TDS (.70), Na (.67)	TDS (.96), Ca (.95), Cl (.87), Na (.73)
Fluoride	As (.66), Na (.54)	As (.73), pH (.56)
TDS	Na (.83), Ca (.72), SO_4 (.70), Mg (.57)	SO_4(.96), Cl (.92), Ca (.92), Na (.81)

Arsenic and Fluoride

Arsenic and fluoride concentrations are correlated and both increase with pH. **Figure 13** depicts arsenic versus fluoride and pH. (pH versus As is in the upper portion of the graph and the y-axis label is to the right; fluoride versus As is in the lower portion and the y-axis is to the left). In both cases the correlations are influenced by the higher arsenic concentrations observed in the South Management Area (as noted by squares drawn around the data points). Every occurrence of arsenic above the MCL of 10 µg/L is associated with pH values greater than 8.5 (upper portion of the graph).

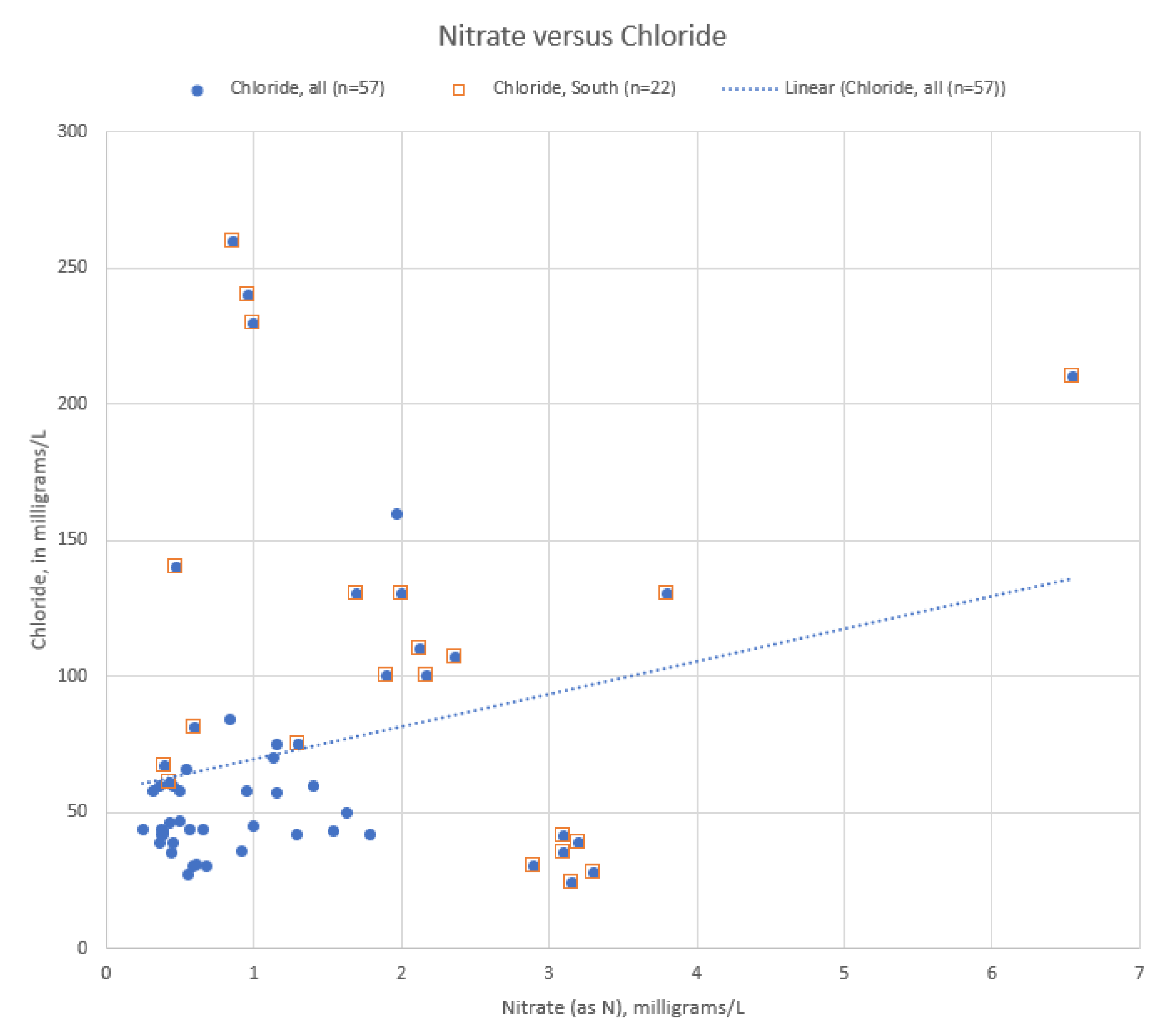
FIGURE 13



Nitrate

Nitrate had few water quality parameter correlations. Nitrate versus chloride is depicted in **Figure 14**. While there was a statistically-indicated correlation in **Table 3** for the North and Central Management Areas, chloride does not appear to be a globally useful predictor of nitrate.

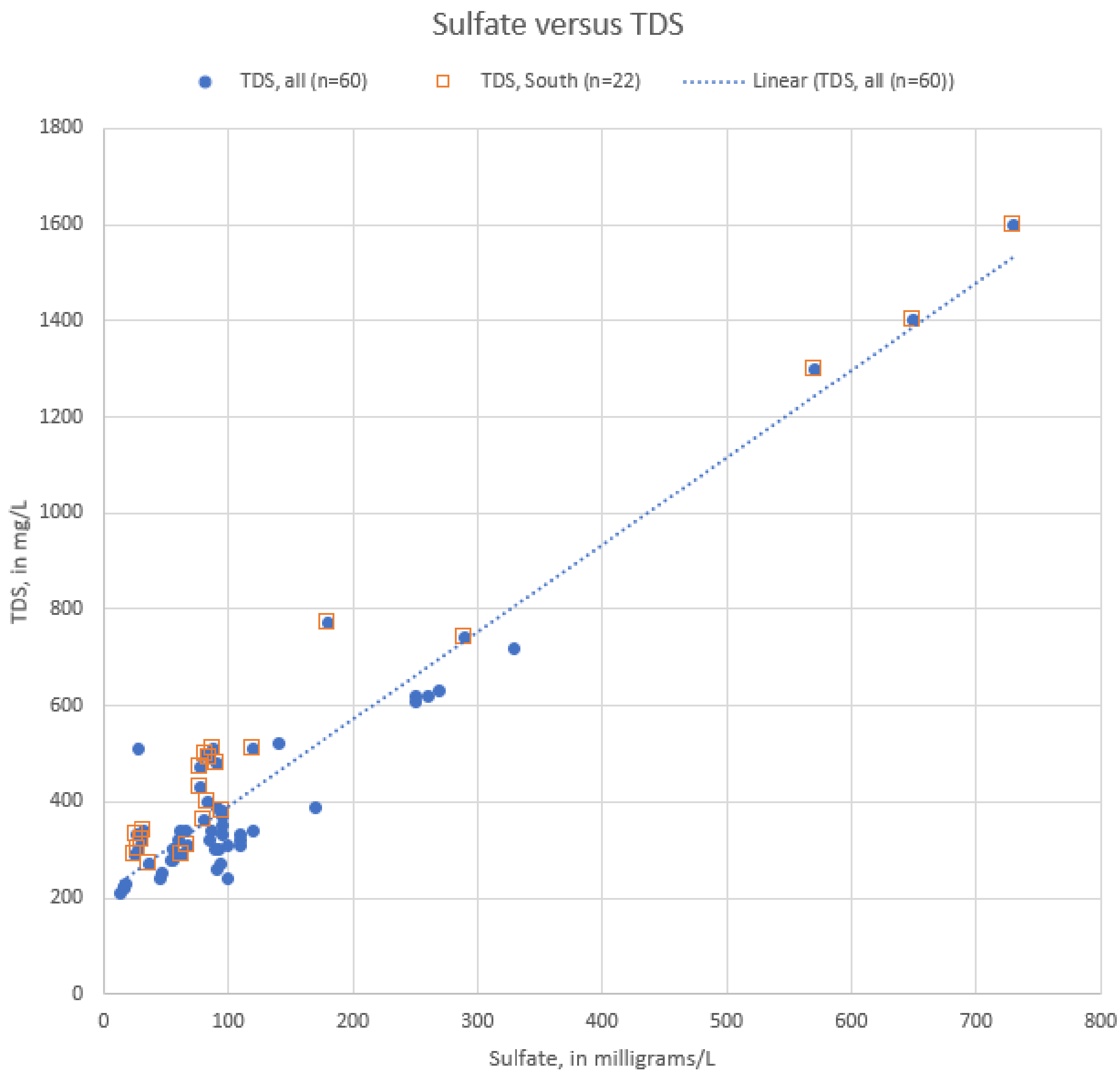
FIGURE 14



Sulfate

The correlation of sulfate with TDS is depicted in **Figure 15**. The three high sulfate values (> 500 mg/L) from the South Management Area strongly influence the correlation.

FIGURE 15

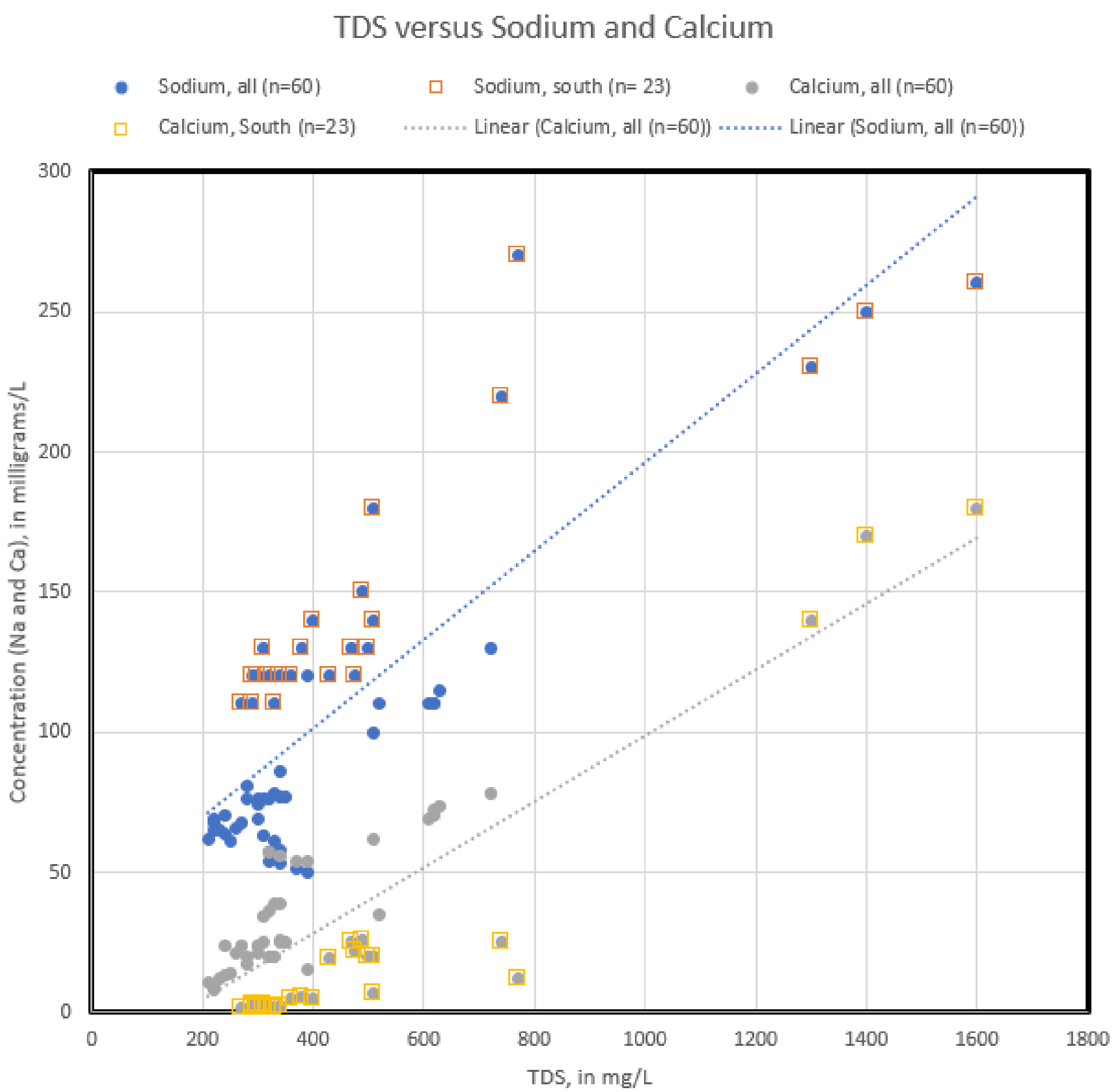


TDS

Multiple analytes correlated with TDS. Sulfate is shown in the previous figure. Sodium and calcium are shown versus TDS in **Figure 16**, and chloride versus TDS is shown in **Figure 17**. Both figures show that the South Management Area water chemistry is different than that observed to the north. The regression lines in **Figure 16** effectively split the two sets of data by management area.

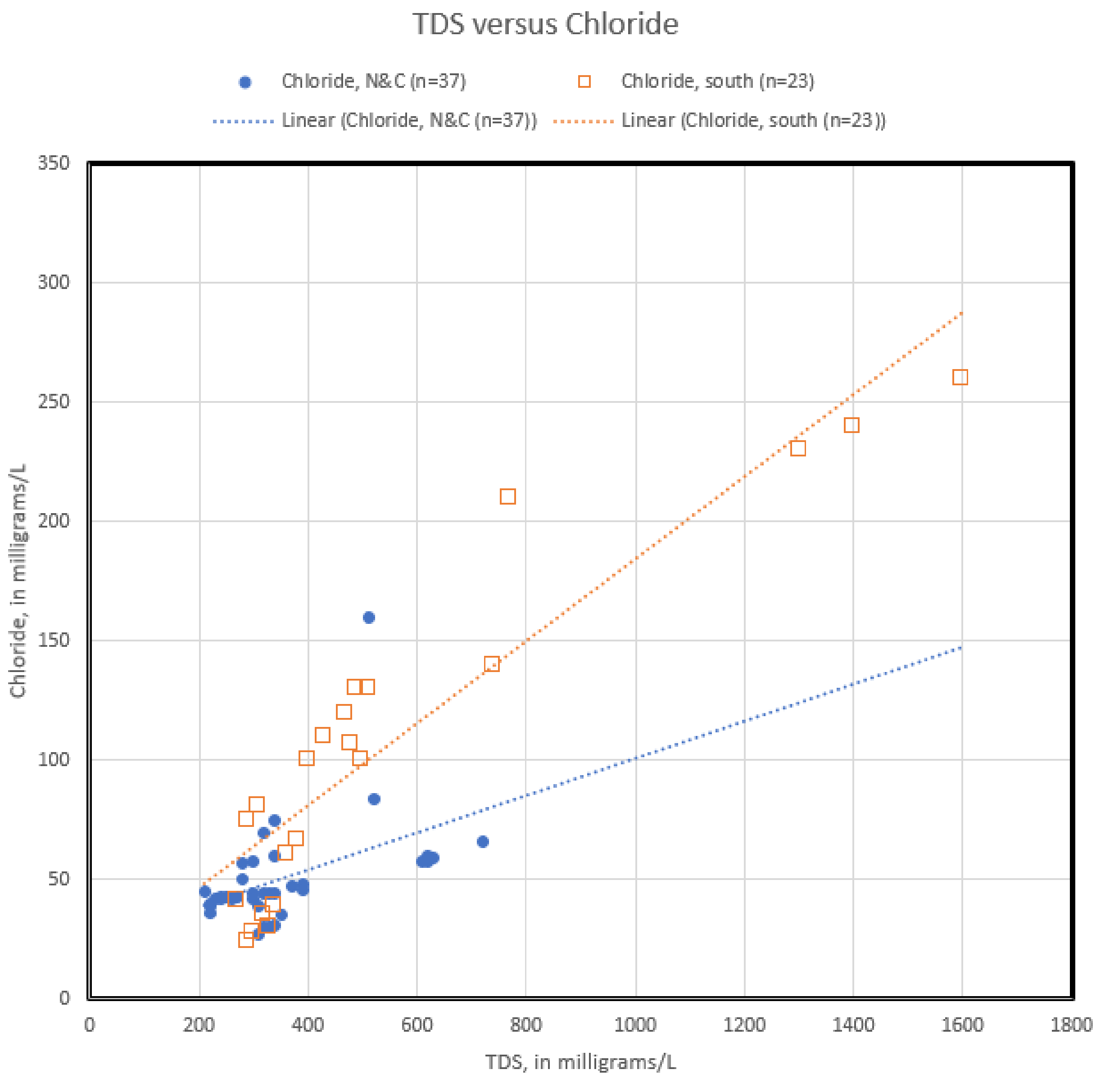
While correlations exist for all three analytes, sodium and chloride represents a higher percentage of TDS and calcium represents a smaller percentage of TDS in the South Management Area.

FIGURE 16



Chloride data segregated by management area are depicted in **Figure 17**. The highest chloride concentrations typically occur in the South Management Area.

FIGURE 17



3.8 General Minerals: Summary of Observations

A summary of the Piper diagram analyses for the 23 wells used in this Report is included in **Table 1B**.

- Water quality has clearly changed over time. Of the 23 wells, six had insufficient general minerals data to assess trends. Of the 17 wells with sufficient temporal data, approximately 70 percent showed a change in natural water chemistry over time.
- Sulfate is the general mineral most commonly observed to be increasing in groundwater (as a relative percentage per the Piper diagrams).
- Groundwater quality systematically varies with distance along the valley, with water in the South Management Area being noticeably different. Here the well data were not differentiated by aquifer or relative depth

Five COCs are included in this Report. Nitrate and arsenic are currently the chemical of highest concern specific to BWD drinking water quality. Fluoride, sulfate, and TDS are other three COCs. The data were collected over varying time periods and not all sampling events included a complete set of the eight general minerals. A review of the COCs for all of the active BWD wells is provided in **Section 4**.

Limited depth-specific hydraulic and contaminant data are available to assess the nature and extent of COCs in groundwater. As a result, the analyses among wells is limited to spatial comparisons. The lack of depth-specific data is a data gap that affects the assessment of all water quality parameters. The primary impact of this data gap is that the depth-dependent data will provide a good indication of how water quality will change over time as water levels decline. If specific zones are contributing poor water quality, then the data can be used to selectively complete future water wells to reduce the impact of the inflow of poor water quality.

4.0 CHEMICALS OF CONCERN (COCs) AT BWD WATER SUPPLY WELLS

The five chemicals of concern (COCs) include arsenic, total dissolved solids, nitrate, sulfate, and fluoride (As, TDS, NO_3, SO_4, and F). There are nine BWD water supply wells reviewed here. The COC and Piper diagram data for these wells is depicted in the following Figures that follow this subsection:

Figure 18 ID4-4 (Well #4, as depicted in Figure 4)
Figure 19 ID4-11 (Well #5, as depicted in Figure 4)
Figure 20 ID4-18 (Well #2, as depicted in Figure 4)
Figure 21 ID1-10 (Well #14, as depicted in Figure 4)
Figure 22 ID1-12 (Well #9, as depicted in Figure 4)
Figure 23 ID1-16 (Well #12, as depicted in Figure 4)
Figure 24 ID5-5 (Well #8, as depicted in Figure 4)
Figure 25 Wilcox (Well #13, as depicted in Figure 4)
Figure 26 ID1-8 (Well #15, as depicted in Figure 4)

Of these, three wells are being considered for replacement- ID4-4, ID4-18, and ID1-10. **Table 4** summarizes the review of **Figures 18 through 26**.

Water quality trends, if identified, are based on visual description of the various data. The GSP describes the use of Mann-Kendall statistical trend analyses, a non-parametric way to detect a monotonic trend (up or down), to assess individual water quality parameters. The work here is focused on identifying correlations among parameters.

NOTE: Well ID4-4 was redrilled in 1979. Water chemistry changed.

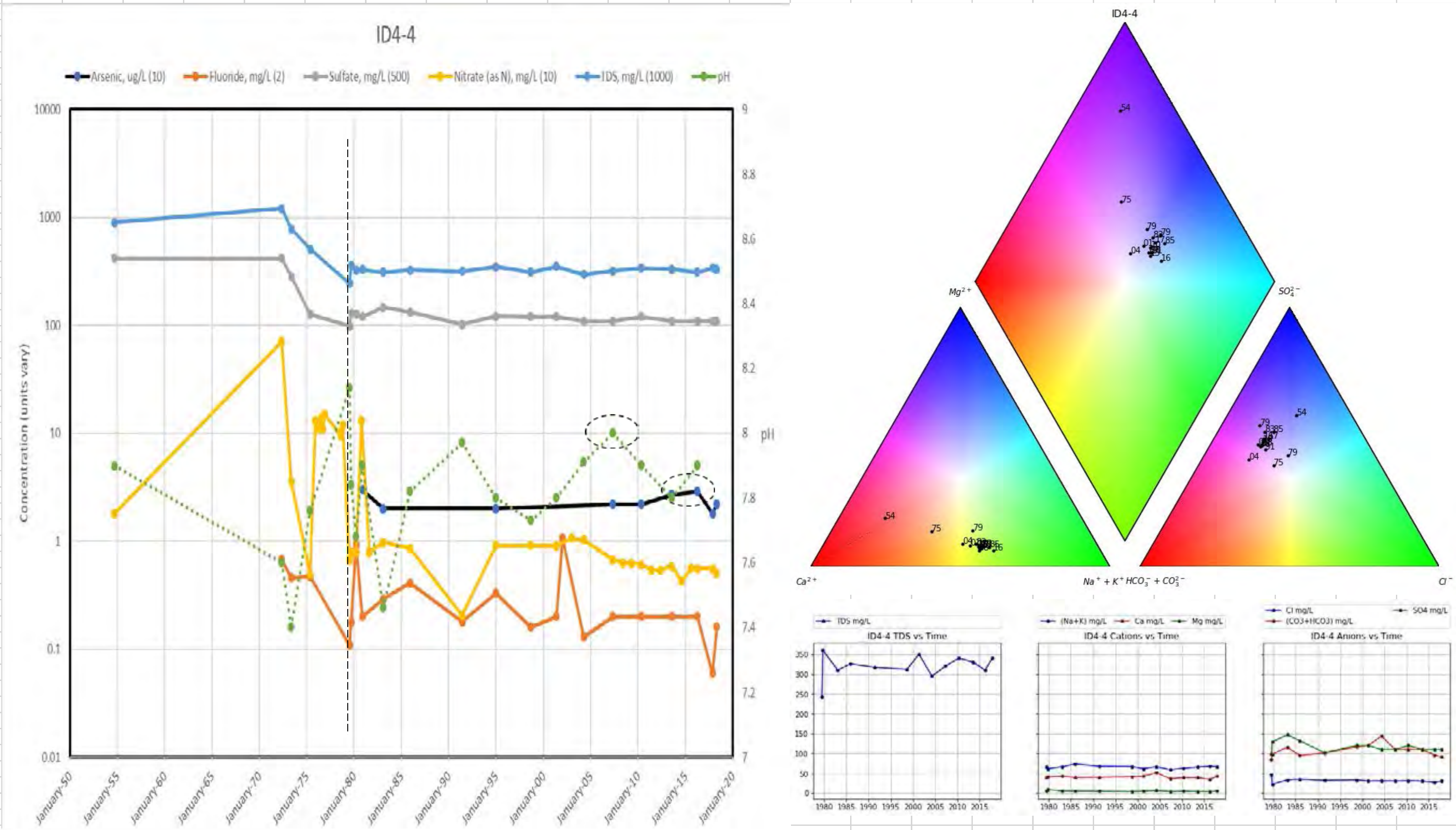


FIGURE 18. BWD Well ID4-4

Notes: pH and COC concentrations versus time shown left panel.

Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

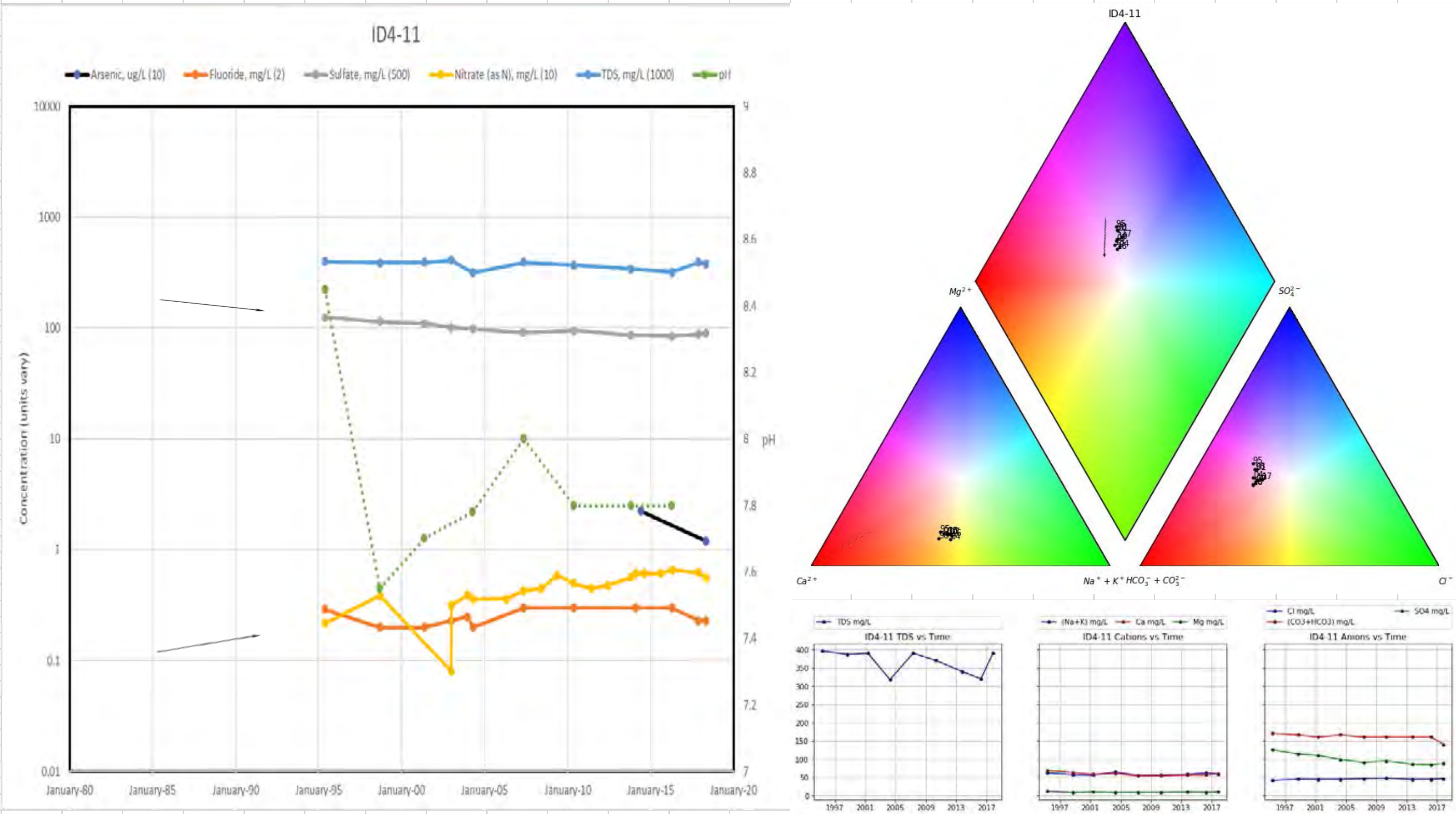


FIGURE 19. BWD Well ID4-11

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

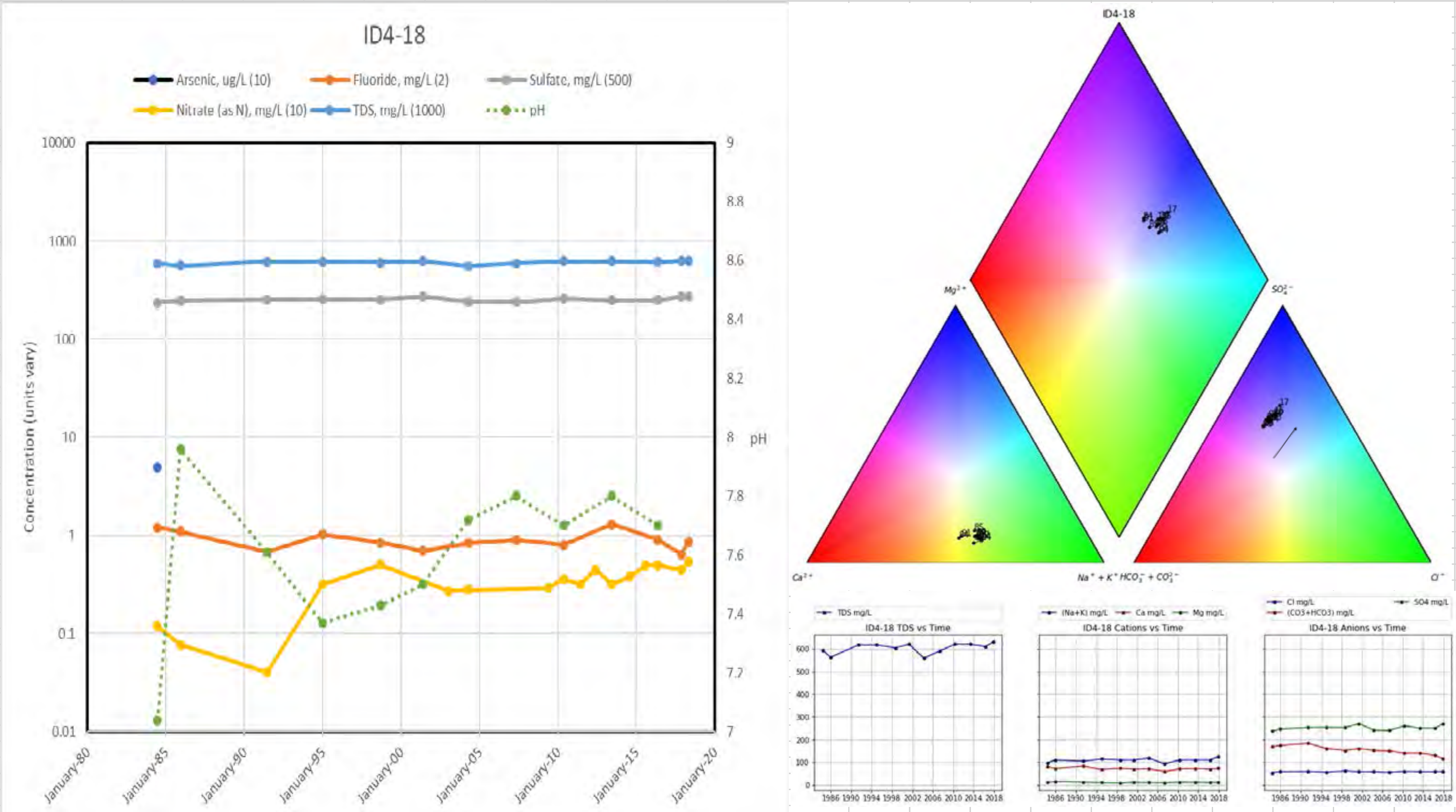


FIGURE 20. BWD Well ID4-18

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

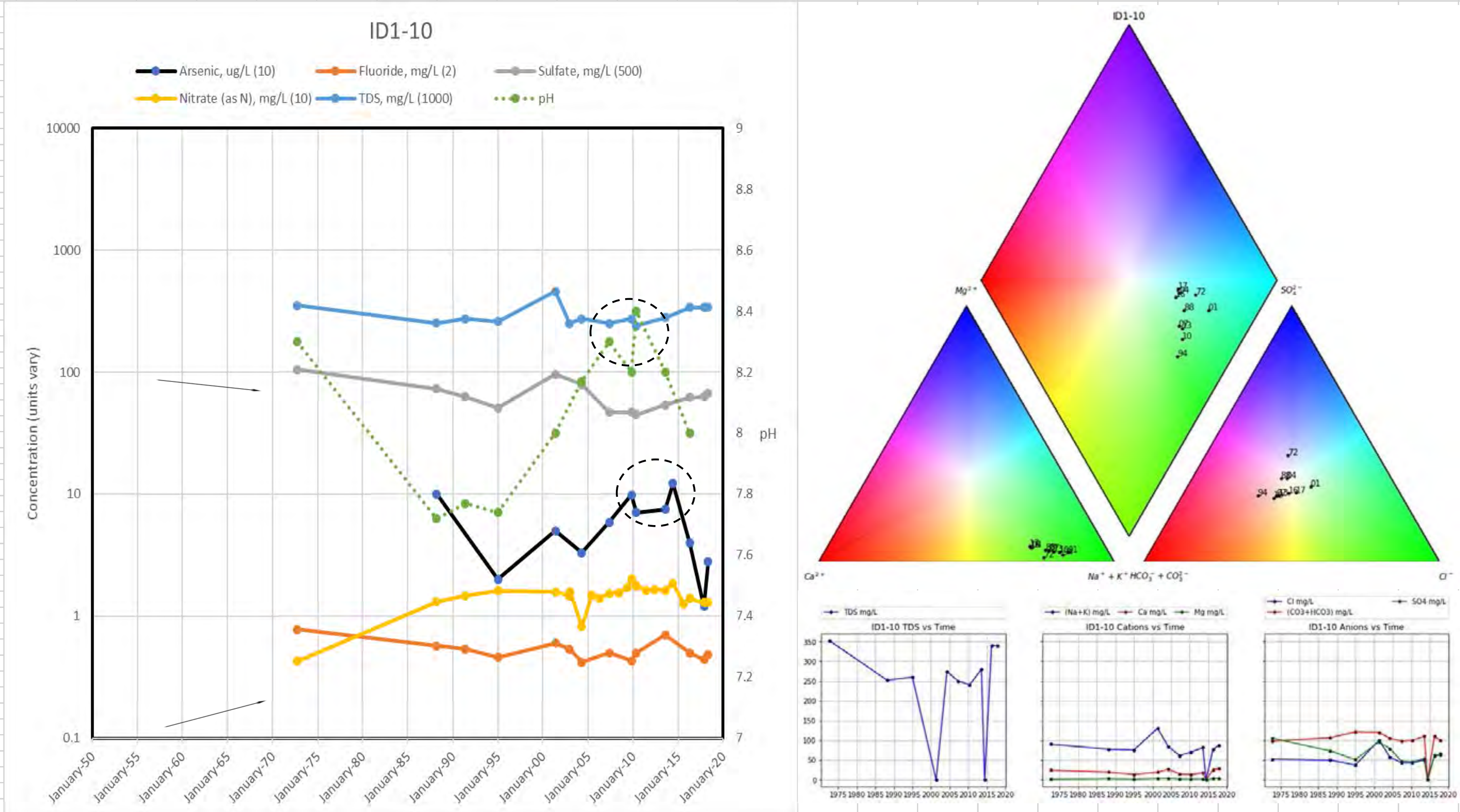


FIGURE 21. BWD Well ID1-10

Notes: pH and COC concentrations versus time shown left panel.

Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

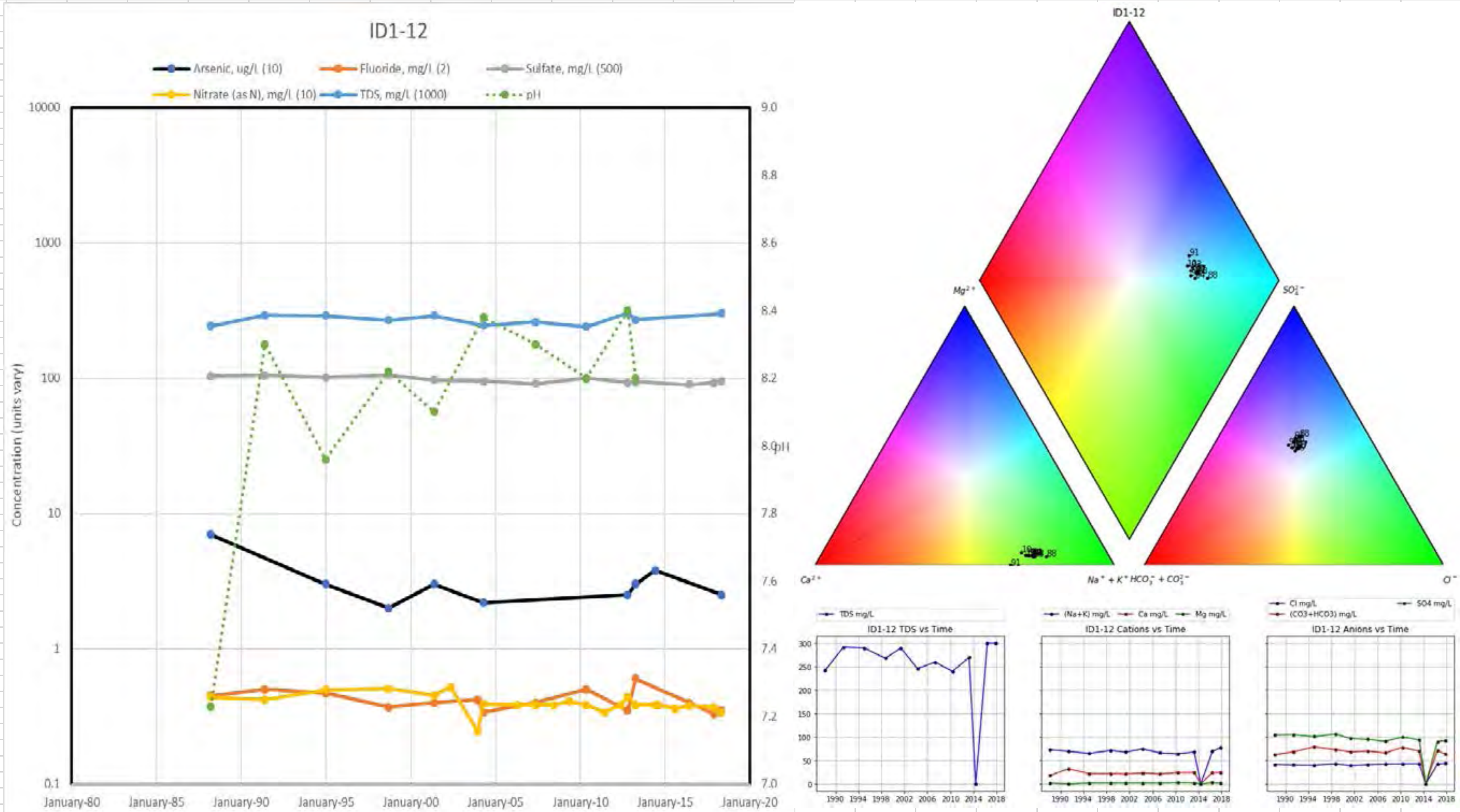


FIGURE 22. BWD Well ID1-12

Notes: pH and COC concentrations versus time shown left panel.

Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

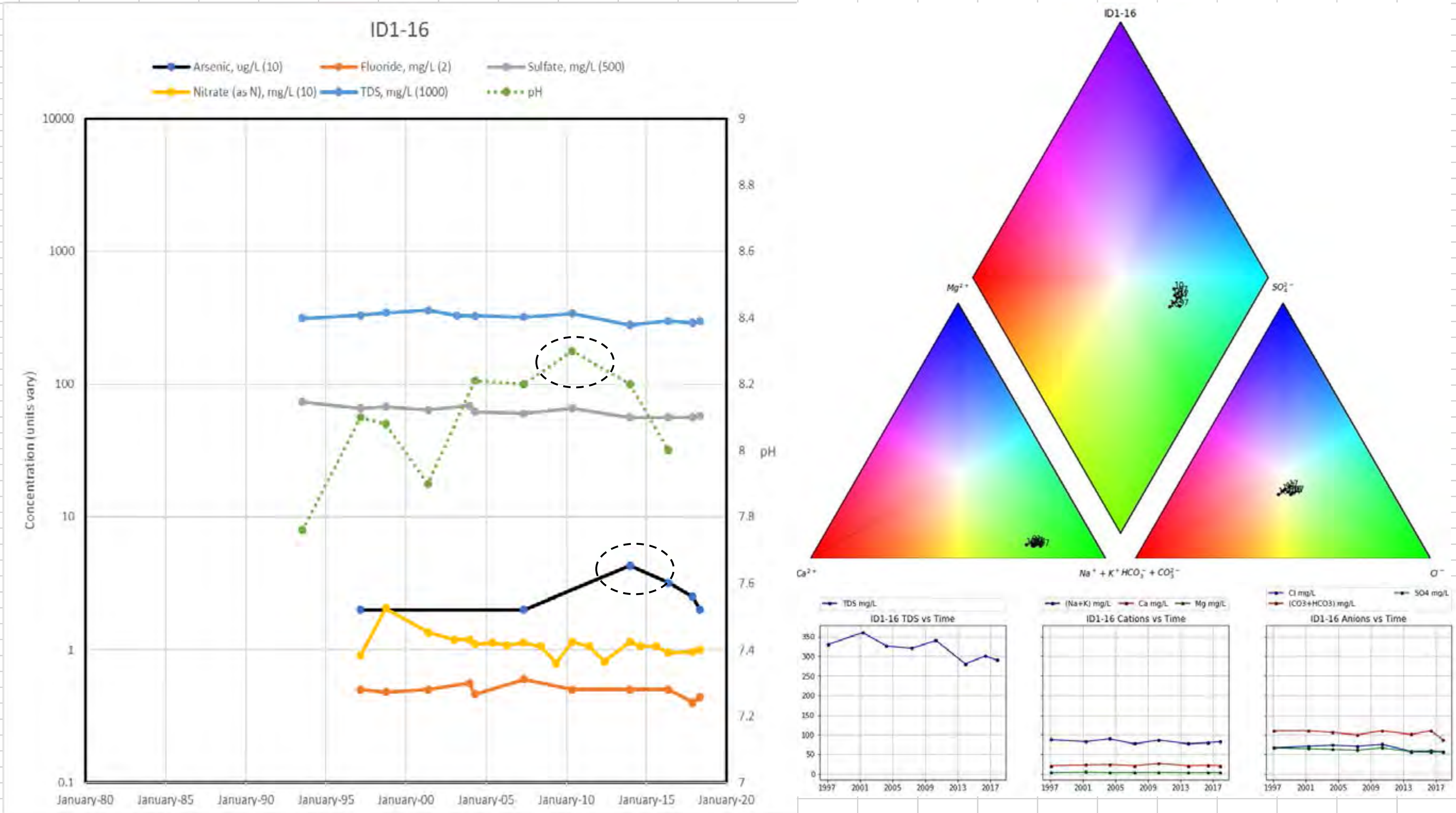


FIGURE 23. BWD Well ID1-16

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

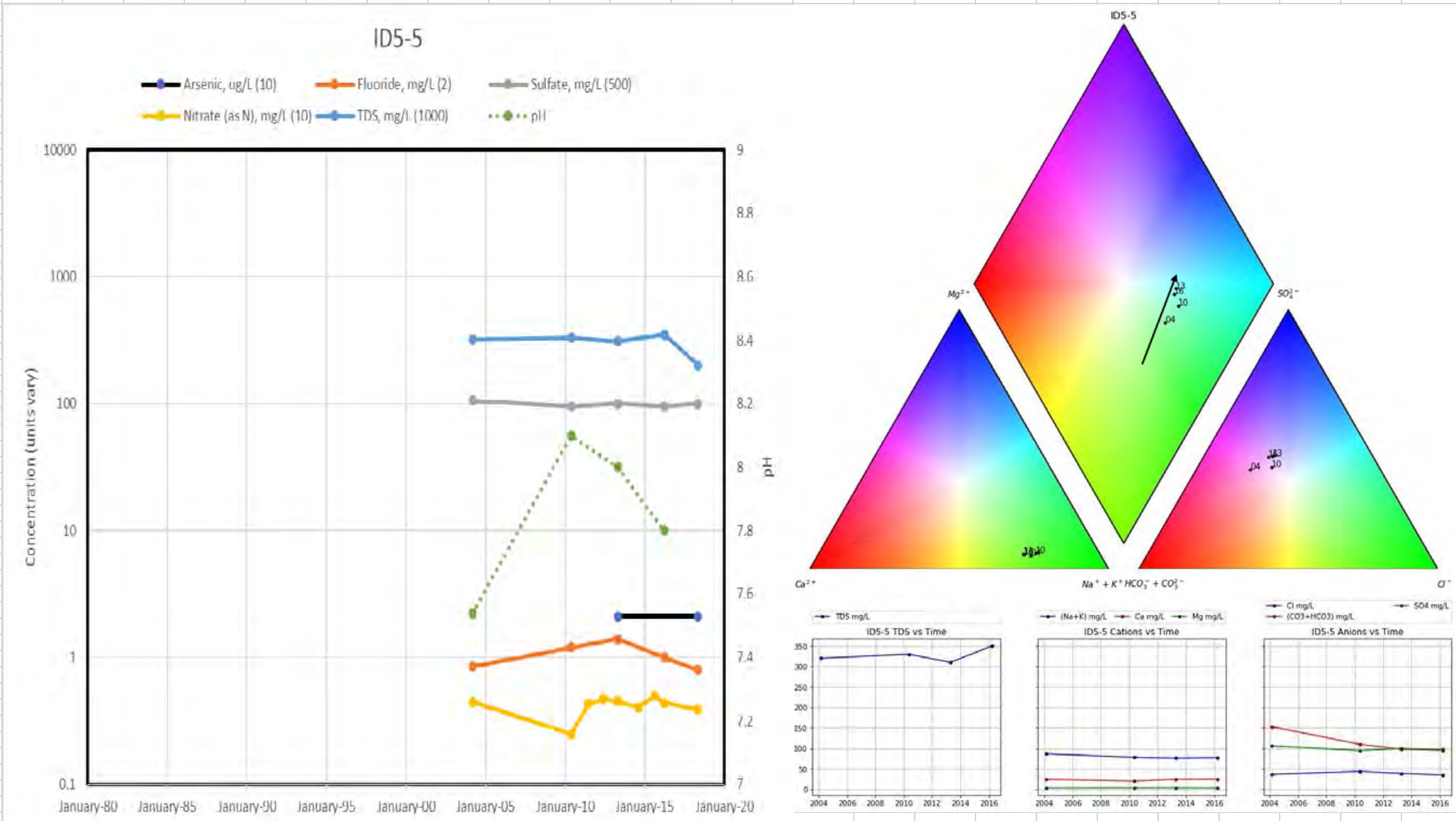


FIGURE 24. BWD Well ID5-5

Notes: pH and COC concentrations versus time shown left panel.

Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

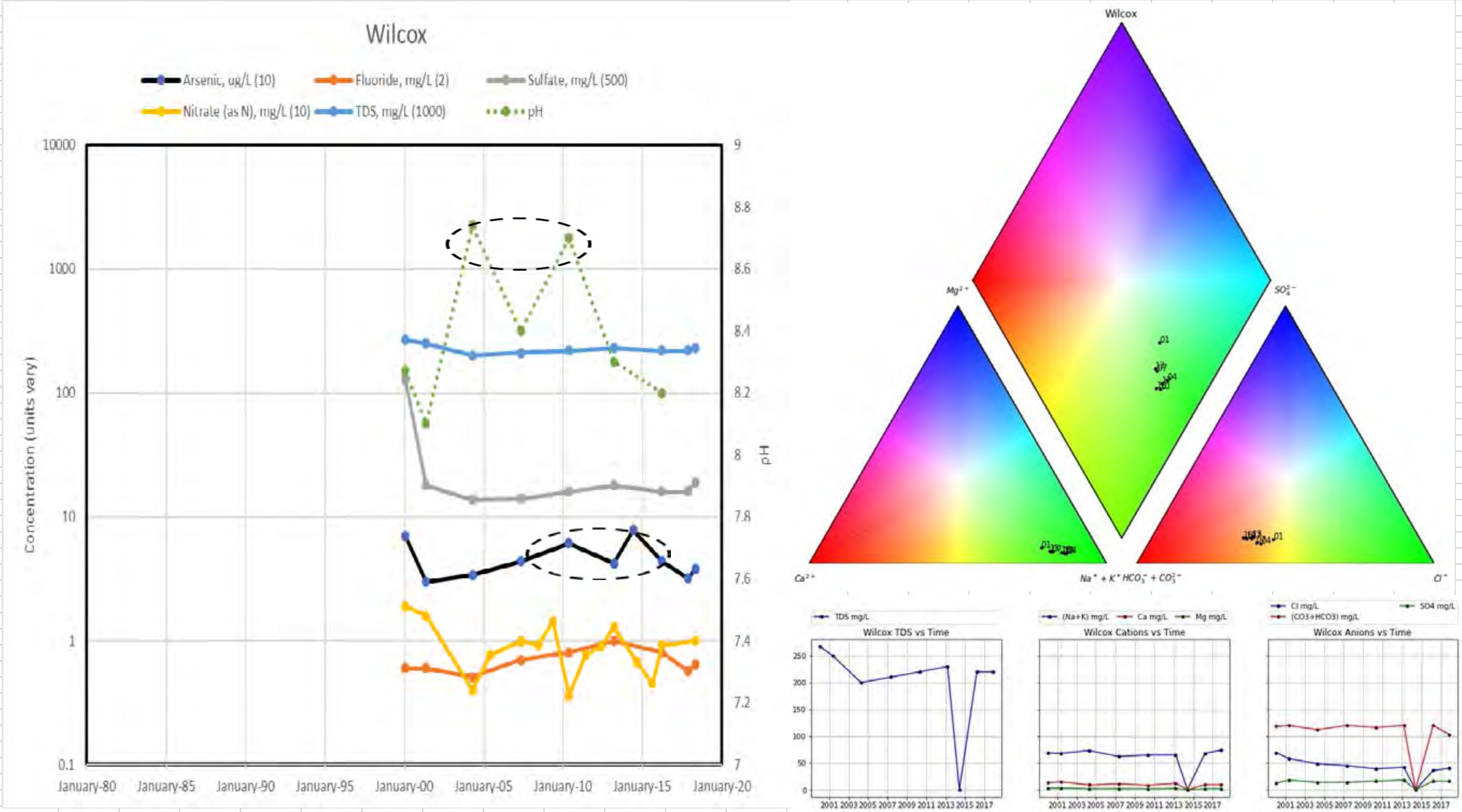


FIGURE 25. BWD Wilcox Well

Notes: pH and COC concentrations versus time shown left panel.

Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

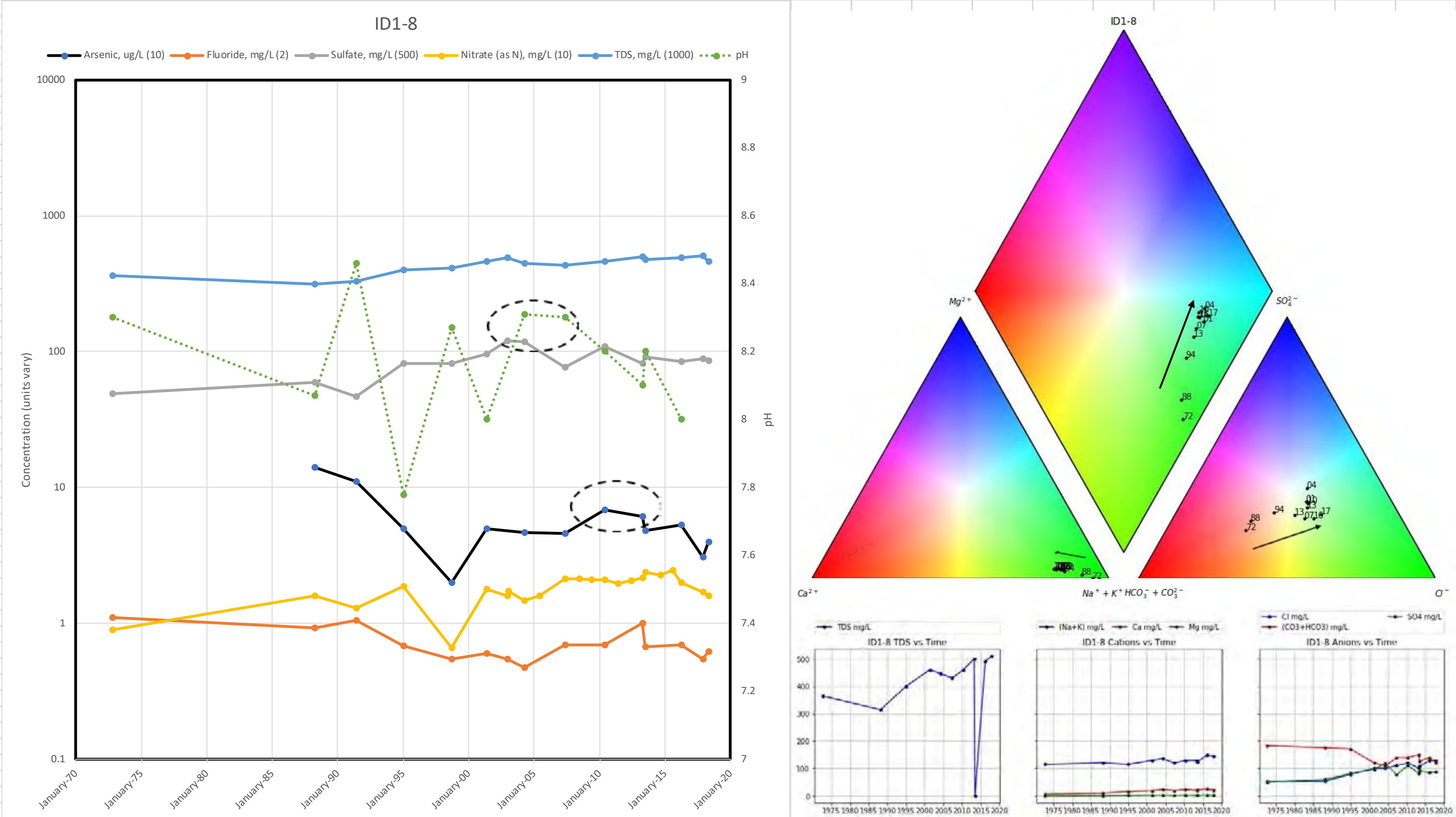


FIGURE 26. BWD Well ID1-8

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

TABLE 4

WELL	TDS/ Gen Min (MCL: 500 recc/1000 max, mg/L)	Sulfate (MCL: 250 recc/500 max,mg/L)	Arsenic (MCL: 10 ug/L)	pH	Nitrate (MCL: 10 mg/L as N)	Fluoride (MCL: 2 mg/L)
ID4-4 (#4)**	Stable (330) TDS: 320 to 340 GenMins*: Vble, cation trend may develop	Stable (110) SO4: 110 to 120	In Range (2.2) As: 1.8 to 2.9	Stable Range pH*: 7.8 to 8	Decreasing (0.5) NO3: 1.0 to 0.43	In Range (0.16) 0.6 to 0.2
ID4-11 (#5)	Stable (380) TDS: 320 to 390 GenMins*: Vble, anion trend may develop	Stable SO4: 91 to 95 Was decreasing prior to 2005	Insuff. Data (2.1) As: 1.2 to 2.2 Two recent detects	Stable Range pH*: 7.8 to 8	Increasing (0.56) NO3: 0.36 to 0.66	In Range (0.23) 0.23 to 0.3
ID4-18 (#2)**	Possibly Increasing (630) TDS: 590 to 630 GenMins: inc SO4, dec HCO3	Increasing (**270**) SO4: 240 to 270 Slowly changing	Non-Detect	Stable Range pH*: 7.7 to 7.8	Increasing (0.54) NO3: 0.29 to 0.54	In Range (0.87) 0.54 to 1.3
ID1-10 (#14)**	Possibly Increasing (340) TDS: 250 to 340 GenMins: inc SO4, dec HCO3 (major changes since 1972)	Increasing (67) SO4: 45 to 67 Slowly changing	In Wide Range (2.8) As: 1.2 to **12.2** Maximum 6/2014	In Wide Range pH*: 8.0 to 8.4 Maximum 5/2010 (*~2 yr ahead of As*)	In Range (1.3) NO3: 1.27 to 2.02	In Range (0.48) 0.43 to 0.7
ID1-12 (#9)	Stable (300) TDS: 260 to 300 GenMins: Stable	Stable (95) SO4: 91 to 95	In Range (2.5) As: 2.5 to 3.79	In Range pH*: 8.2 to 8.4	In Range (0.34) NO3: 0.34 to 0.44	In Range (0.34) 0.38 to 0.6
ID1-16 (#12)	Possibly Decreasing (340) TDS: 280 to 340 GenMins: SO4 slowly decreasing	Decreasing (58) SO4: 56 to 66 Slowly changing	In Range (2.0) As: 2.0 to 4.3 Maximum 12/2013	In Range pH*: 8.0 to 8.3 Maximum 5/2010 (*~3 yr ahead of As*)	In Range (1.3) NO3: 1.27 to 2.02	In Range (0.48) 0.43 to 0.7
ID5-5 (#8)	Stable (350) TDS: 202 to 350 GenMins*: Vble, anion trend may develop (inc SO4)	Stable (100) SO4: 95 to 106	Insuff. Data (2.1) As: 2.1 (twice) Two recent detects	In Wide Range pH*: 7.54 to 8.1	In Range (0.39) NO3: 0.25 to 0.50	In Range (0.8) 0.85 to 1.4
Wilcox (#13)	Stable (230) TDS: 210 to 230 GenMins: SO4 slowly increasing	Increasing (19) SO4: 14 to 19 Slowly changing	In Range (3.8) As: 3.2 to 7.8 Maximum 6/2014	In Range pH*: 8.2 to 8.7 Maximum 5/2010 (*~4 yr ahead of As*)	In Range (1.0) NO3: 0.36 to 1.42	In Range (0.64) 0.57 to 0.87
ID1-8 (#15)	Possibly Increasing (460) TDS: 430 to 510 GenMins: long-term inc SO4 & Cl & Ca, dec HCO3 (major changes since 1972)	Stable (86) SO4: 82 to 110	In Range (4.0) As: 3.1 to 6.8 Maximum 5/2010	In Range pH*: 8.0 to 8.4 Maximum during 2004 to 2007 (*~3 to 6 yr ahead of As*)	In Range (1.6) NO3: 1.6 to 2.46 (long-term inc)	In Range (0.62) 0.55 to 1.0

Notes:
* Most recent general minerals and pH analyses done in 2016
** Wells expected to be replaced or re-drilled in short-term

Explanation:
Trends noted as Stable, Increasing, Decreasing, Possibly Increasing/Decreasing, or In a Range
Number after descriptor – e.g. Stable (330), is the most recent sampling result from Spring 2018
Next line is the range of values observed since 2005
GenMins refers to the set of general minerals data- eight major anions and cations
xx, a value that is highlighted occurs at a concentration greater than 50% of the MCL
xx, a value that is highlighted and bold occurs at a concentration greater than the MCL

4.1 North Management Area (3 Wells: ID4-4, ID4-11, and ID4-18)

The North Management Area wells are generally located to the west and upgradient of the irrigated agricultural areas visible in **Figures 4 and 7**. COC-specific observations are included in **Table 4**.

ID4-4

ID4-4 was re-drilled in 1979 due to high nitrate concentrations related to the upper aquifer. Nitrate remains detectable but at low concentrations. Water quality is good and reasonably stable. The District is currently planning to re-drill this well at the same site as a result of poor well conditions that resulted in sanding and the installation if a well liner that limits the depth to which the pump can be installed in the well.

Additional information regarding the well replacement can be found in a 8/30/2018 Dudek presentation entitled “Water Vulnerability & New Extraction Well Site Feasibility Analysis” posted at the County SGMA website:
https://www.sandiegocounty.gov/content/dam/sdc/pds/SGMA/Prop-1-SDAC-Grant-Task-5-New-Extraction-Well-Site-Feasibility-Analysis.pdf

ID4-11

Water quality in ID4-11 is good and reasonably stable.

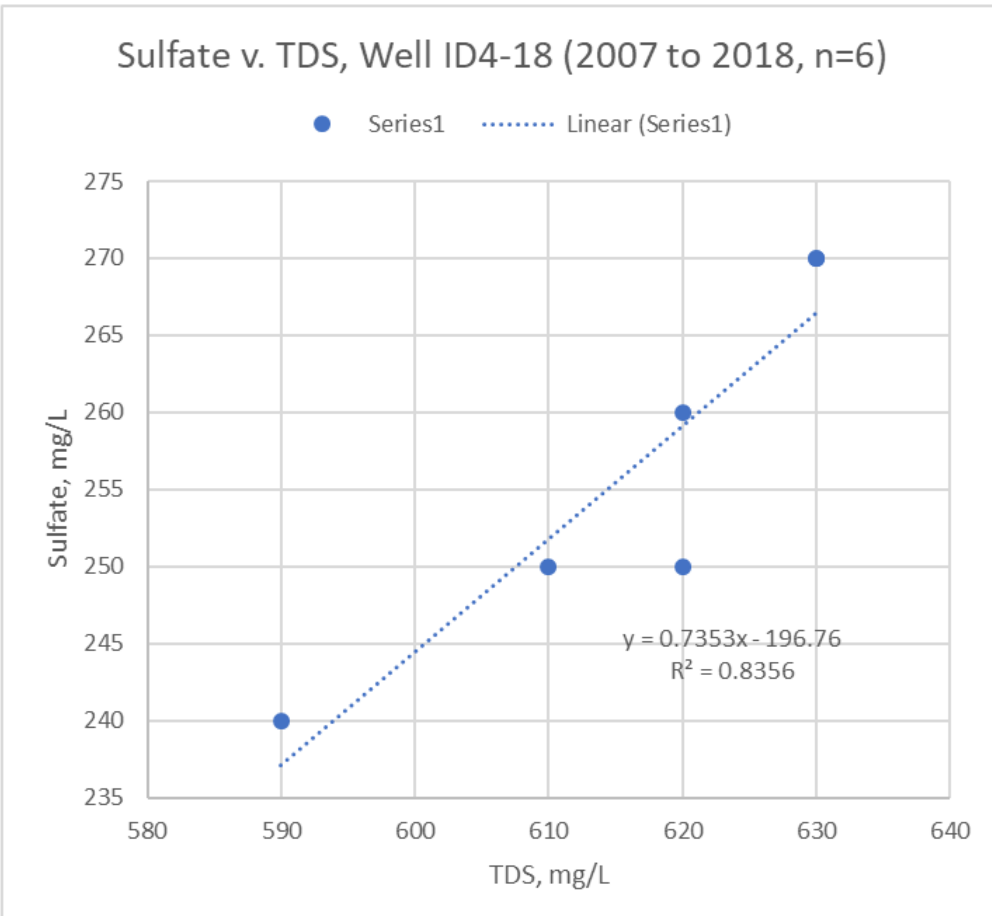
ID4-18

TDS is between the recommended and upper secondary MCL (currently at 630 mg/L). Sulfate is slowly increasing and is above the recommended secondary MCL of 250 mg/L. Arsenic has not been detected in this well (last reported as ND < 1.2 µg/L).

Figure 27 shows how TDS and sulfate are correlated and is presented as an example of how TDS measurements based on electrical conductivity testing may be able to be used to assess sulfate.

FIGURE 27

Date	TDS	Sulfate
5/8/2007	590	240
5/11/2010	620	260
6/10/2013	620	250
5/16/2016	610	250
11/17/2017	630	270
4/30/2018	630	270



4.2 Central Management Area (5: ID1-10, ID1-12, ID1-16, ID5-5, and Wilcox)

The Central Management Area is associated with both the "central" and "transitional" water quality type as indicated in **Figure 6** and COC-specific observations included in Table 4.

ID1-10

Water quality in ID1-10 is currently good and reasonably stable.

Elevated arsenic concentrations (a maximum of 12.2 µg/L that exceeded the MCL of 10 µg/L) were observed in 2014 that were preceded by elevated pHs of 8.2 to 8.4 (see **Figure 21**). Arsenic concentrations and elevated pH conditions have since declined.

ID1-12

Water quality in ID1-12 is currently good and reasonably stable.

ID1-16

Water quality in ID1-12 is currently good and reasonably stable.

Elevated arsenic concentrations (a maximum of 4.3 µg/L) were observed in 2014 that were preceded by and elevated pH of 8.3 (see **Figure 23**). Arsenic concentrations and elevated pH conditions have since declined.

ID5-5

Water quality in ID5-5 is currently good and reasonably stable.

Wilcox

Water quality in the Wilcox well is currently good and reasonably stable.

Elevated arsenic concentrations (a maximum of 7.8 µg/L) were observed in 2010 and 2014 that were preceded by elevated pH of greater than 8.6 (see **Figure 25**). Arsenic concentrations and elevated pH conditions have since declined.

4.3 South Management Area (1: ID1-8)

As previously discussed, the water chemistry observed in the South Management Area is distinctly different than that observed to the north. COC-specific observations are included in Table 4.

ID1-8

Water chemistry at ID1-8 has significantly changed over time, but now appears to be stabilizing. Water quality in ID1-8 is currently good.

Arsenic is of concern due to MCL exceedances consistently observed in nearby Ram's Hill wells.

Elevated arsenic concentrations (a maximum of 6.8 µg/L) were observed in 2010 that were preceded by an elevated pH of 8.3 (see **Figure 26**). Arsenic concentrations and elevated pH conditions have since declined.

5.0 SUMMARY

The multi-parameter assessment of water quality and COC trends provides additional insight compared to single parameter assessments.

Natural Water Chemistry (anions and cations)

- Natural water chemistry as determined by the eight dominant anions and cation systematically varies across the Subbasin (these include calcium [Ca], magnesium [Mg], sodium [Na], potassium [K], chloride [Cl], sulfate [SO_4], bicarbonate [HCO_3], and carbonate [CO_3]).

  The observed variations generally correlate with the previously established management areas that are further discussed in the GSP. Overall trends generally correlate with the well location relative to the pre-development groundwater flow paths and distance from where recharge waters enter the Subbasin,

- Water samples from BWD water supply wells show that the dominant cations and anions are sodium and calcium; and bicarbonate, sulfate, and chloride, respectively.

- The water type transitions from a calcium sulfate to a sodium chloride in the Northern Management Area wells.

- Sodium bicarbonate type water generally occurs in the South Management Area as tested. The groundwater analysis further supports that the South Management Area has distinctly different water quality than observed in the north and central groundwater management areas.

- The primary causes for the difference in water quality within the Subbasin include variations in the water being recharged (e.g. Coyote Creek versus San Felipe Creek), proximity of irrigated lands (e.g. nitrate impacts due to fertilizer application), aquifer lithology (local deposits of evaporites and potential arsenic-bearing clays), aquifer depth (related to increase in TDS), and location within the Subbasin with respect to the Borrego Sink where enhanced evaporation of ephemeral surface water occurs.

- Due to the location of the BWD wells this analysis does not fully represent the water quality distribution in the Subbasin. Refer to **Figures 4 and 7** for the well locations. As result the spatial trends identified among the wells are limited to examining variations along the western side of the Subbasin.

- Water quality as a function of depth has not been assessed in the BWD water supply wells, for example by the use of depth-specific water sampling. Well profiling data obtained by the DWR (**Figure 10**, for example) indicate that TDS linearly increases with depth. Given the high correlation with sulfate, the increase in TDS implies that sulfate will also increase with depth.

- Multiple aquifers are represented in the water chemistry data because of the construction of the 23 wells used in this report. As a result, water quality could not be differentiated in terms of the three-layer aquifer system (upper/middle/lower) used by the USGS and others (for example in the USGS Model Report).

- Temporal trends are more readily identified when multiple general mineral analyses are considered for each of the wells. Here Piper trilinear diagrams were used to assess the eight dominant anions and cations.

- 17 of the 23 wells had sufficient anion and cation data for temporal analysis and in some cases, well over 40 years data are available. Of these approximately 70 percent have experienced changes in water chemistry over time. The changes are generally attributed to long-term overdraft.

Chemicals of Concern (COCs)

- Five COCs were examined: arsenic, nitrate, TDS, sulfate, and fluoride. The overall analyses are improved when all five parameters are considered together and geochemical factors such as pH are included. The five COCs are depicted together with pH for each of the nine active BWD water supply wells in **Section 4**.

- Single parameter trend assessments, for example using Mann-Kendall trend analyses included in previous studies, are not repeated here.

- The COC analysis is based on a comparison of concentrations with current MCLs. Down-revision of the criteria, especially for arsenic, could have a large impact on BWD operations should water treatment be required. The State of California MCL for arsenic was last revised (from 50 to 10 ug/L) on 1/28/2008[25]. As of February 2017, there is no indication that the State Water Resources Control Board is planning to revise the arsenic MCL[26].

- Overall the water quality is currently good and water can be delivered without the need for advanced treatment. However, short-term water quality trends have been of concern, especially for arsenic. The following summarizes the analysis per COC.

[25] See: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Arsenic.html

[26] Per a state review from 2017: "We are not aware of changes in treatment that would permit materially greater protection of public health, nor of new scientific evidence of a materially different public health risk than was previously determined. Thus, we do not plan on further review of the arsenic MCL." See: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/reviewofmaximumcontaminantlevels-2017.pdf

Arsenic and Fluoride

Arsenic concentrations were increasing in multiple BWD water supply wells until 2014 and have since decreased. The potential for MCLS to be exceeded is of high concern to BWD due to the potential cost of water treatment and/or well replacement. The MCL was temporarily exceeded in one well, ID1-10. Review of the data shows that there is a relationship between pH and arsenic where elevated arsenic concentrations occur under alkaline conditions with pH levels of approximately 8 and greater. Especially noteworthy is that peak arsenic concentrations can be observed to occur after the peak pH was observed in multiple wells (ID1-10, ID1-16, Wilcox, and ID1-8). The lag time is approximately 2 to 4 years. While additional data and observations are required to further assess the connection between arsenic and pH, this relationship could prove important toward the monitoring and management of BWD's water supply.

Fluoride is discussed with arsenic because it has been observed to correlate with arsenic. While fluoride occurs at detectable concentrations in all of the active BWD wells, it has not been of concern as concentrations have typically been well less than 1.0 mg/L, less than half the MCL. Given the correlation it may prove useful towards future trend analyses for arsenic.

TDS and Sulfate

TDS represents the sum of all anions and cations that occur in the water. Here a number of these anions and cations have been observed to correlate with TDS. **Figures 15 through 17** show the correlation with TDS for sulfate, sodium, calcium, and chloride. A specific example is shown for well ID4-18 in **Figure 27** where TDS and sulfate are well correlated.

The USGS Model Report (p. 2) identified TDS and sulfate as "the only constituents that show increasing concentrations with simultaneous declines in groundwater levels".

Electrical conductivity measurements are commonly used to assess TDS. In this case they can be used as a field-based monitoring tool for TDS, and in turn support tracking of sulfate. The TDS profiles presented by DWR (**Figure 10**) are examples of electrical conductivity measurements used to evaluate TDS.

Nitrate

Historically there have been significant nitrate-related water quality problems encountered in BWD wells that led to well reconstruction, abandonment, and replacement. These wells were typically producing water from the uppermost portion of the aquifer system. As noted in **Table 4**, nitrate occurs in all of the active BWD wells at varying concentrations well below the MCL. Nitrate predominantly occurs as a result of fertilizers contained in irrigation return flow, and from septic systems. Historically, because the upper portion of the aquifer system is unconfined, nitrate has primarily affected wells that were completed (open to flow) at the water table.

The USGS Model Report (p.2) noted that "TDS and nitrate concentrations were generally highest in the upper aquifer and in the northern part of the Borrego Valley where agricultural activities are primarily concentrated".

Nitrate concentrations are primarily related to land-based activities and do not correlate with inorganic water quality data. Overall determination of historical impacts and ongoing susceptibility of the aquifer to nitrate contamination will require review of prior, current, and future land use placed in a spatial context. Work done by DWR (for example as illustrated in **Figure 11**) is an example of how land use information can be used. Among the land use parameters that would go into a nitrate source analysis would the location and types of septic and sewer systems, current and historical agricultural activities, and current and historical irrigated turf/golf courses.

5.1 Other Potential COCs

This report focused on the dominant anions and cations, and the five primary COCs. Other potential COCs include naturally-occurring uranium and radionuclides. Anthropogenic COCs include herbicides, pesticides, and similar chemicals used for agriculture and turf management. Microbial contamination, typically associated with animal wastes and sewage/septic, is also of potential concern.

Groundwater quality provided by BWD water supply wells is currently good and meets California drinking water maximum contaminant levels (MCLs). To date the current wells are producing water without the need for treatment. The BWD public water supply monitoring program is conducted in compliance with the State of California's requirements as administered by the State Water Resources Control Board Division of Drinking Water (DDW) and includes a wide range of analytes.

BWD provides all sampling data to the DDW, and is listed as public water supply CA3710036. A summary of BWD's sampling program for other COCs can be reviewed in the annual consumer confidence report, available online at http://nebula.wsimg.com/c30a61991a5160ddf5e577fe9f7b3c01?AccessKeyId=D2148395D6E5BC38D600&disposition=0&alloworigin=1. The BWD is also sampling all of its water supply well semi-annually as part of the GSA monitoring network rather than the minimum 3-year timeframe currently required by DDW.

5.2 Recommendations

- The COC analysis supports expansion of groundwater monitoring and testing program to include field-based water quality measurements of water being produced by BWD. Monthly wellhead measurements are recommended for electrical conductivity (EC), pH, and oxidation-reduction (redox) potential. These could be conducted at the same time BWD personnel collect monthly bacteria samples. EC can be used to calculate TDS, and by correlation estimate sulfate in some wells. Redox and pH are key geochemical parameters that can readily be measured at the wellhead by BWD personnel.

- Conduct vertical profiling and depth-specific sampling of water supply wells when the wells become accessible, for example during pump removal for maintenance. The primary goals of the testing are to identify potential zones where water quality may be poor and to examine the relative rate of flow of water into the well with depth. Both types of information will support assessment of well performance as overdraft continues.

  Long-term the vertical profiling will provide data to better understand the water quality trends and support BWD water management planning. For example, the data will support assessment of sulfate trends by understanding how concentrations may or may not be increasing with depth and support projections of how water quality will change as overdraft while pumping reductions occur over the 20-year GSP planning period.

- Use the groundwater model to assess pre- and post-SGMA groundwater flow conditions and potential changes in water chemistry. Current pumping conditions have changed groundwater flow patterns within the North and Central Management Area due to the establishment of two pumping centers. Future pumping reductions will likely alter groundwater flow patterns. The model can be used to support calculations of groundwater flow rates and directions using ‘particle tracking’, a methodology that looks at how water flows over time. The modeling software (USGS Modflow model) includes Modpath, a post-processing software that works with the model output.

- Use the groundwater model water balance to develop a ‘mixing cell’ calculation of salt balance to assess the potential rate of accumulation of dissolved minerals associated with water use. The Subbasin is effectively a closed system where dissolved minerals and other solutes have will continue to accumulate over time. The primary purpose of the calculations is to assess long-term TDS changes that result from irrigation and septic return flows as overdraft continues. The calculations will also support examination of areas where BWD water production may need to be established using new or existing water wells.

- Investigate the potential causes of the temporary increases in arsenic concentrations and pH observed in BWD wells as a means of predicting future arsenic concentrations. A lag time of 2 to 4 years is observed in multiple BWD wells where elevated pH preceded the increase in arsenic concentrations that could prove to be important towards BWD's water supply and risk management.

- Expand on the analysis of nitrate in groundwater relative to land use as described by the DWR (e.g. **Figure 11**). Additional discussion of the occurrence of nitrate in groundwater is included in the GSP that describes land uses within the Subbasin.

- Expand the water chemistry and water quality evaluation to areas within and downgradient of the agricultural areas in the North and Central Management Areas.

- Continue to collect the full suite of general minerals (8 anions and cations) together with pH and redox measurements. Water chemistry parameters should be collected using 'flow cells' where the chemistry of the water is tested before it is exposed to the atmosphere.[27]

- Conduct selective sampling for phosphate and review the overall electrochemical balance for all potential anions and cations to determine why the current data have excess cations relative anions (see **Section 3.2.1**).

- Further assess lithologic and geochemical conditions associated with the occurrence of arsenic. For example, work done in the San Joaquin valley (discussed in **Section 3.6.1**) linked the release of water from clay to increased arsenic concentrations in groundwater. Further review of Subbasin stratigraphy work done by Netto (2001) is warranted. Re-analysis of the geostatistical work done by the USGS to evaluate sediment lithologies may also prove useful towards understanding the nature and extent of sediments potentially associated with arsenic. Lithologic sampling and

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[27] An example is shown below. Water flows directly from the well into a chamber where measurements are made. From: http://www.geotechenv.com/flowcell_sampling_systems.html. It is understood that Dudek staff are using flow cells during sampling of Rams Hill wells to measure pH, specific conductance, temperature, turbidity, dissolved oxygen, oxygen-reduction potential, and color. Their Sampling and Analysis Plan could be used for the remaining wells within the GSP monitoring program.

Geotech Flowblock
<40 mL cell volume for flow rates of
100 mL/min to 1 gpm (3.8 LPM)

geochemical testing for arsenic and related minerals is recommended during the installation of new wells.

- Investigate the potential interaction of microbially-mediated oxidation and reduction processes (e.g. denitrification and sulfate reduction) specific to arsenic mobility.

- Examine the potential application of recharge basins to facilitate arsenic removal as a result of geochemical processes in the vadose zone (see discussions in Section **3.6.1**).

- Develop an inventory of abandoned wells, including well completion information and potential condition. Abandoned wells have the potential to act as conduits for the downward flow of shallow groundwater contaminants such as surface applied fertilizers, agricultural chemicals, and turf management chemicals. Abandoned wells may need to be properly destroyed per California Well Standards (See information available from the County of San Diego https://www.sandiegocounty.gov/content/sdc/deh/lwqd/lu_water_wells.html)

- Continue to track changes in groundwater quality as a function of water level to assess trends relative to the potential for water quality degradation and the likelihood of the need for water treatment. Use the data to assess potential cost and water system reliability risks to BWD.

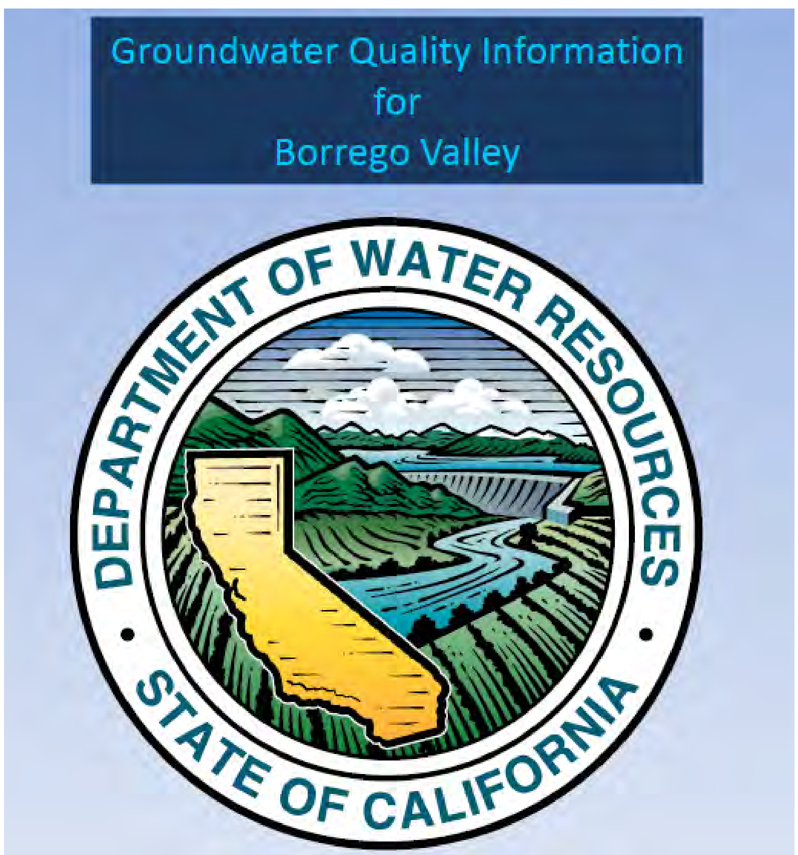
- Continue to track water treatment technologies and costs for arsenic as the potential for revision of the arsenic MCL is, in part, dependent on cost-benefit analyses for water treatment (see COC discussion in Section 5).

6.0 REFERENCES

All references are cited within the text using footnotes.

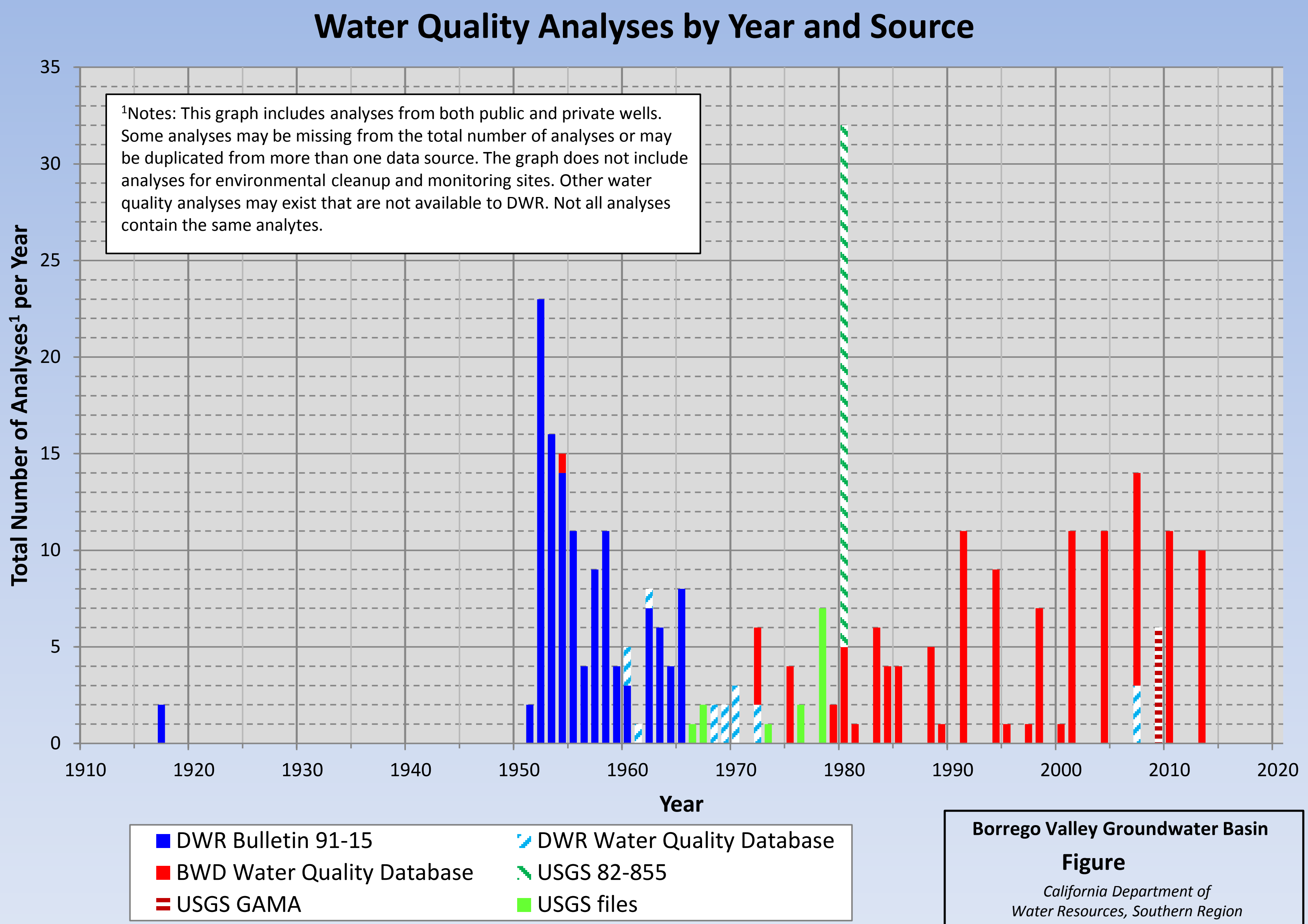
APPENDIX A

DWR, 2014



Groundwater Quality Information for Borrego Valley

Southern Region May 2014



Borrego Valley Groundwater Basin

Figure

California Department of Water Resources, Southern Region

More than 300 water quality analyses have been identified.

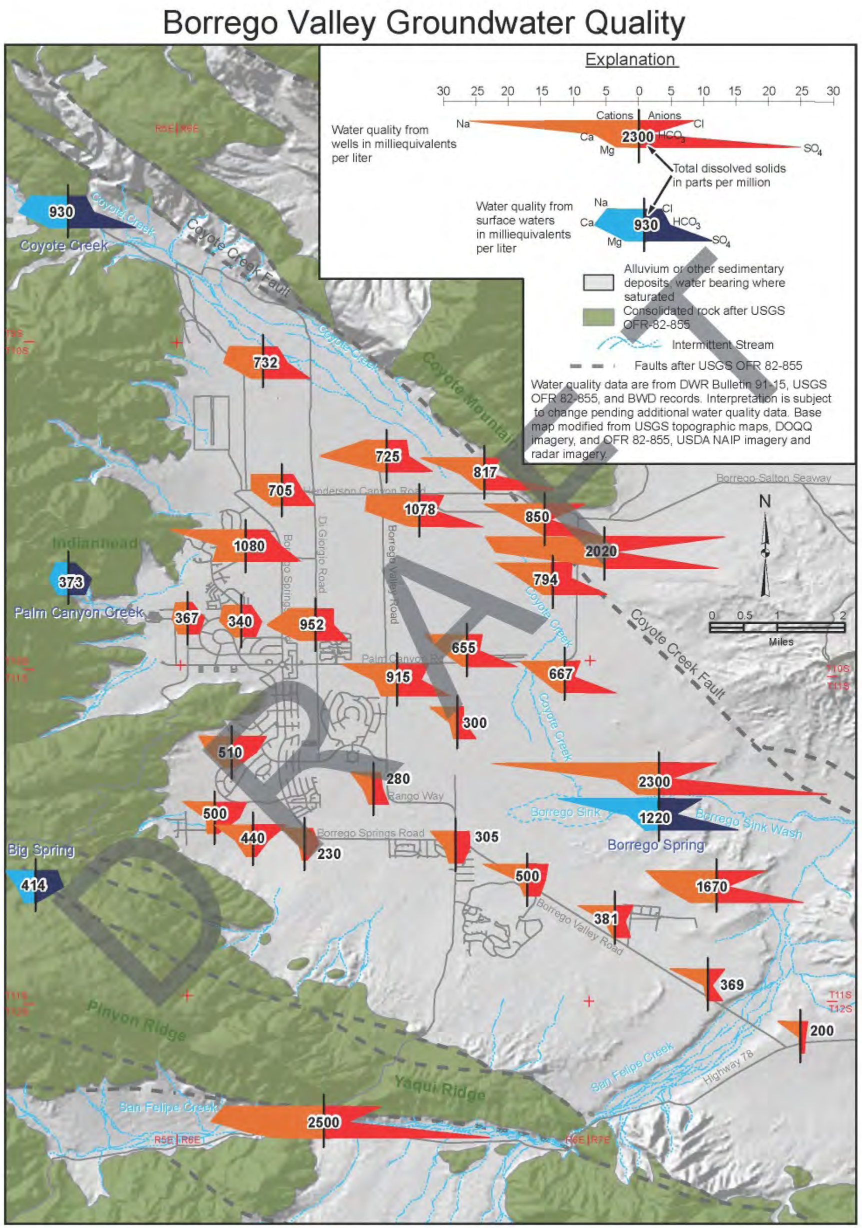


Figure showing major water quality constituents in groundwater and surface water in Borrego Valley. The high proportion of Sulfate in the surface water of Coyote Creek appears to dominate the character of groundwater in the northern and eastern parts of the basin. The more Bicarbonate waters of Borrego Palm Canyon and Big Spring influence the groundwater along the western and southern parts of the basin.

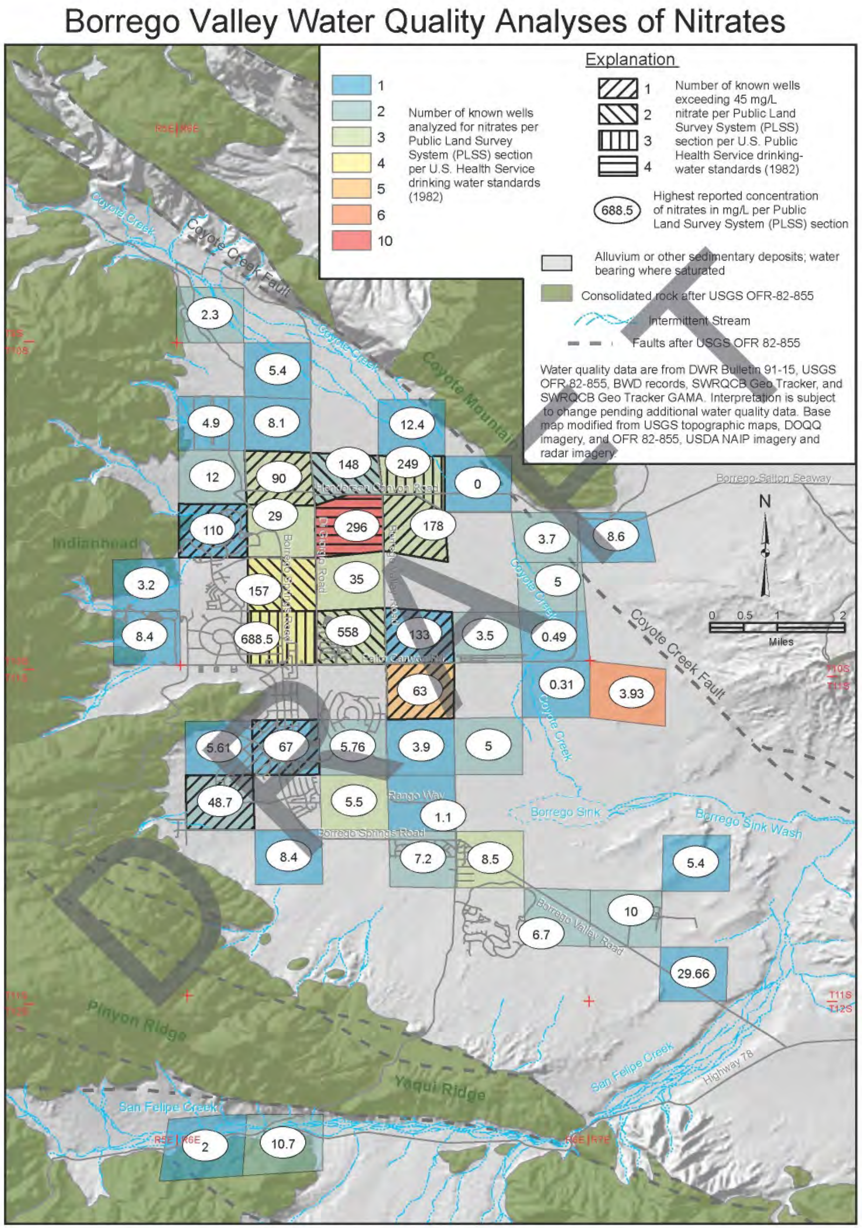
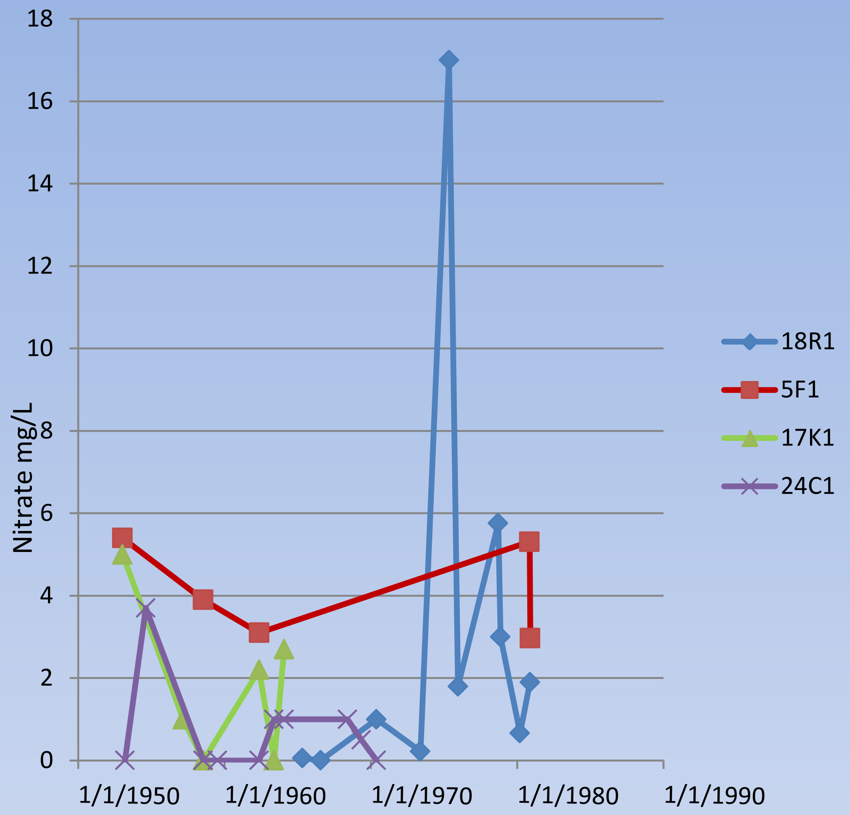
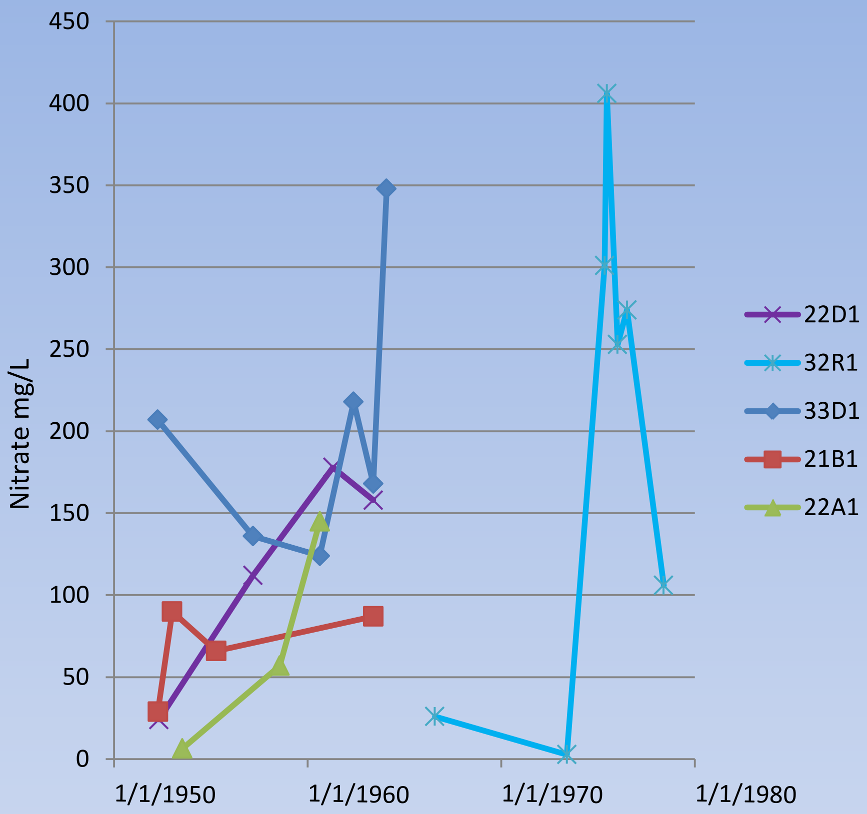


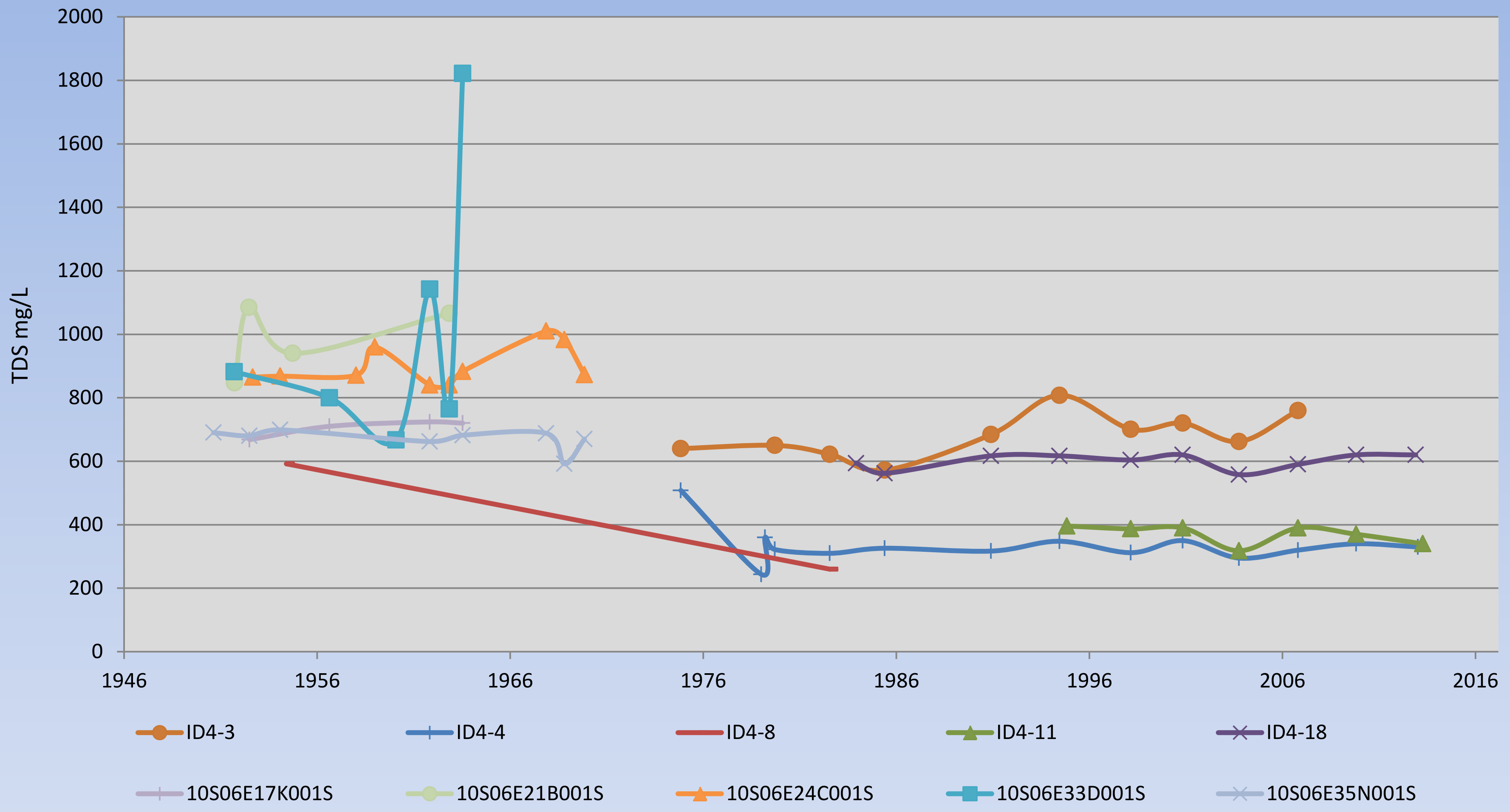
Figure showing the distribution of Nitrate analyses for the Borrego Basin. Maximum content is shown per section and sections are colored according to the number of analyses in the section. Sections where the maximum contaminant level (MCL) are exceeded are shown in hatched patterns.





Nitrate content is graphed through time for several wells in the Borrego Basin.
No obvious trend is apparent. (MCL is 45 mg/L)

North Borrego Valley



Graph showing change in TDS content through time for several wells in the northern part of the basin. No clear increase in TDS is observed.

South Borrego Valley

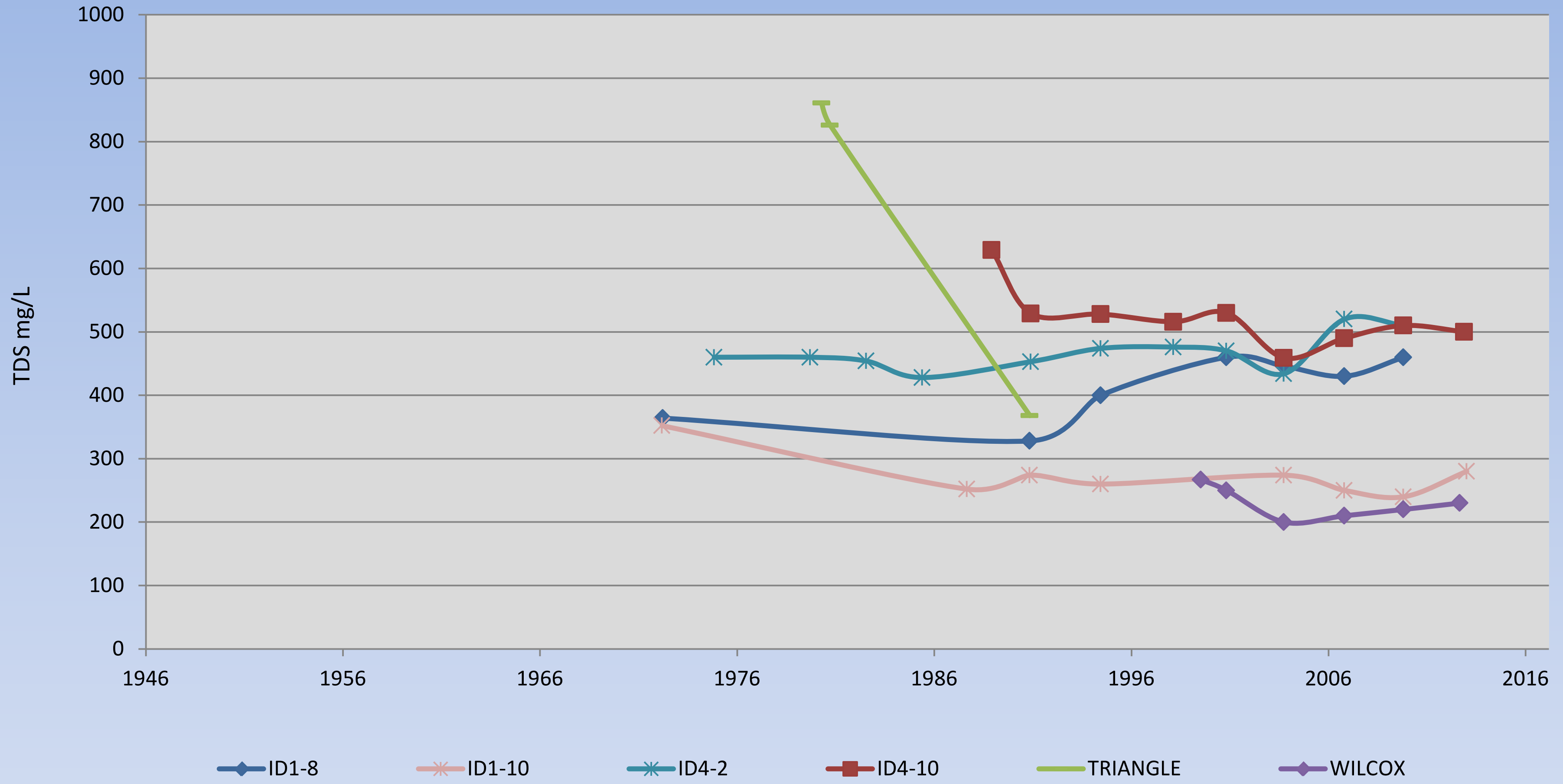
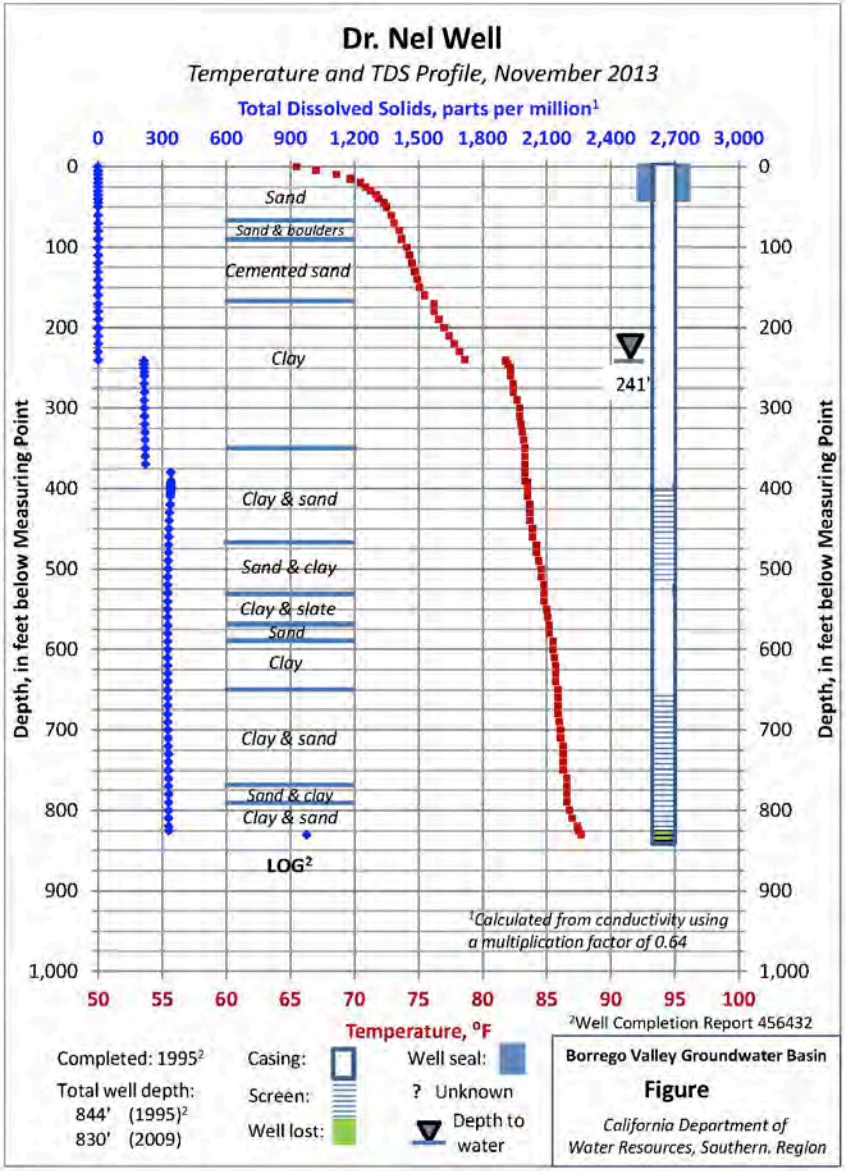
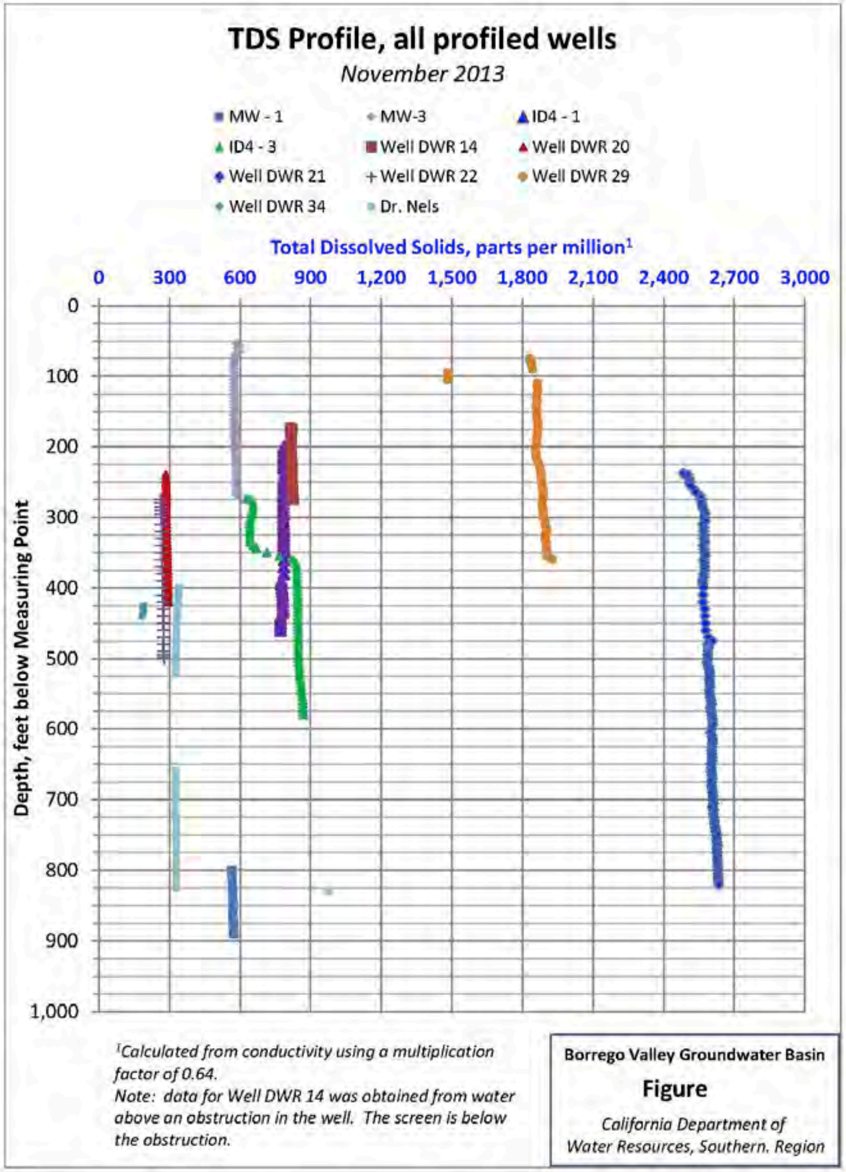


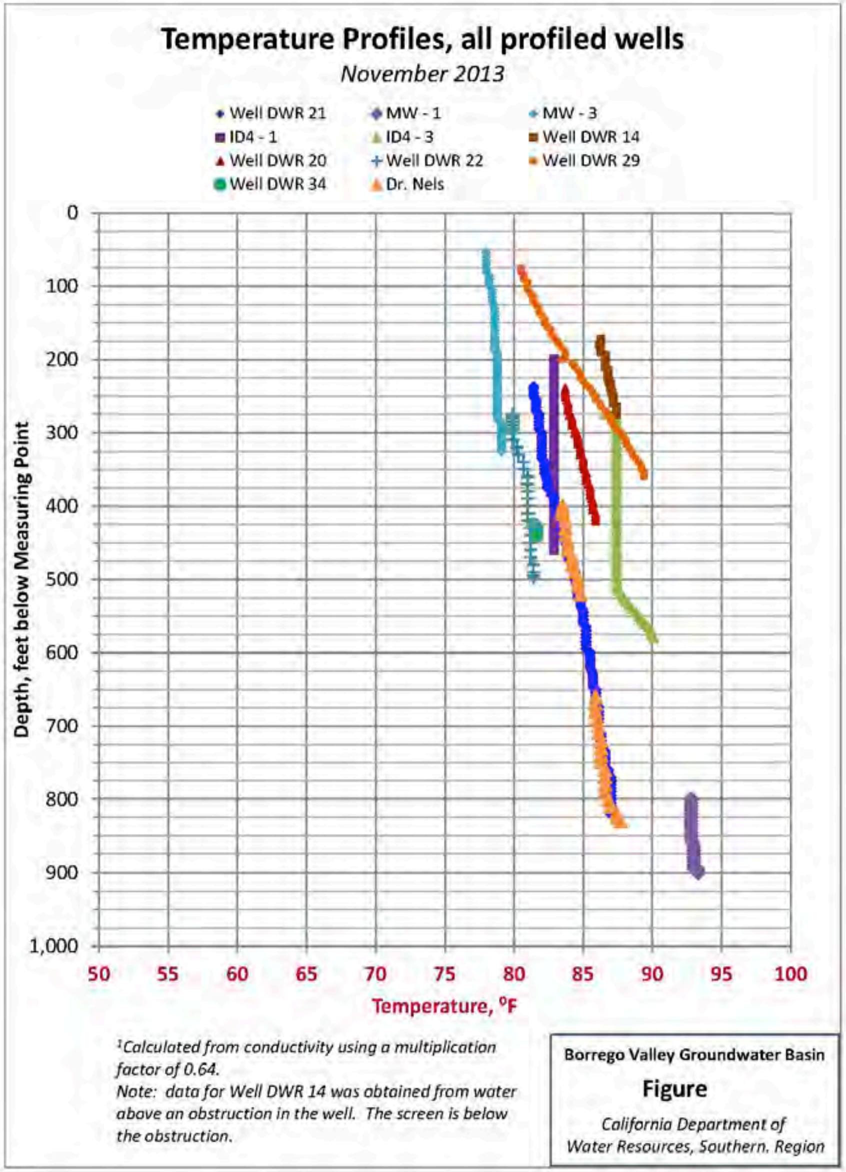
Figure showing TDS content through time for several wells in the southern portion of the basin. Most show decrease in TDS through time.



A profile of TDS content and temperature for Dr. Nel's Well. Changes in TDS appear to occur at the well screen. TDS does not change appreciably with depth through the screened interval. Temperature rises steadily with depth.



Profiles of TDS with respect to depth for wells in Borrego Valley. Most show slight increase in TDS with depth



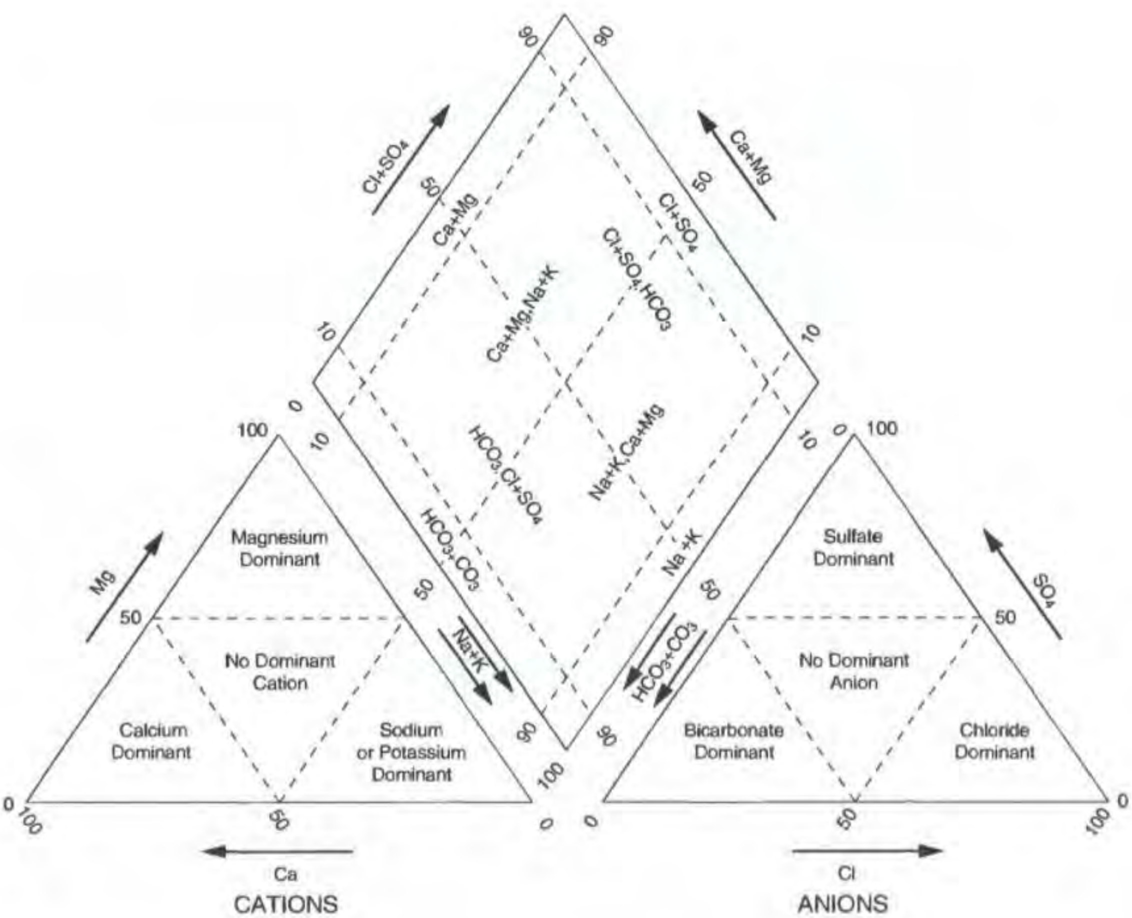
Profiles of Temperature with respect to depth. Most wells show increase in temperature with depth.

Summary

- More than 300 analyses identified
- Water character reflects recharge source
- More than 100 Nitrate analyses, widespread
- No apparent trend through time for Nitrate or TDS
- 11 Wells profiled for Temperature and TDS
- No consistent trend for TDS with depth in well.

APPENDIX B

PIPER DIAGRAMS, ALL WELLS

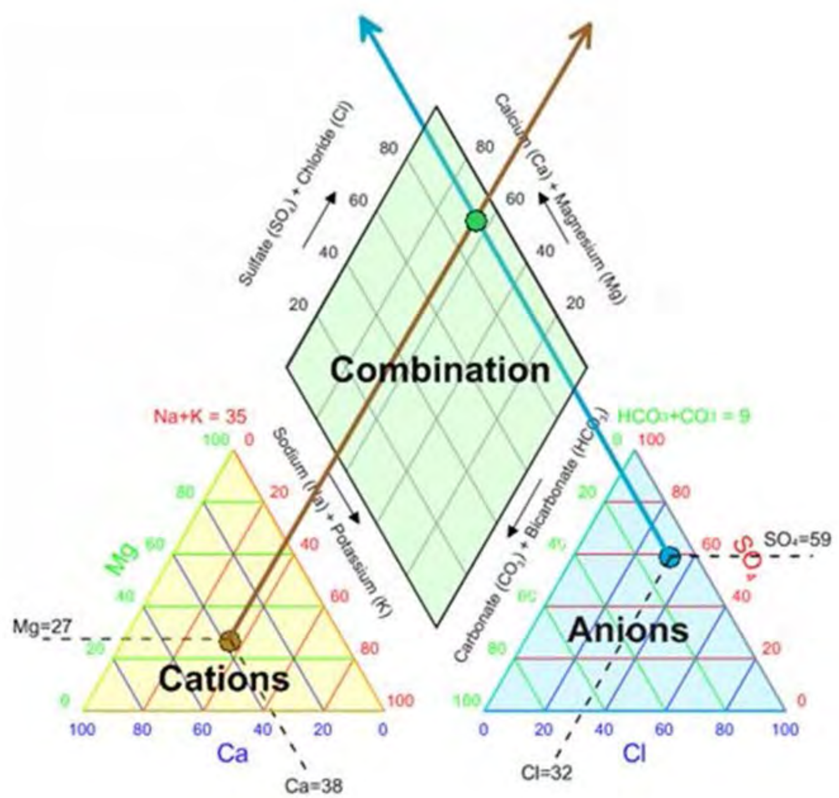


A. Classification scheme for hydrochemical facies.

APPENDIX B: PIPER DIAGRAMS

B.1 EXPLANATION OF PIPER DIAGRAMS

The eight dominant anions and cations that occur in groundwater can be used to describe of the type of water. A Piper trilinear diagram[1] combines sodium and potassium (cations), and carbonate and bicarbonate (anions) to reduce the total number of anions and cations from eight to six, with 3 values for each. This allows the anions and cations to be depicted using ternary diagrams. The values are then then projected onto a central diamond. An example of the projection follows:



From: https://support.goldensoftware.com/hc/en-us/articles/115003101648-What-is-a-piper-plot-trilinear-diagram-

The values used for the anions and cations are converted from mass/liter to milliequivalents/liter, a measure of the relative number of anions and cations in the solution. For example, if NaCl is dissolved into pure water there are an equal number of sodium cations (Na^+) and chloride anions (Cl^-). An analysis by weight will show that there is more chloride because chloride has a larger molecular weight (MW) - the MW of Na is 22.9 grams/mole versus Cl that has a MW of 35.45 grams/mole. 'Equivalents' are derived by dividing the reported mass by the MW so that the relative number of ions (in moles) is calculated.

[1] Piper, A.M. 1944. A graphic procedure in the geochemical interpretation of water-analyses. Transactions-American Geophysical Union 25, no. 6: 914–923

APPENDIX B: PIPER DIAGRAMS

The overall intent of the diagram is to support grouping and classification of water types, also termed hydrochemical facies. An example follows from https://www.hatarilabs.com/ih-en/what-is-a-piper-diagram-and-how-to-create-one

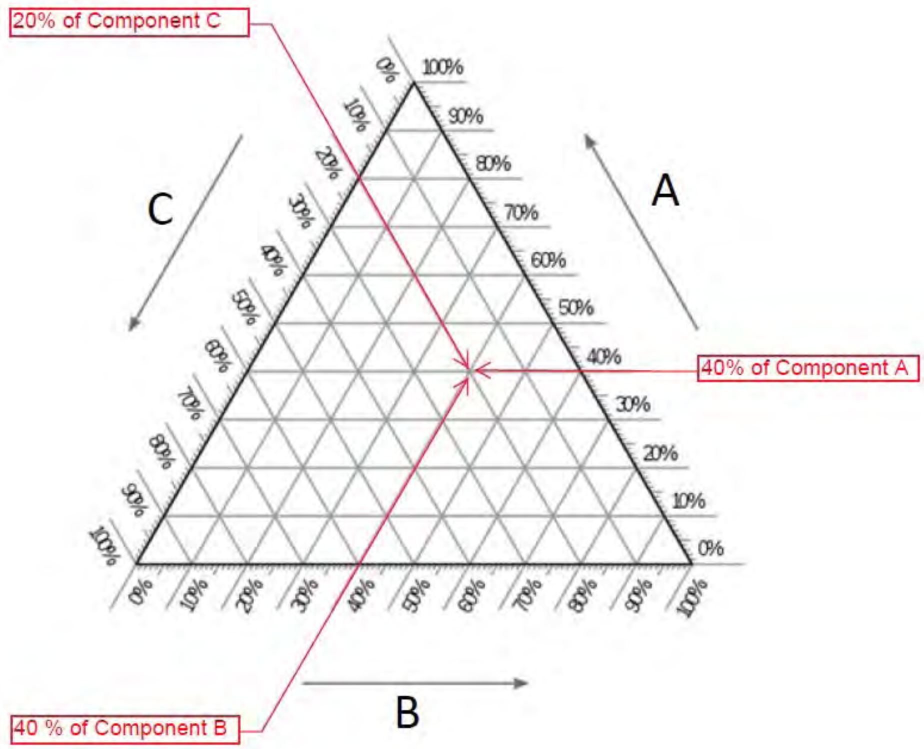
FIGURE 1A: HYDROCHEMICAL FACIES IN THE CATION AND ANION TRIANGLES AND IN THE DIAMOND.

The lower triangles are ternary diagrams that represent the relative proportion of anions or cations. The various types of water, or facies, are shown in the middle diamond.

Piper diagrams depicted in this report use a colored field scheme implemented in the Python programming language as published by Peeters, 2014[2]. Rather than drawing an underlying grid, the colored fields are used to help the visual interpretation of the data. The computations and graphics were developed using open source program code published by Peeters.

[2] Peeters, L., 2014. A Background Color Scheme for Piper Plots to Spatially Visualize Hydrochemical Patterns. Vol. 52, No. 1–Groundwater–January-February 2014

The following is an example of the ternary grid and how data are plotted:



All values equal 100% on the triangular grid. The highest percentage of each of the components occurs in the extreme corners of the triangle.

Values increase as indicated by the arrows.

Source:
https://upload.wikimedia.org/wikipedia/commons/thumb/a/ac/Blank_ternary_plot.svg/486px-Blank_ternary_plot.svg.png

APPENDIX B.2 PIPER DIAGRAMS USED IN THE REPORT

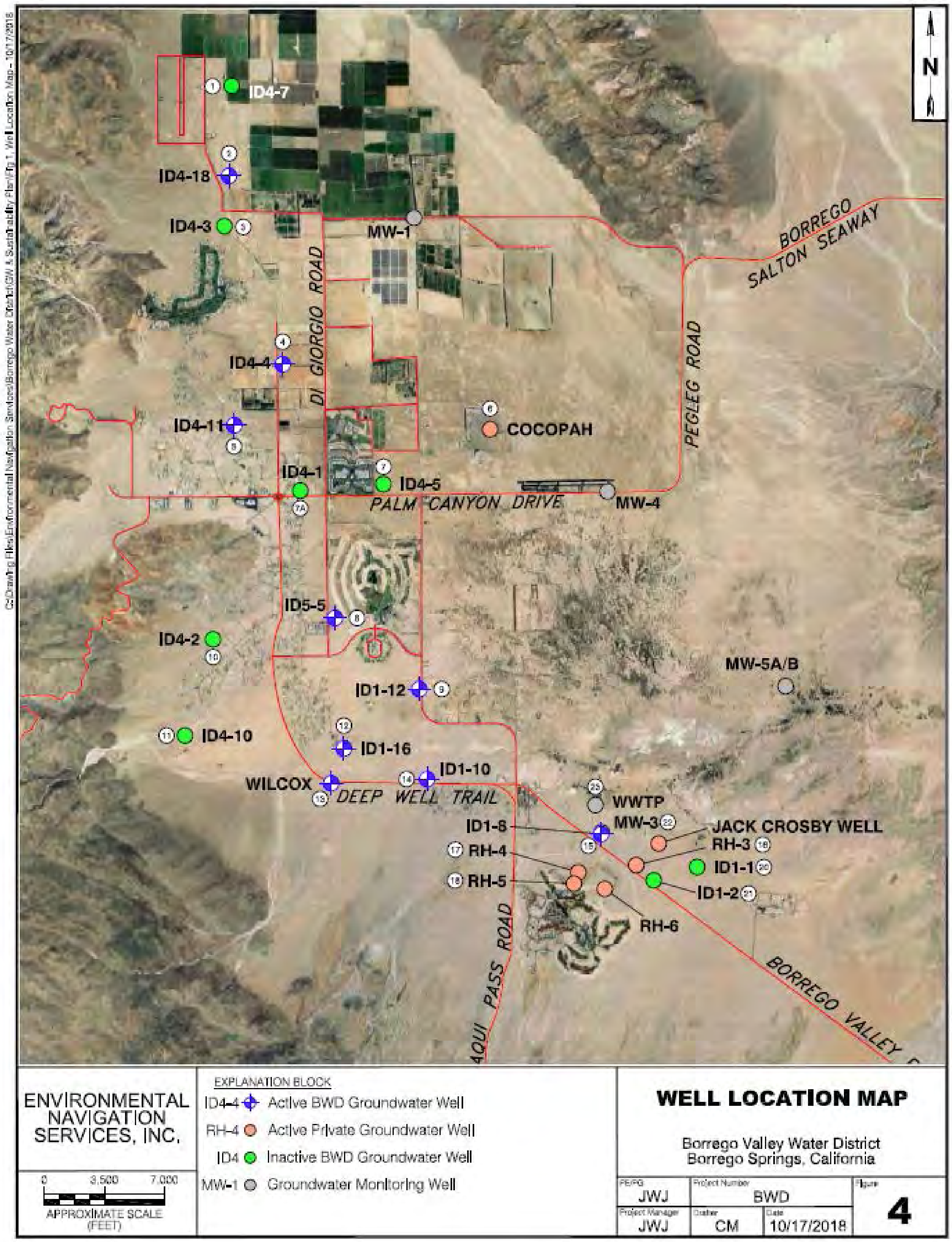
The following diagram are presented in the following order:

1: ID4-7 (not included due to insufficient data)
2: ID4-18
3: ID4-3
4: ID4-4
5: ID4-11
6: Cocopah
7: ID4-5
7A: ID4-1
8: ID5-5
9: ID1-12
10: ID4-2
11: ID4-10
12: ID1-16
13: Wilcox
14: ID1-10
15: ID1-8
16: RH-3
17: RH-4
18: RH-5
19: RH-6
20: ID1-1
21: ID1-2
22: Jack Crosby
23: WWTP (insufficient data)
24: MW-3 (insufficient data)

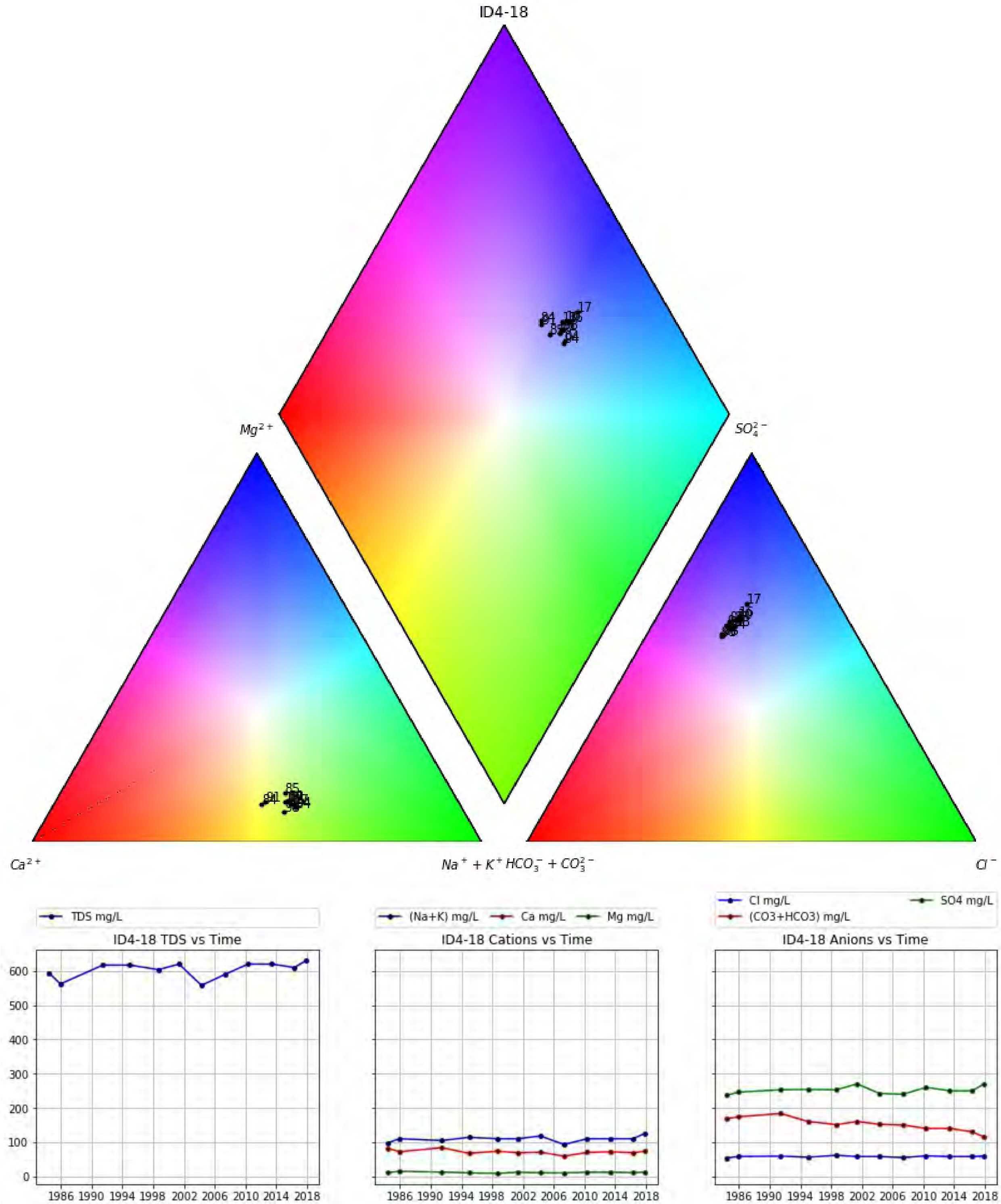
Recent Data: All (Piper only)
Recent Data: North and Central (Piper only)
Recent Data: South (Piper only)

A copy of the map follows (**Figure 4**, from main body of report)

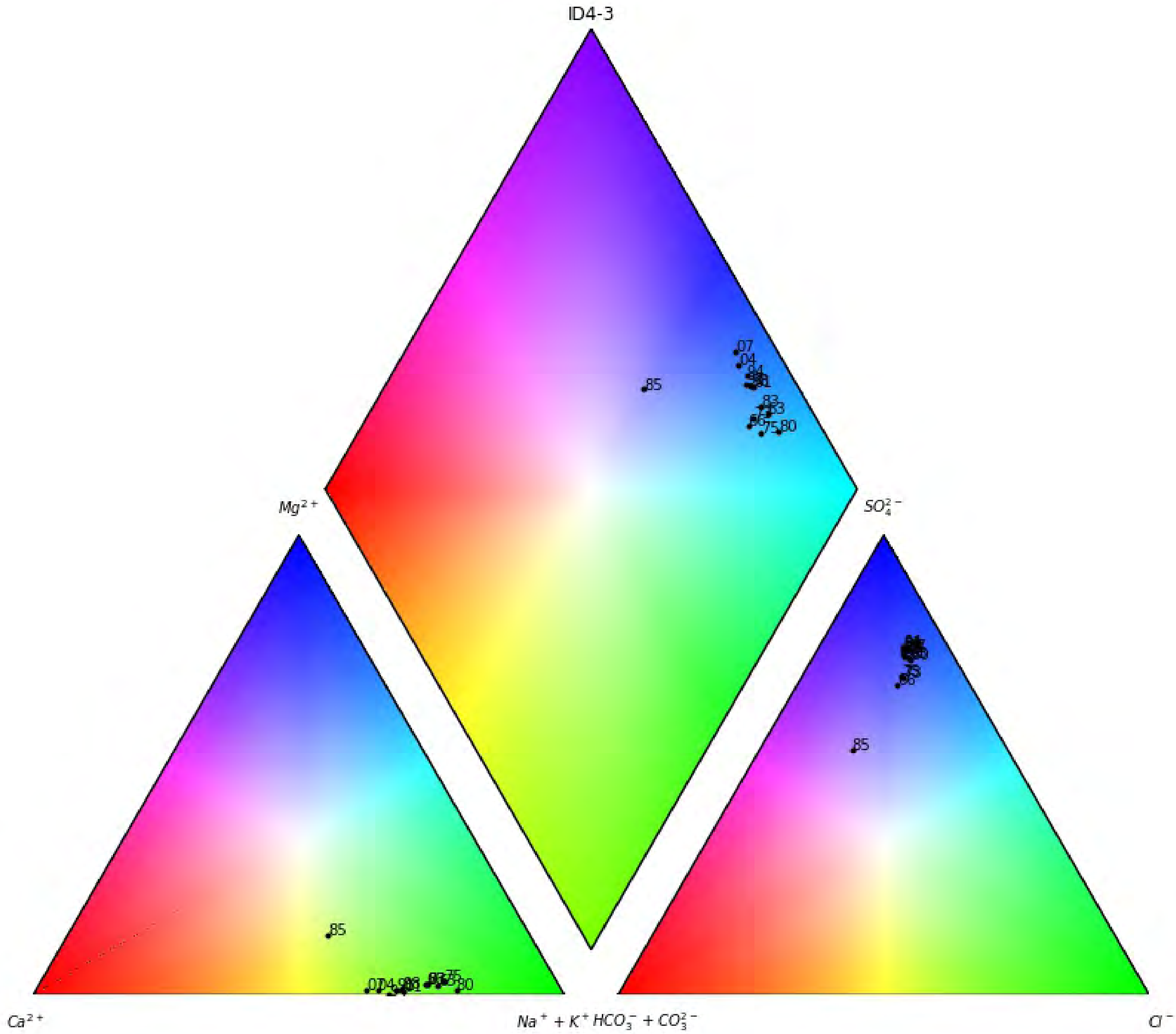
APPENDIX B: PIPER DIAGRAMS

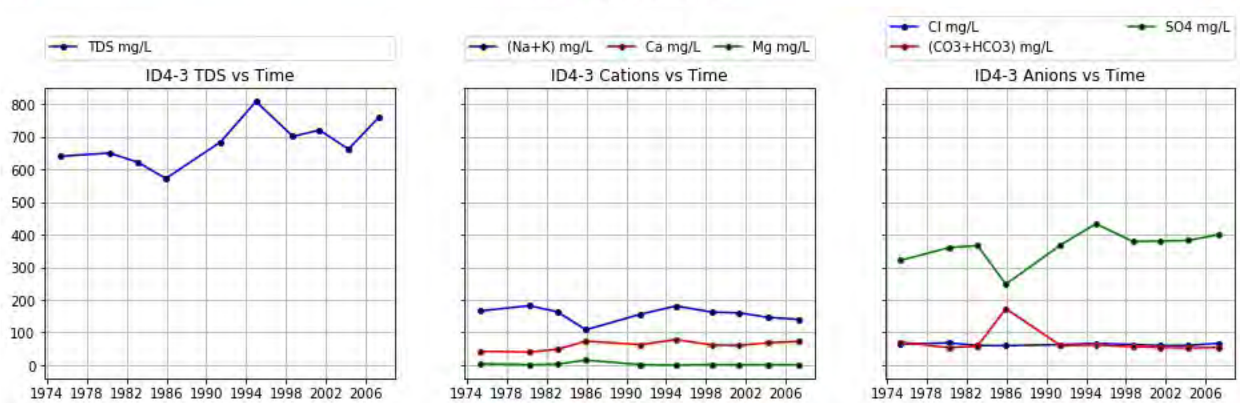


2: ID4-18

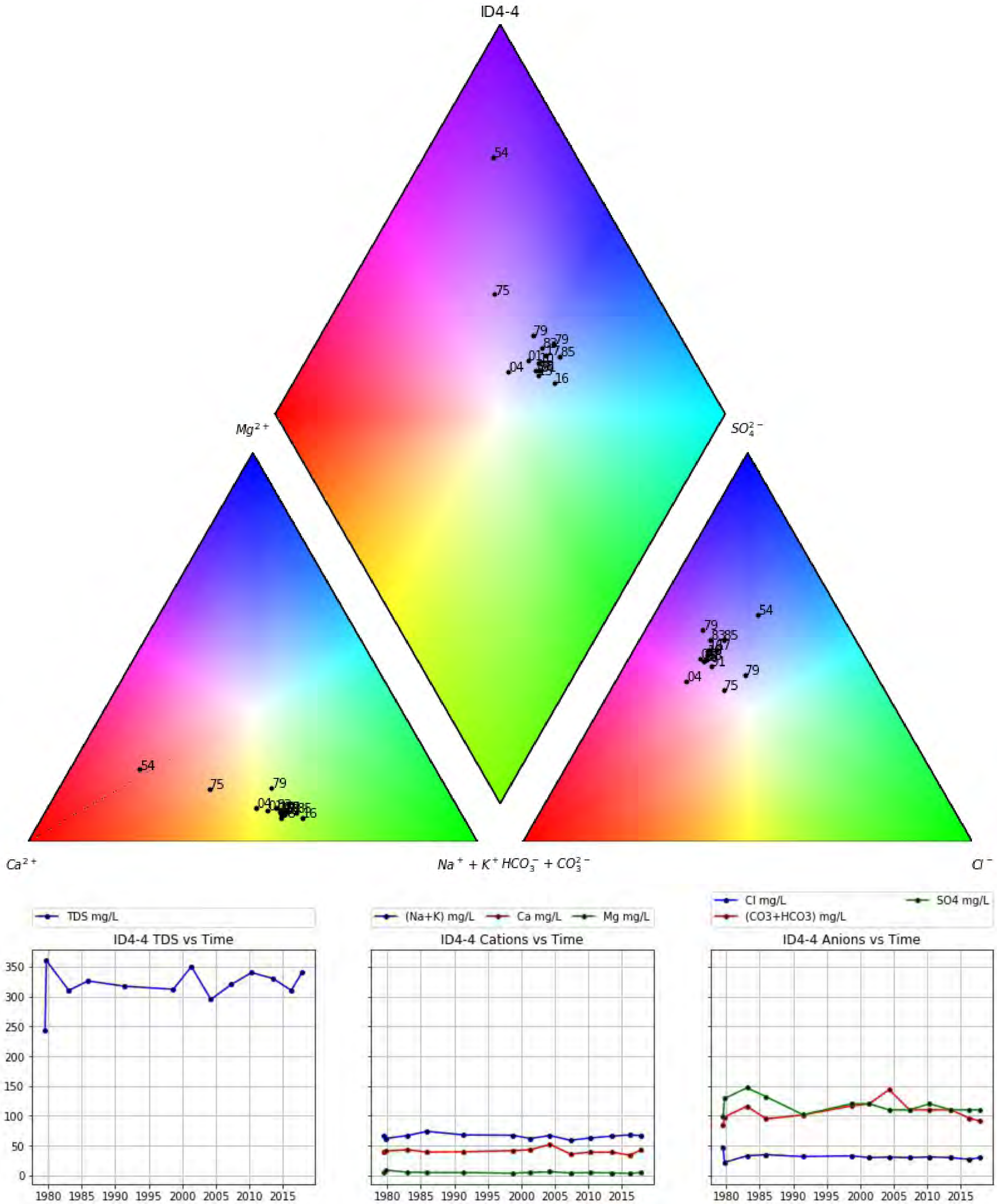

ID4-18
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
ID4-18 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-18 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-18 Anions vs Time
0
100
200
300
400
500
600
1986 1990 1994 1998 2002 2006 2010 2014 2018

3: ID4-3

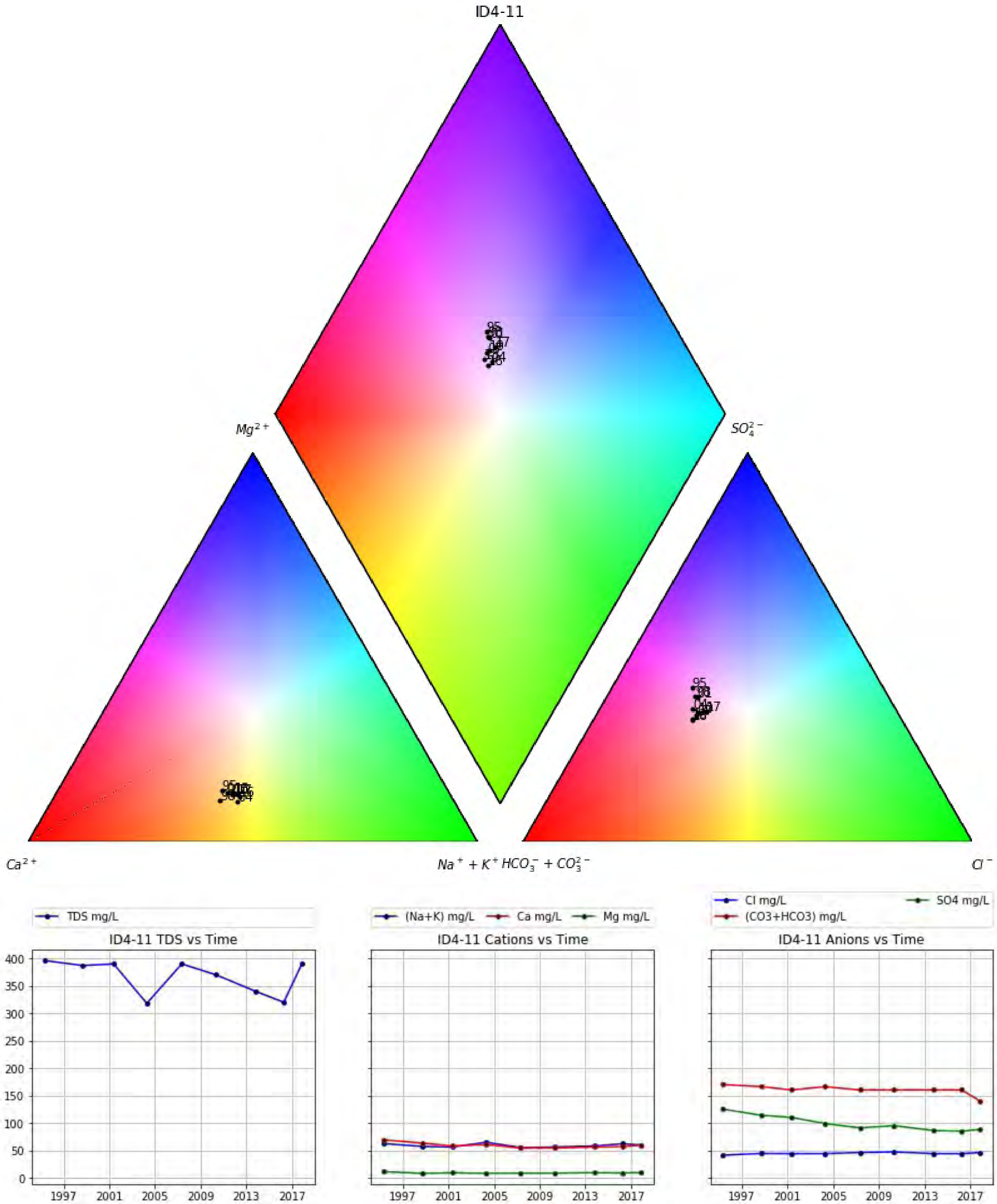

ID4-3
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
85
07
04
75
80
83


TDS mg/L
ID4-3 TDS vs Time
800
700
600
500
400
300
200
100
0
1974 1978 1982 1986 1990 1994 1998 2002 2006
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-3 Cations vs Time
1974 1978 1982 1986 1990 1994 1998 2002 2006
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-3 Anions vs Time
1974 1978 1982 1986 1990 1994 1998 2002 2006

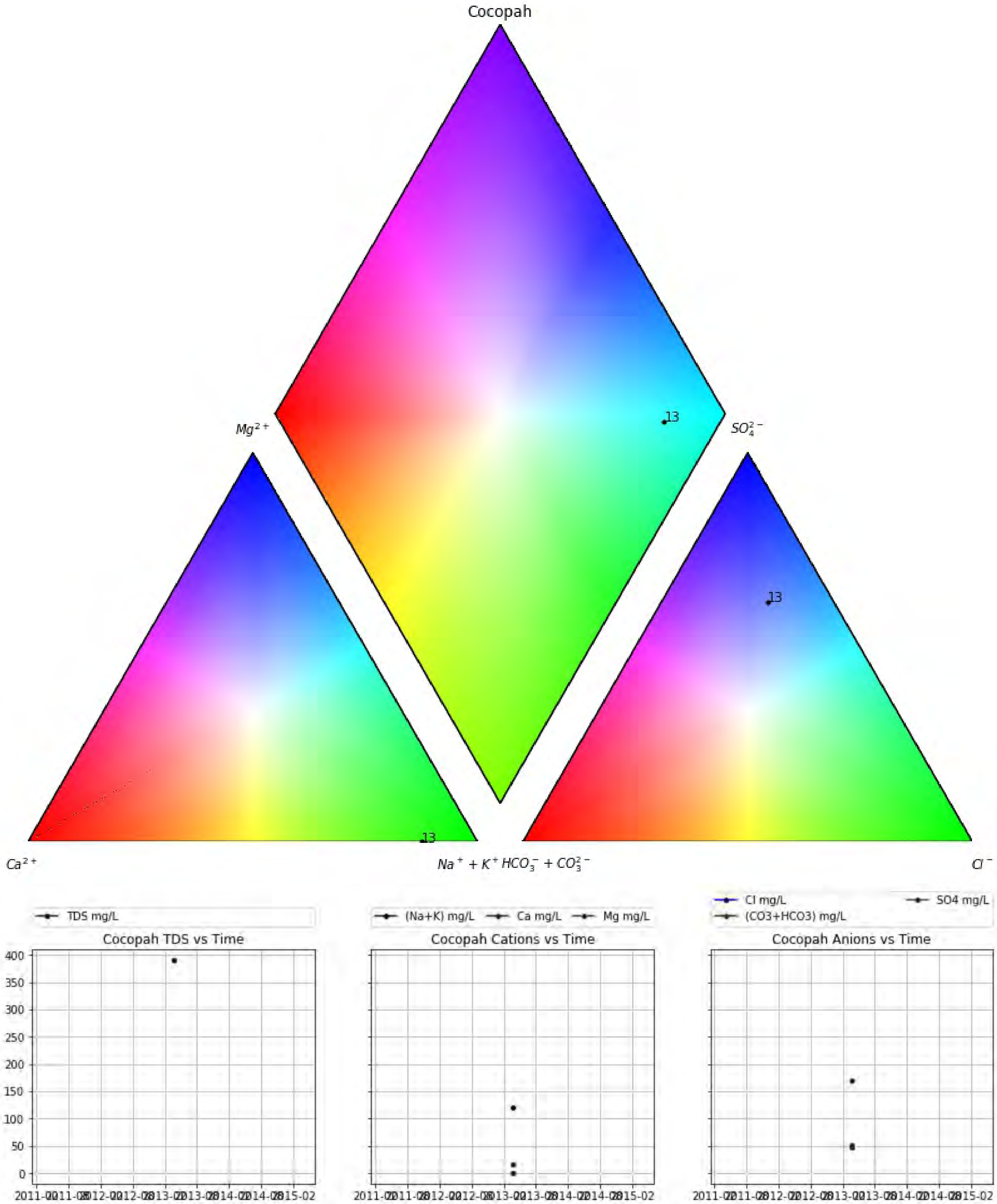
4: ID4-4


ID4-4
54
75
79
04
16
Mg2+
SO4 2-
Ca2+
Na+ + K+ HCO3- + CO3 2-
Cl-
TDS mg/L
ID4-4 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-4 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-4 Anions vs Time

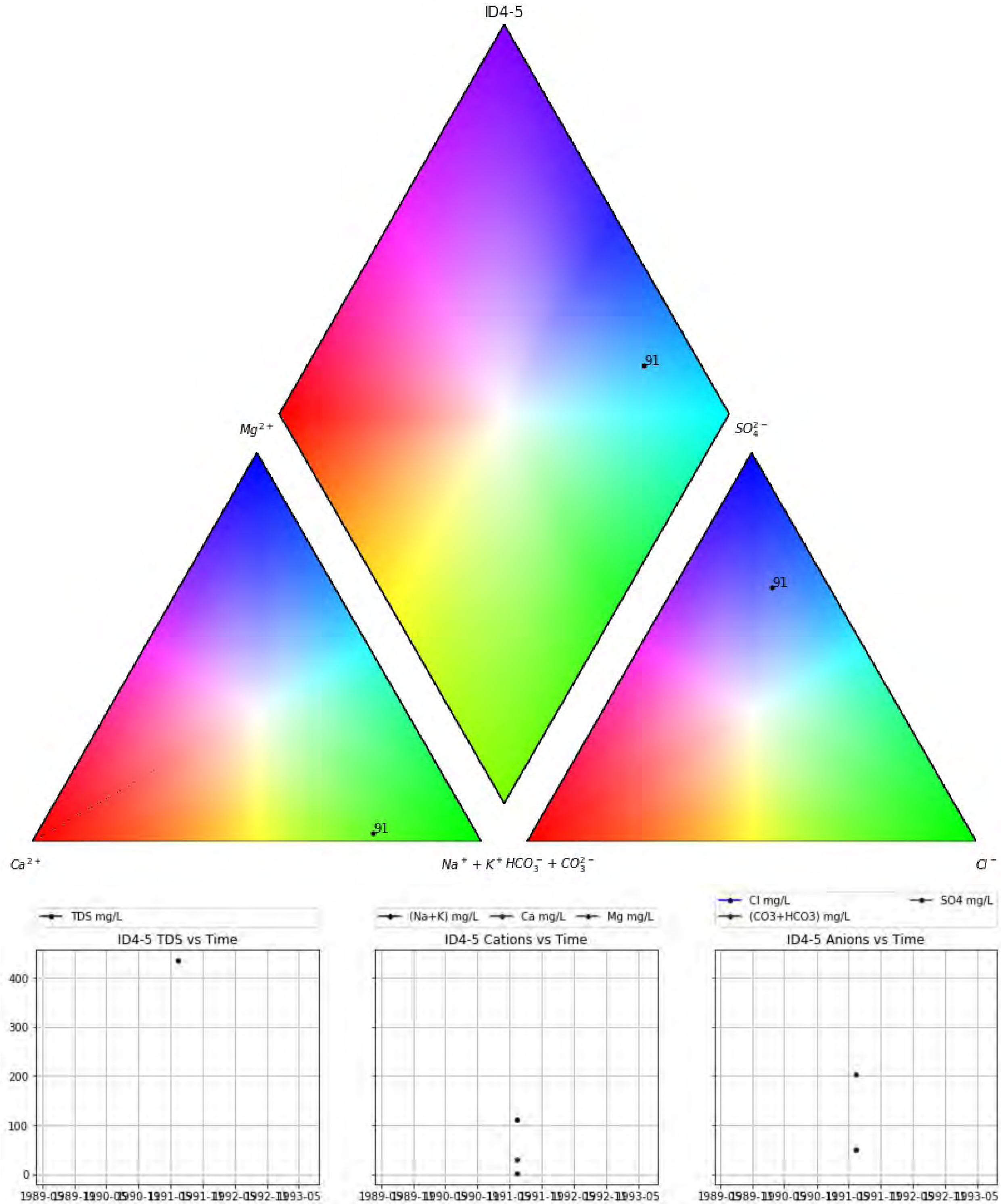
5: ID4-11


ID4-11
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
ID4-11 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-11 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-11 Anions vs Time
1997
2001
2005
2009
2013
2017

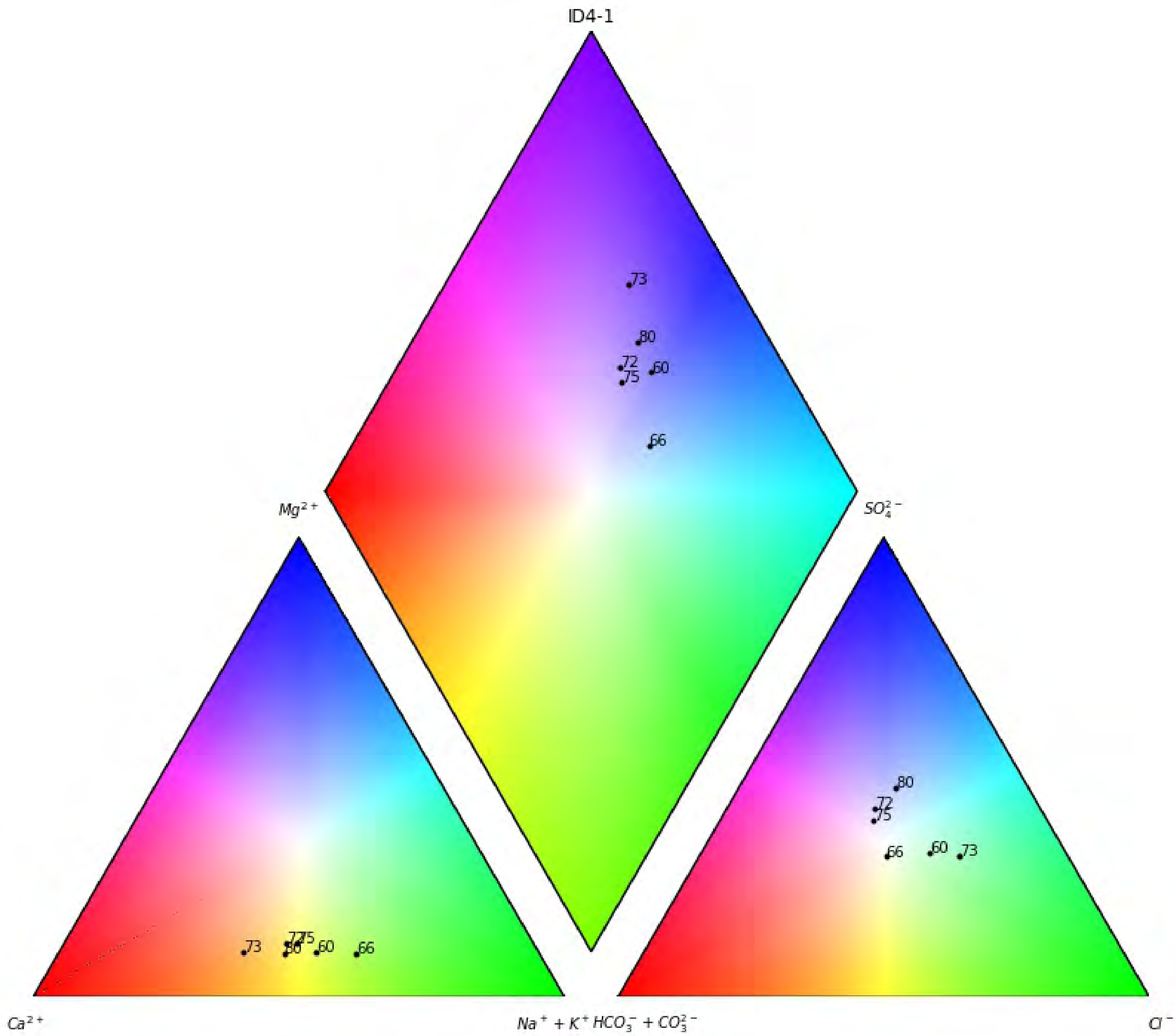
6: Cocopah


Cocopah
13
Mg^{2+}
SO_4^{2-}
13
13
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
Cocopah TDS vs Time
400
350
300
250
200
150
100
50
0
(Na+K) mg/L
Ca mg/L
Mg mg/L
Cocopah Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
Cocopah Anions vs Time

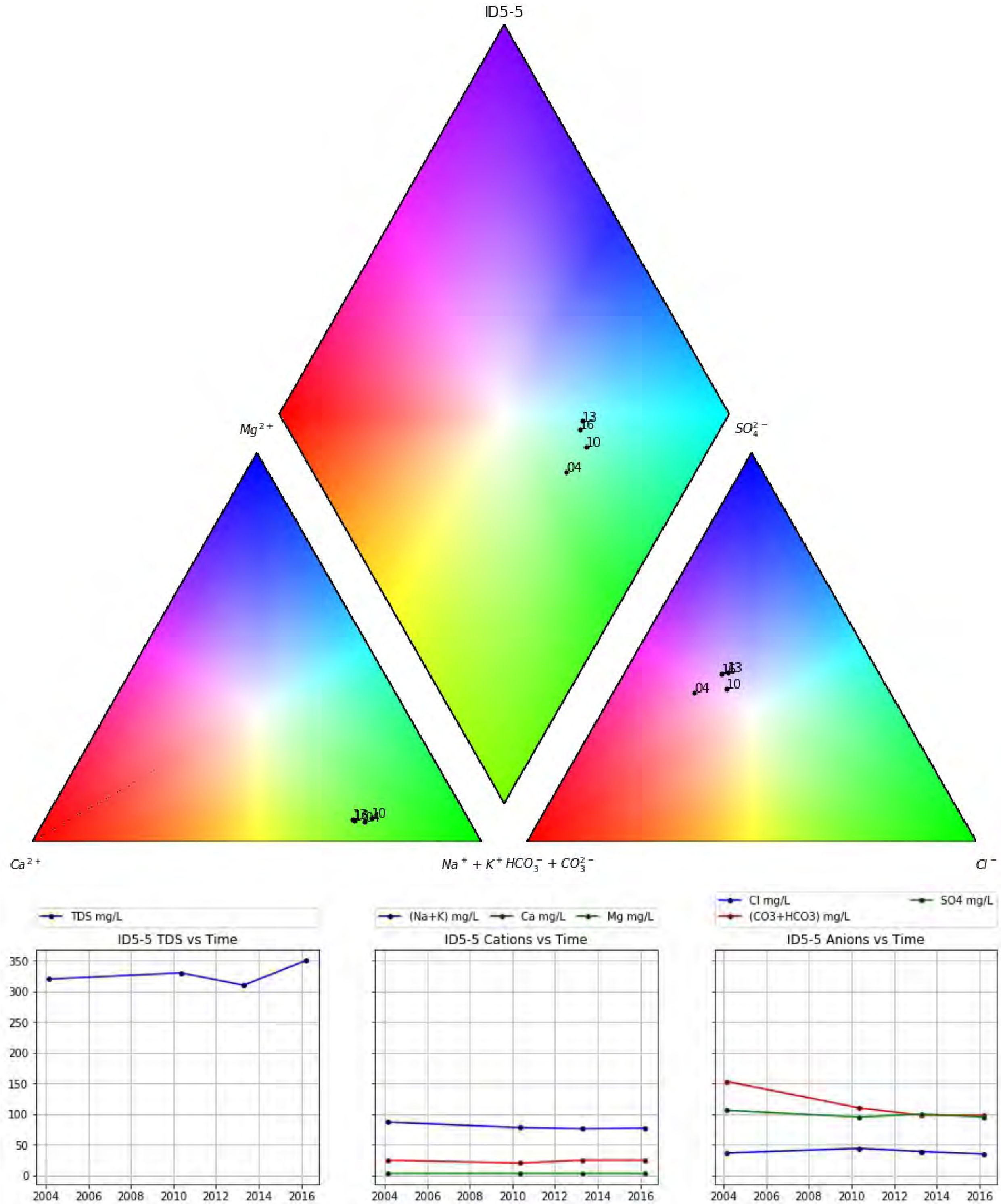
7: ID4-5


ID4-5
91
91
91
Mg²⁺
SO₄²⁻
Ca²⁺
Na⁺ + K⁺ HCO₃⁻ + CO₃²⁻
Cl⁻
TDS mg/L
ID4-5 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-5 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-5 Anions vs Time
400
300
200
100
0

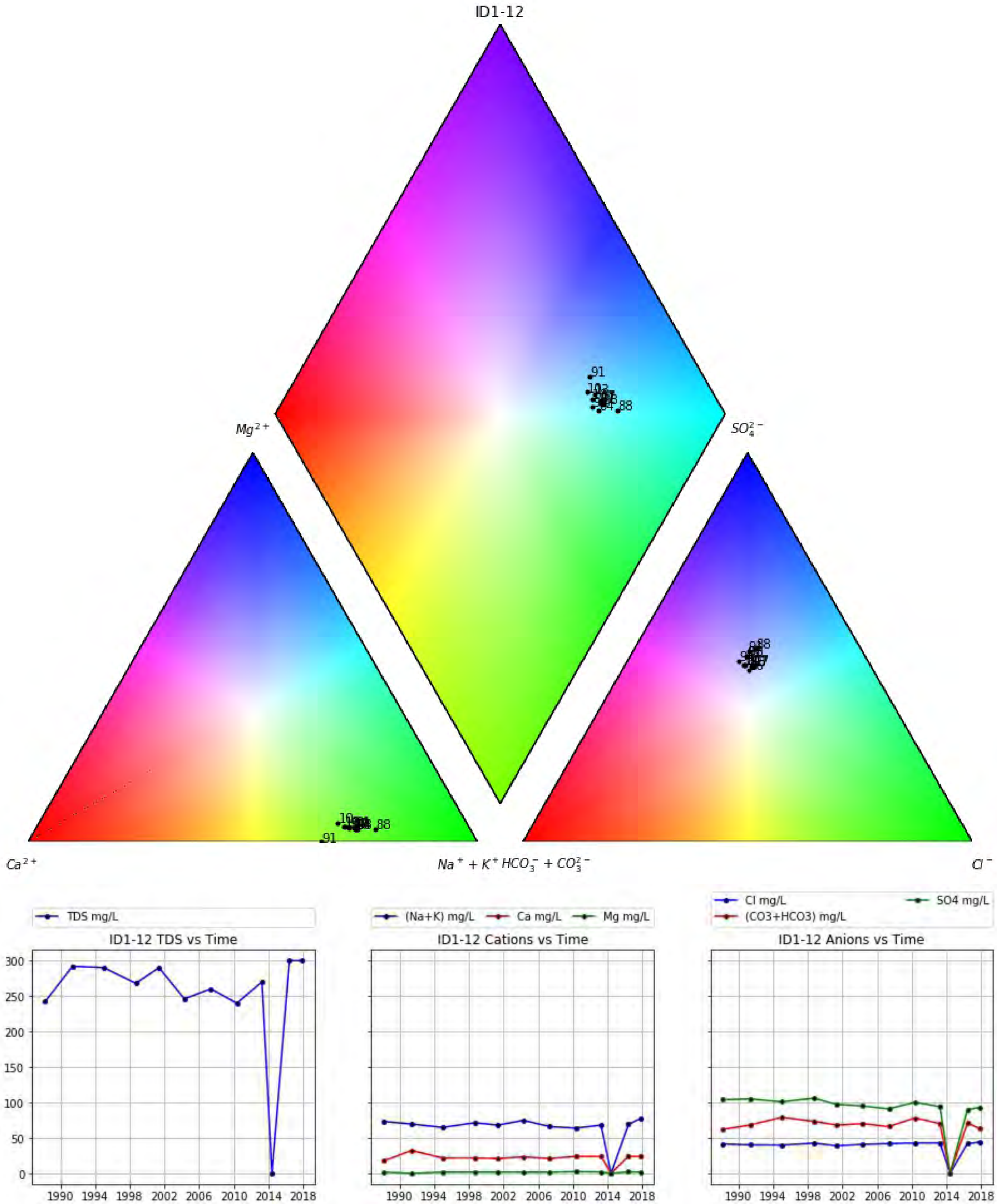
7A: ID4-1


ID4-1
73
80
72
75
60
66
Mg^{2+}
SO_4^{2-}
73
72
75
80
60
66
80
72
75
66
60
73
Ca^{2+}
$Na^+ + K^+$
$HCO_3^- + CO_3^{2-}$
Cl^-

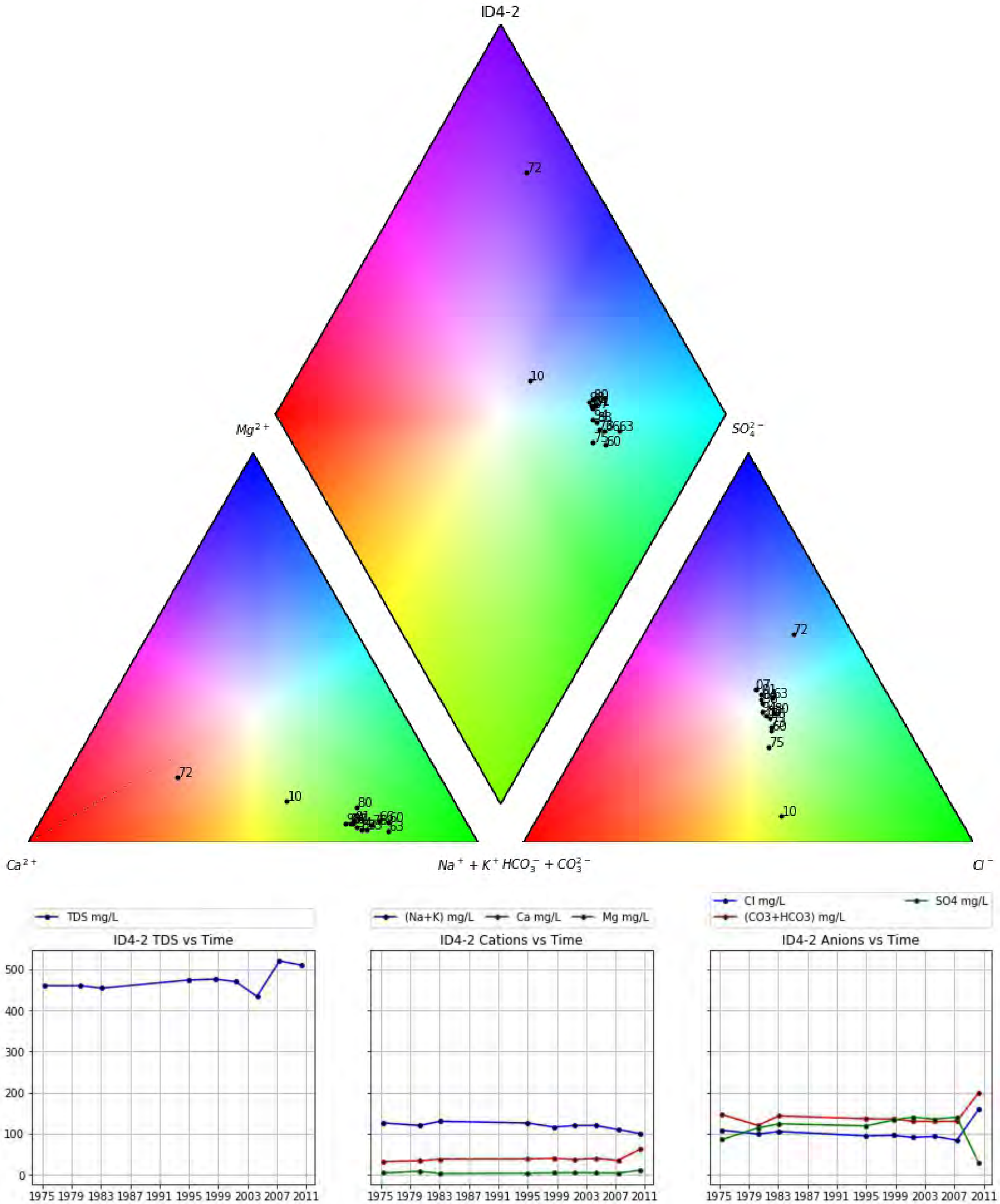
8: ID5-5


ID5-5
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
13
16
10
04
TDS mg/L
ID5-5 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID5-5 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID5-5 Anions vs Time
350
300
250
200
150
100
50
0
2004
2006
2008
2010
2012
2014
2016

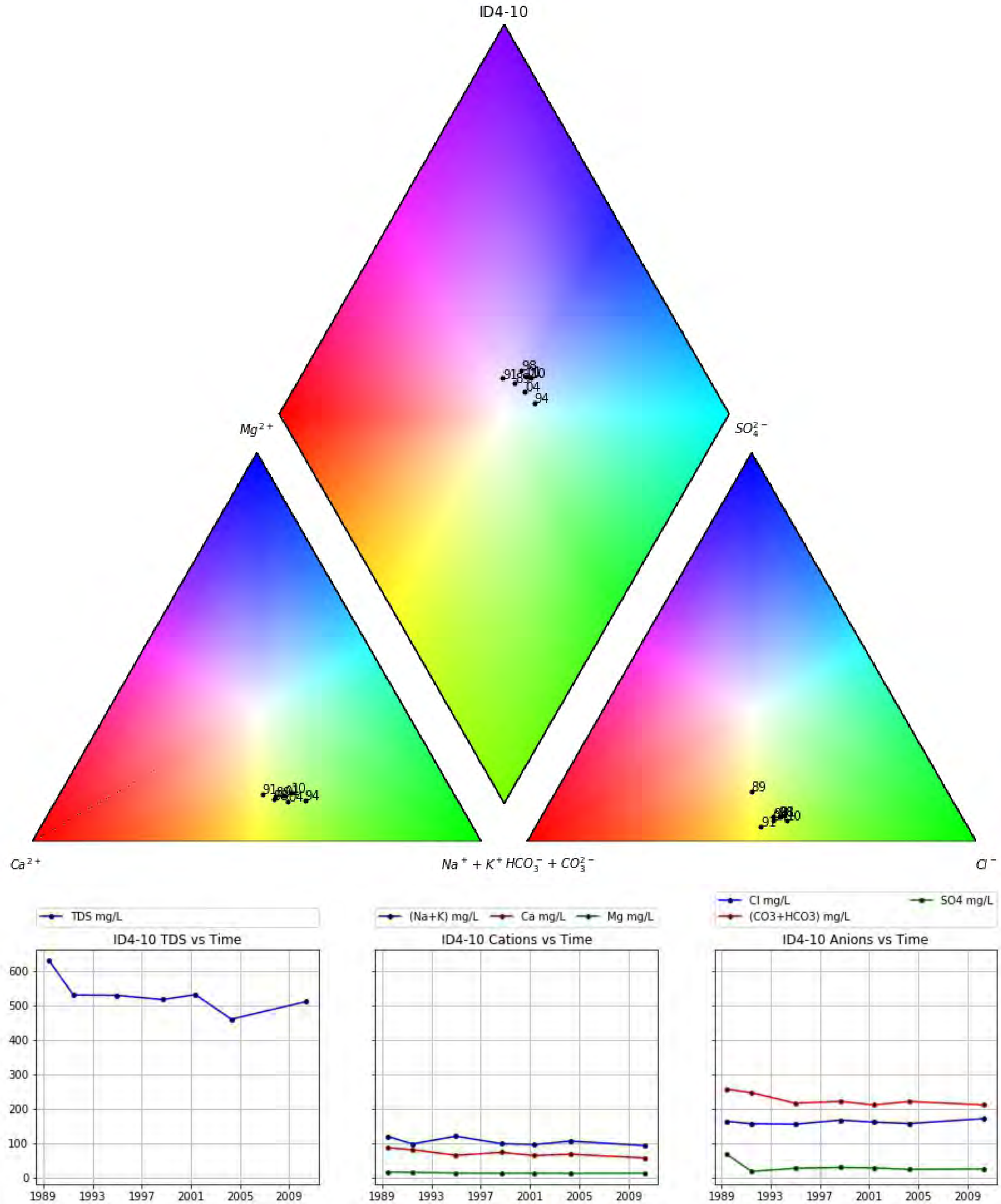
9: ID1-12


ID1-12
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
91
88
TDS mg/L
ID1-12 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-12 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID1-12 Anions vs Time
0
50
100
150
200
250
300
1990
1994
1998
2002
2006
2010
2014
2018

10: ID4-2

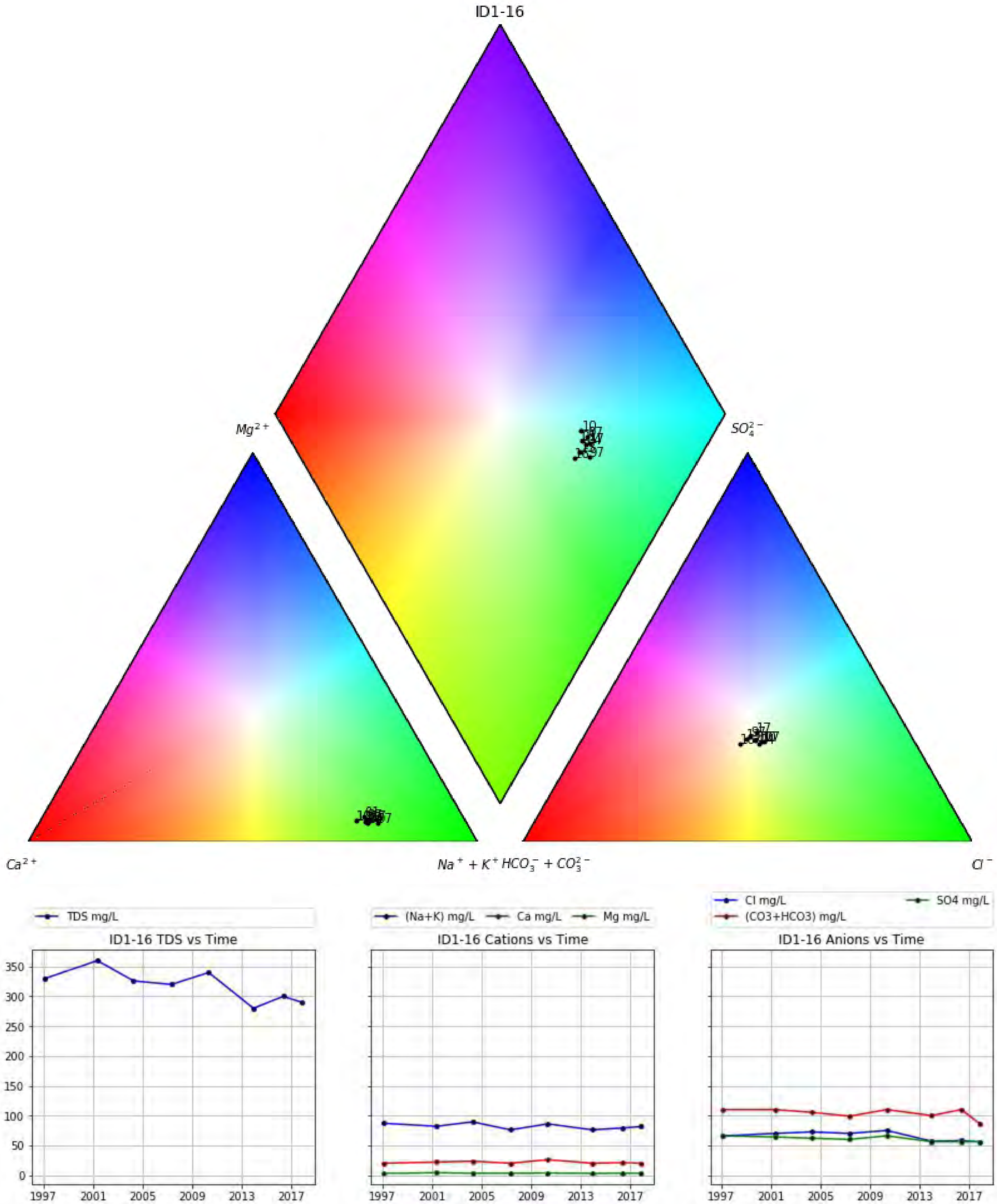

ID4-2
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
ID4-2 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-2 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-2 Anions vs Time

11: ID4-10

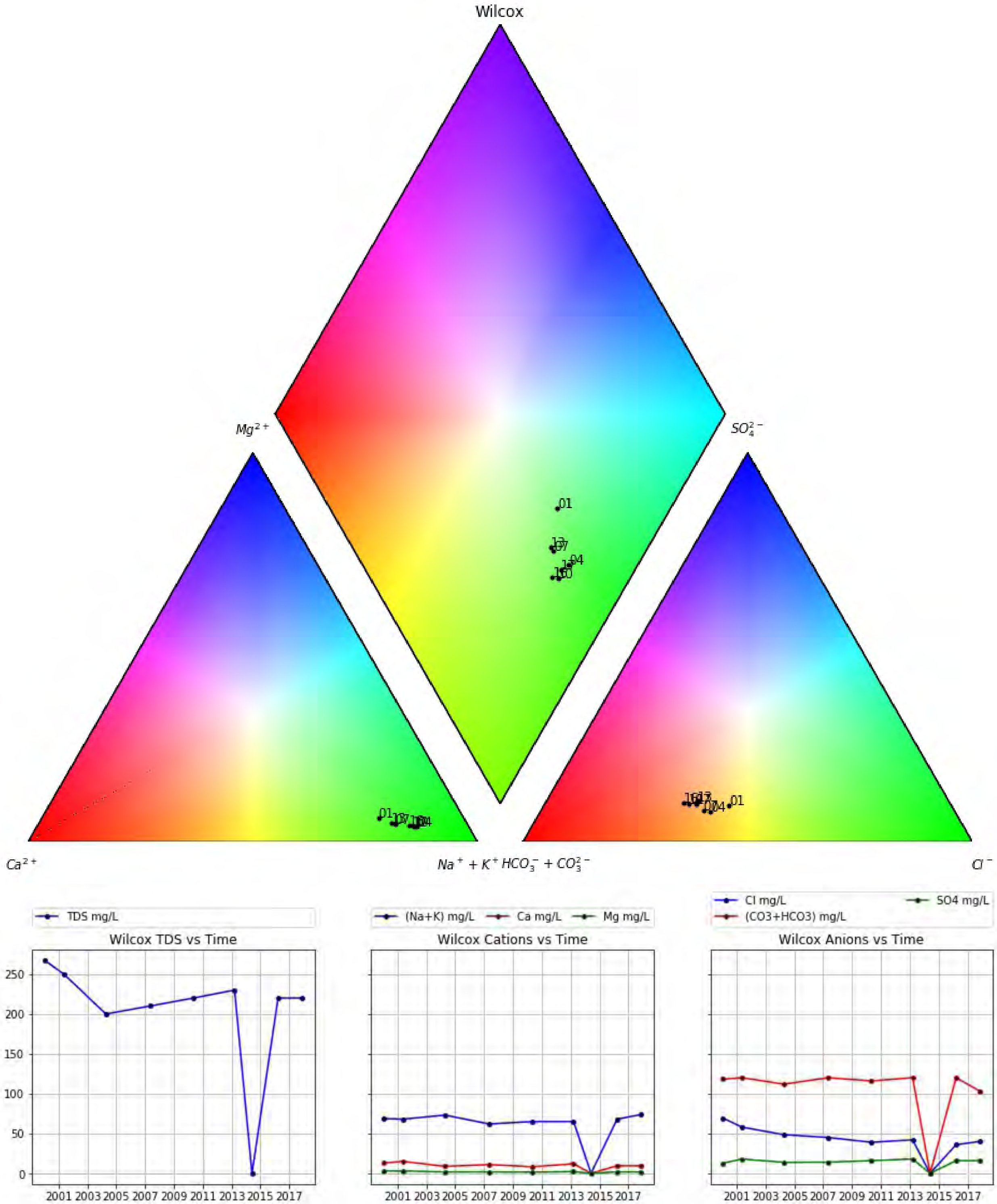


ID4-10
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
ID4-10 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-10 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-10 Anions vs Time

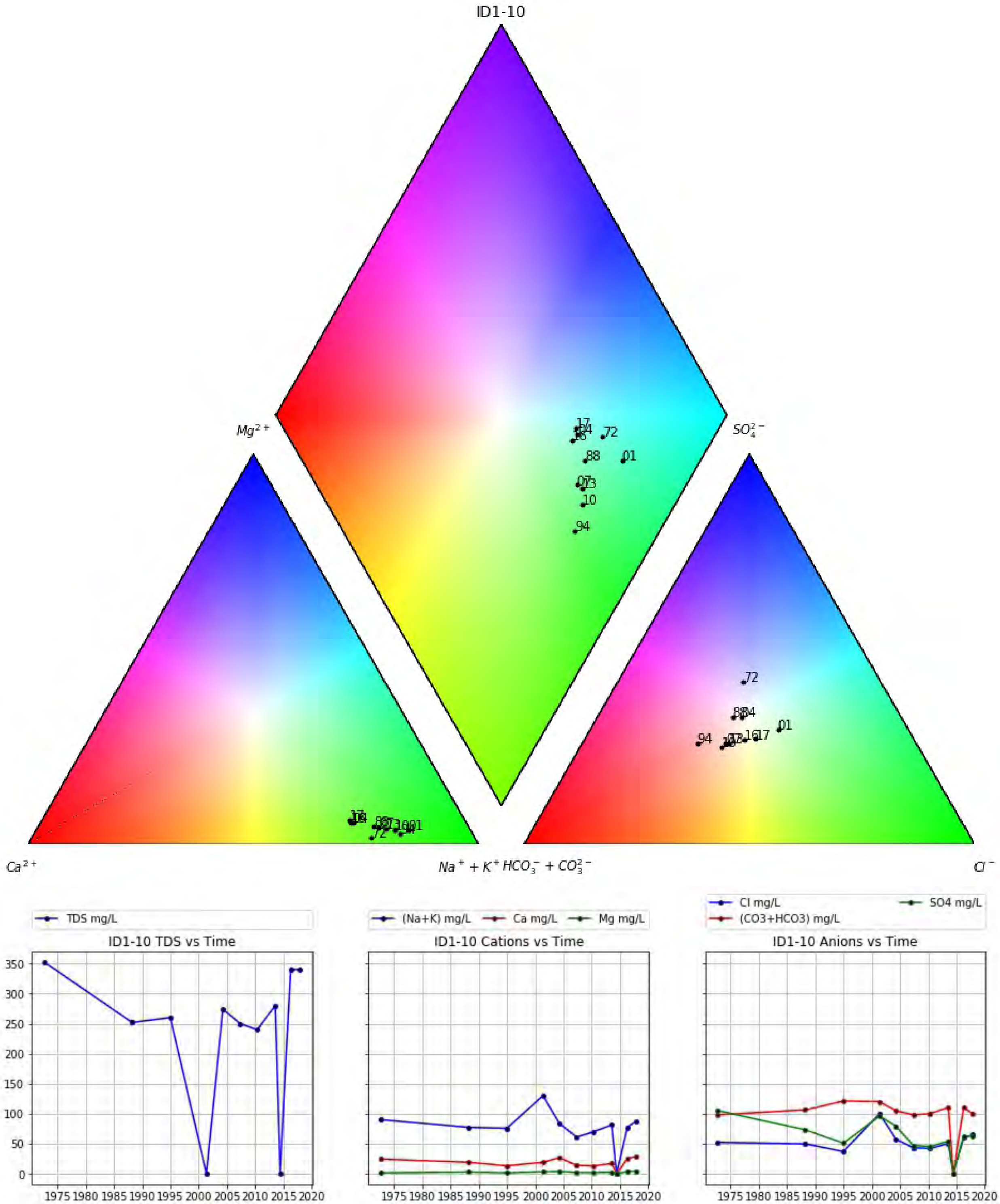
12: ID1-16


ID1-16
Mg²⁺
SO₄²⁻
Ca²⁺
Na⁺ + K⁺ HCO₃⁻ + CO₃²⁻
Cl⁻
TDS mg/L
ID1-16 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-16 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID1-16 Anions vs Time
350
300
250
200
150
100
50
0
1997
2001
2005
2009
2013
2017

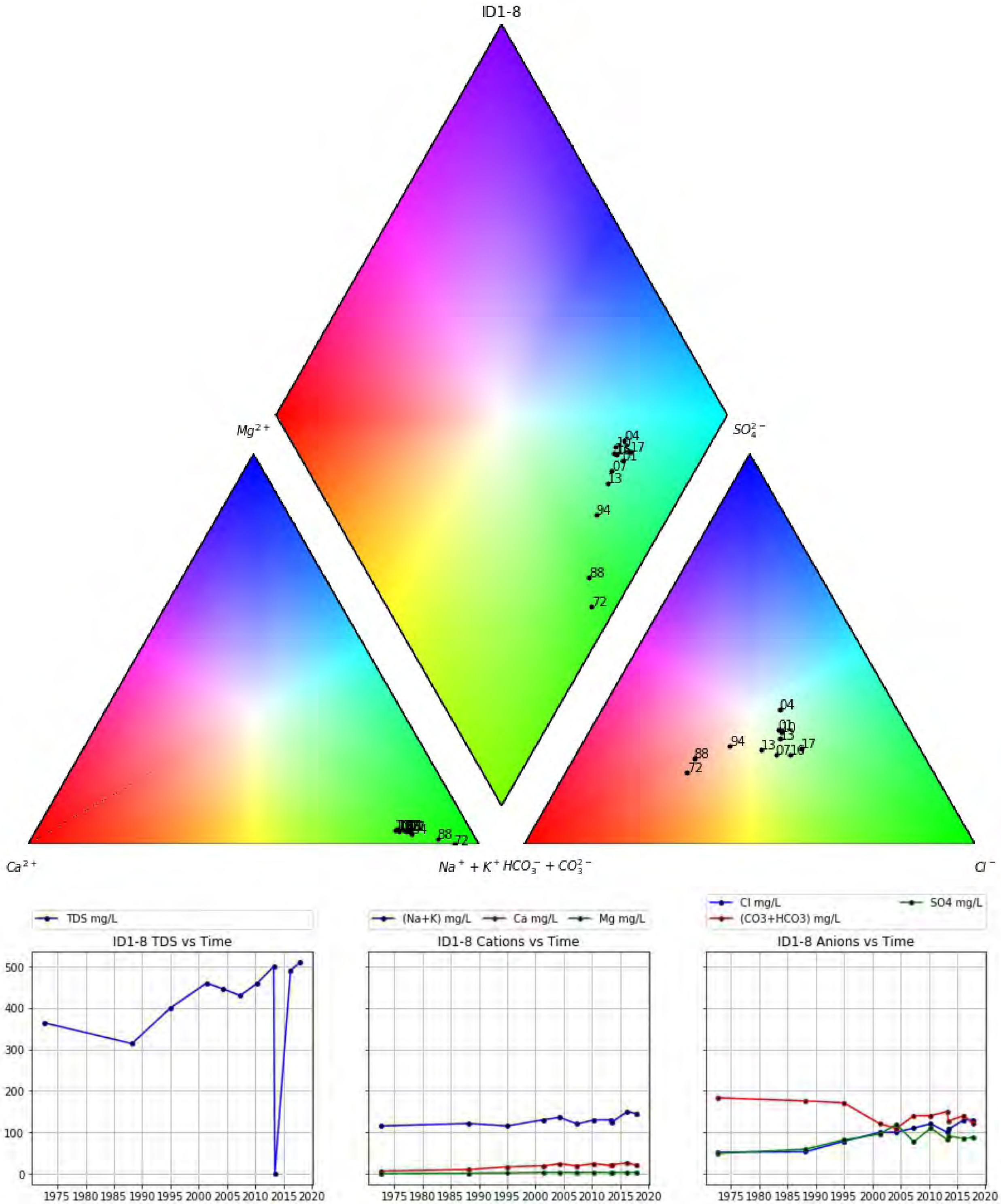
13: Wilcox


Wilcox
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
Wilcox TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
Wilcox Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
Wilcox Anions vs Time
2001 2003 2005 2007 2009 2011 2013 2015 2017
0
50
100
150
200
250

14: ID1-10

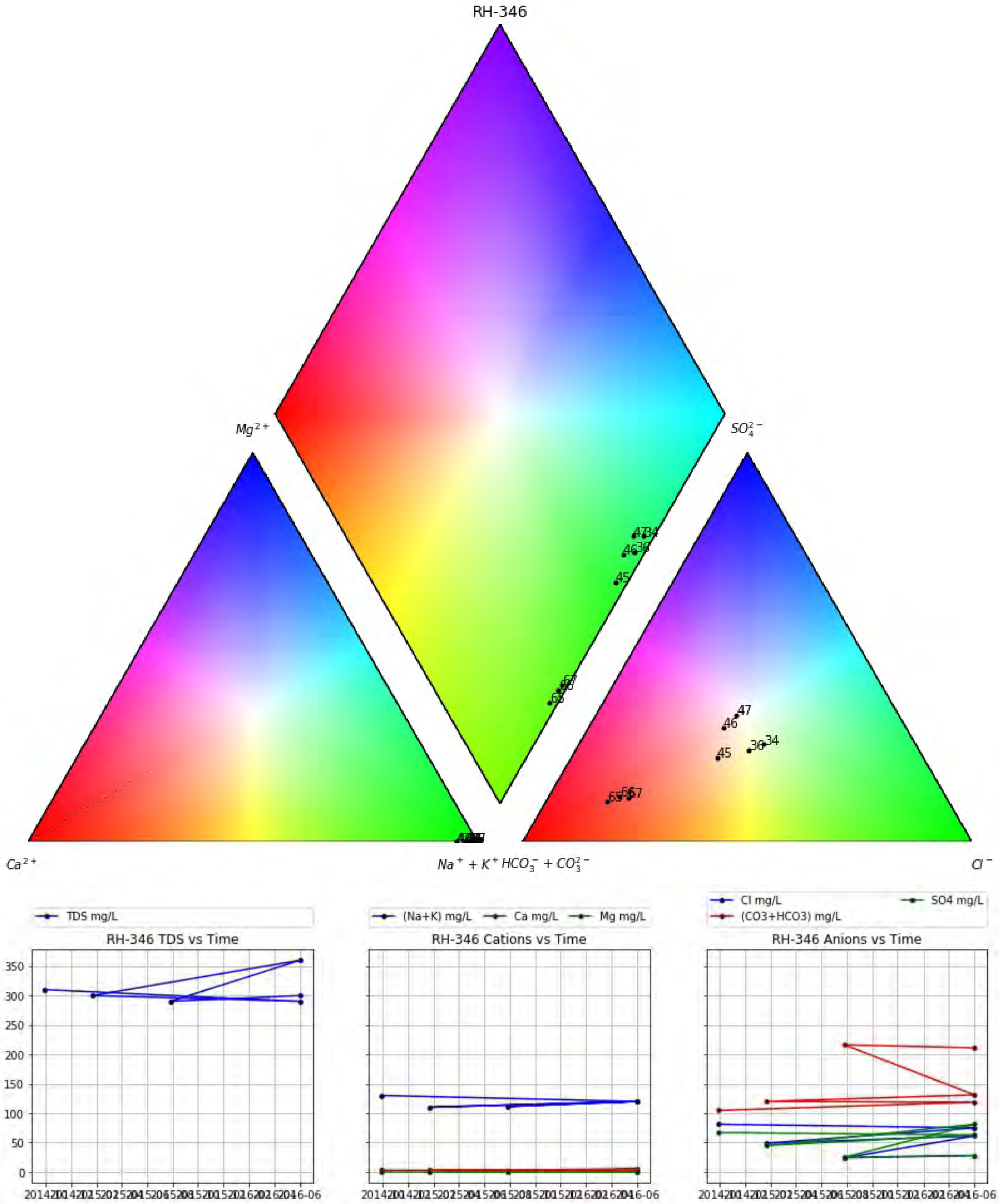

ID1-10
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
ID1-10 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-10 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID1-10 Anions vs Time

15: ID1-8

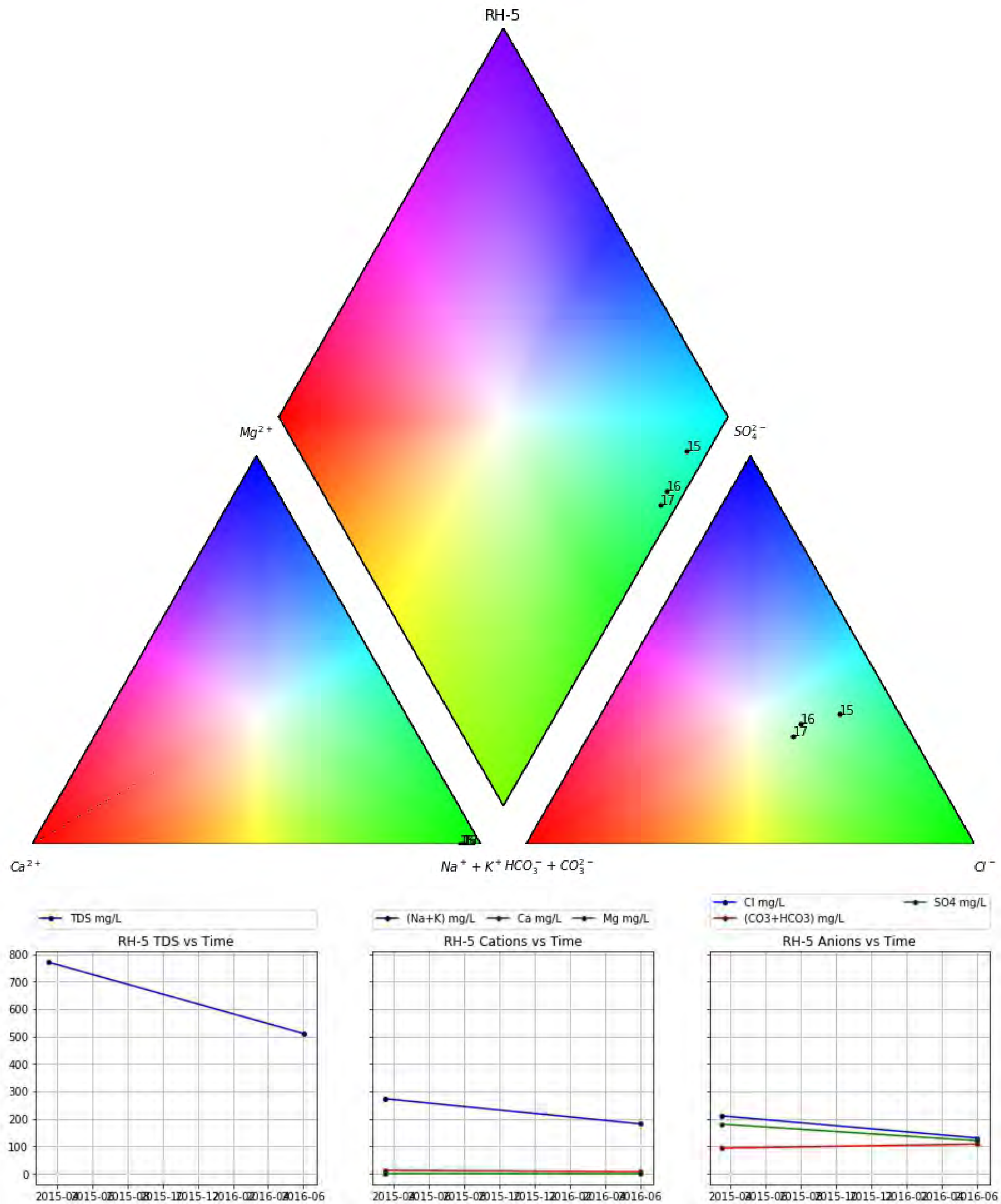


ID1-8
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
04
17
11
07
13
94
88
72
TDS mg/L
ID1-8 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-8 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID1-8 Anions vs Time
0
100
200
300
400
500
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

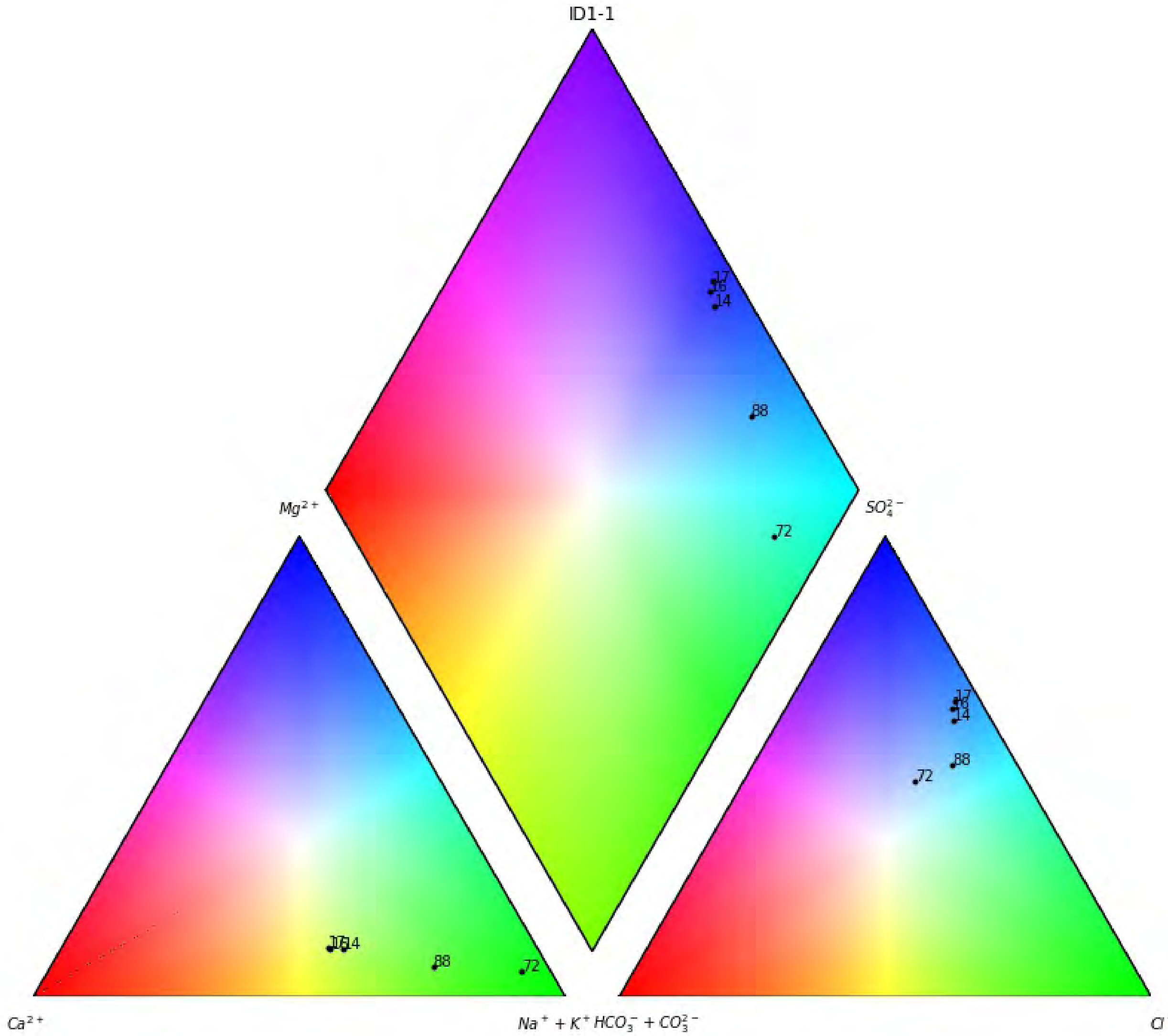
16: RH-3; 17: RH-4; 19: RH-6



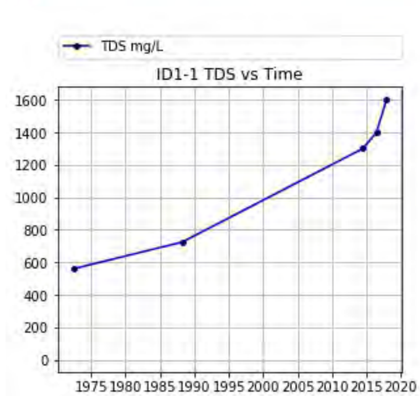
18: RH-5


RH-5
Mg^{2+}
SO_4^{2-}
15
16
17
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
RH-5 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
RH-5 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
RH-5 Anions vs Time
800
700
600
500
400
300
200
100
0
2016-06

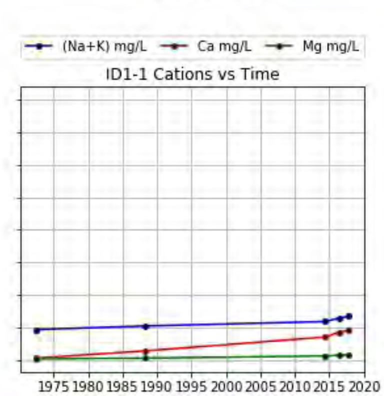
20: ID1-1



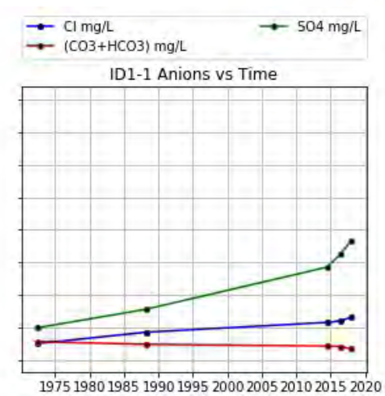
ID1-1
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
17
16
14
88
72



TDS mg/L
ID1-1 TDS vs Time
1600
1400
1200
1000
800
600
400
200
0
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

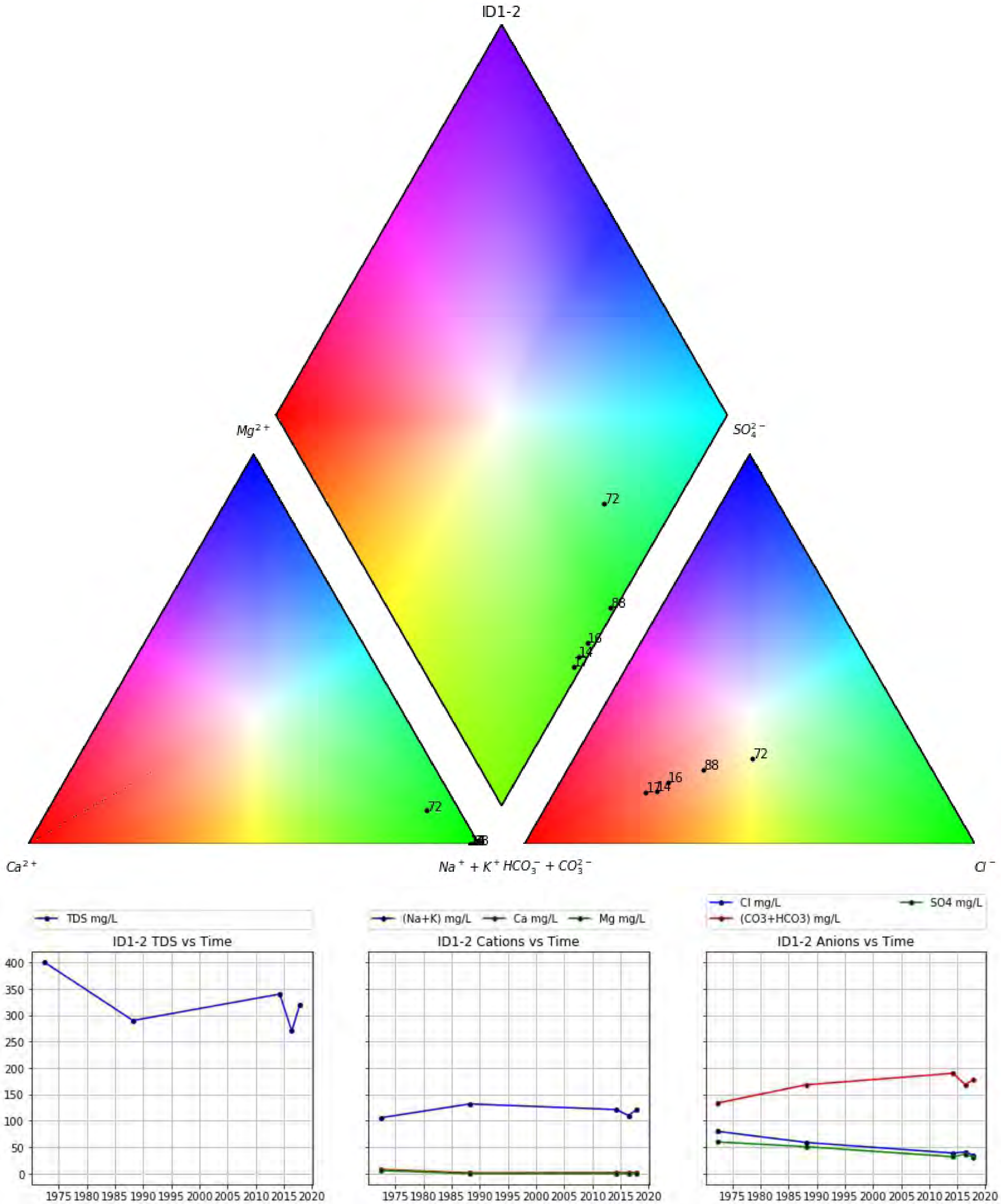


(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-1 Cations vs Time
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

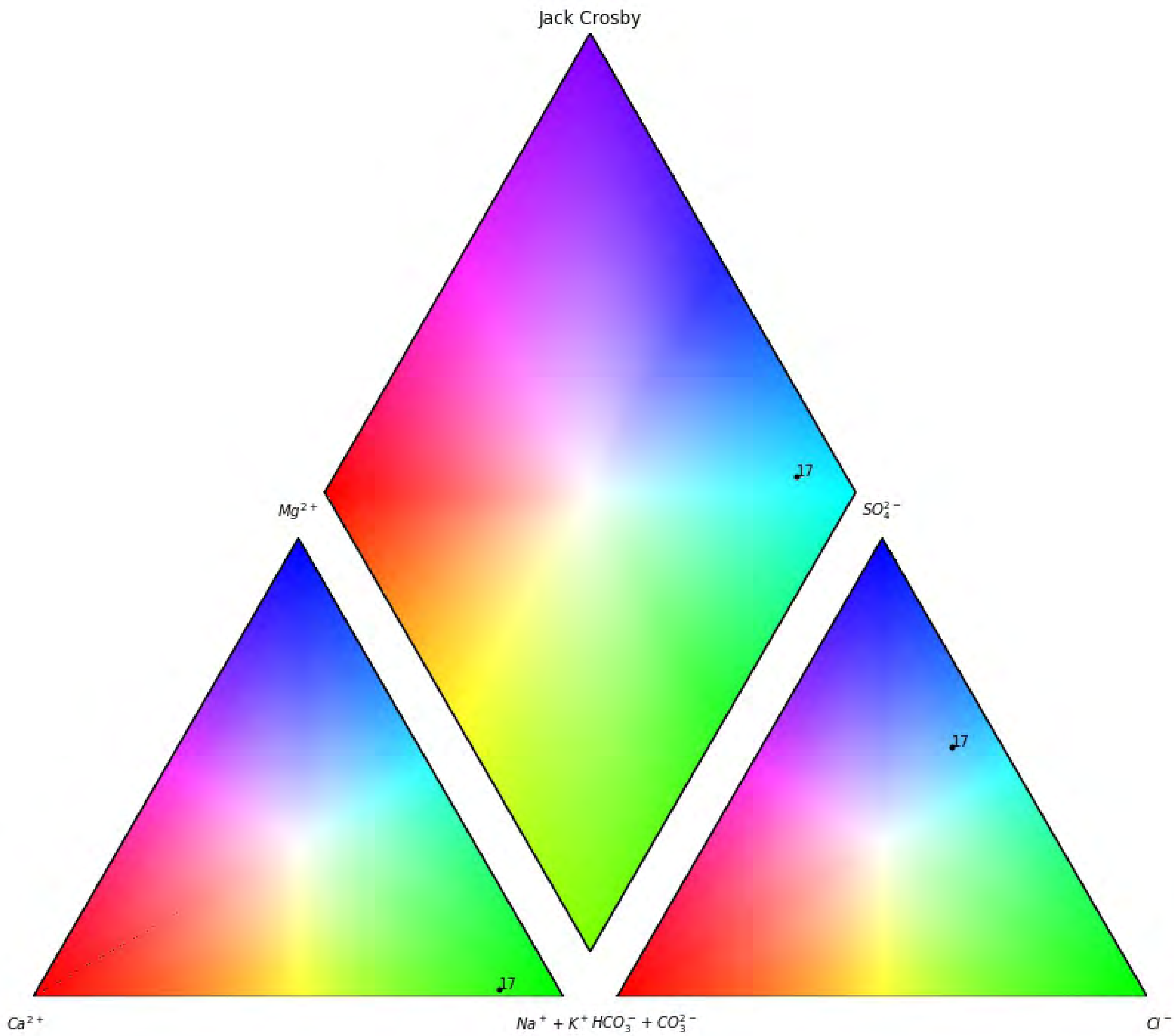


Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID1-1 Anions vs Time
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

21: ID1-2

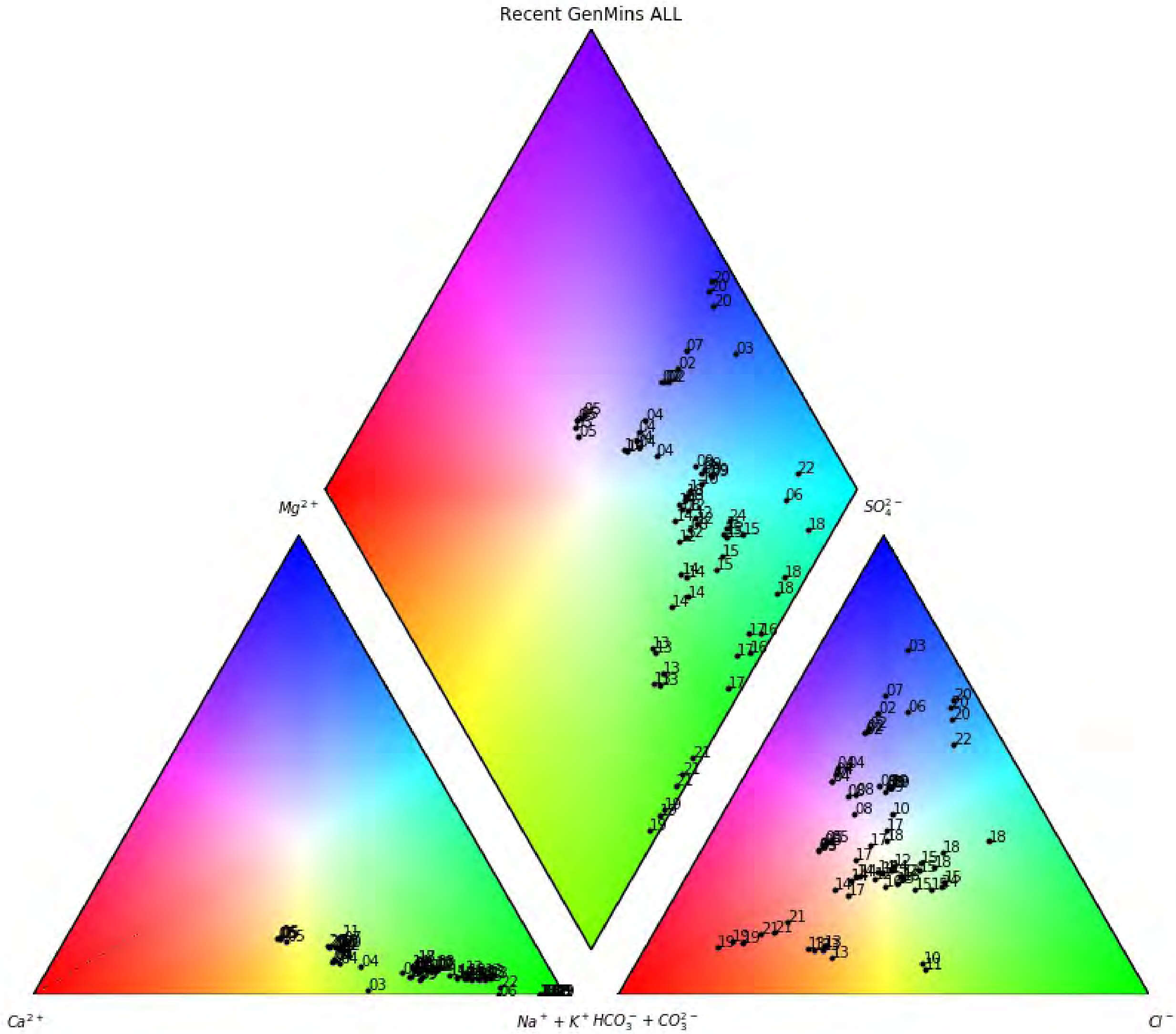

ID1-2
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$
$HCO_3^- + CO_3^{2-}$
Cl^-
72
88
16
14
TDS mg/L
ID1-2 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-2 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID1-2 Anions vs Time
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

22: Jack Crosby



One data point so no plots generated.

Recent Data: All (Piper only)

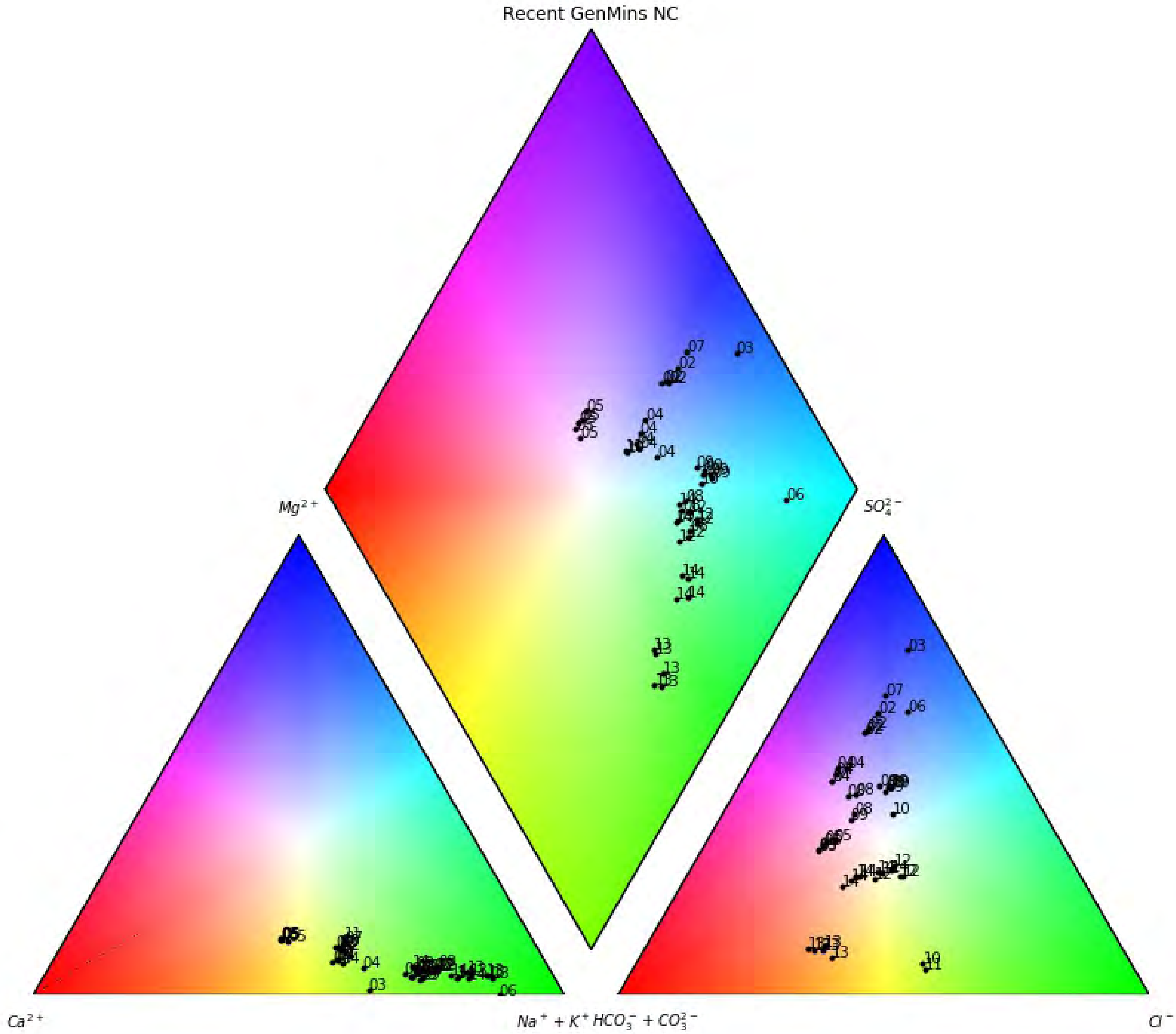


Notes:

The number on the diagrams correspond to sequential well numbers assigned to each of the wells as explained in the text. Data are for the period of 2005 to 2018.

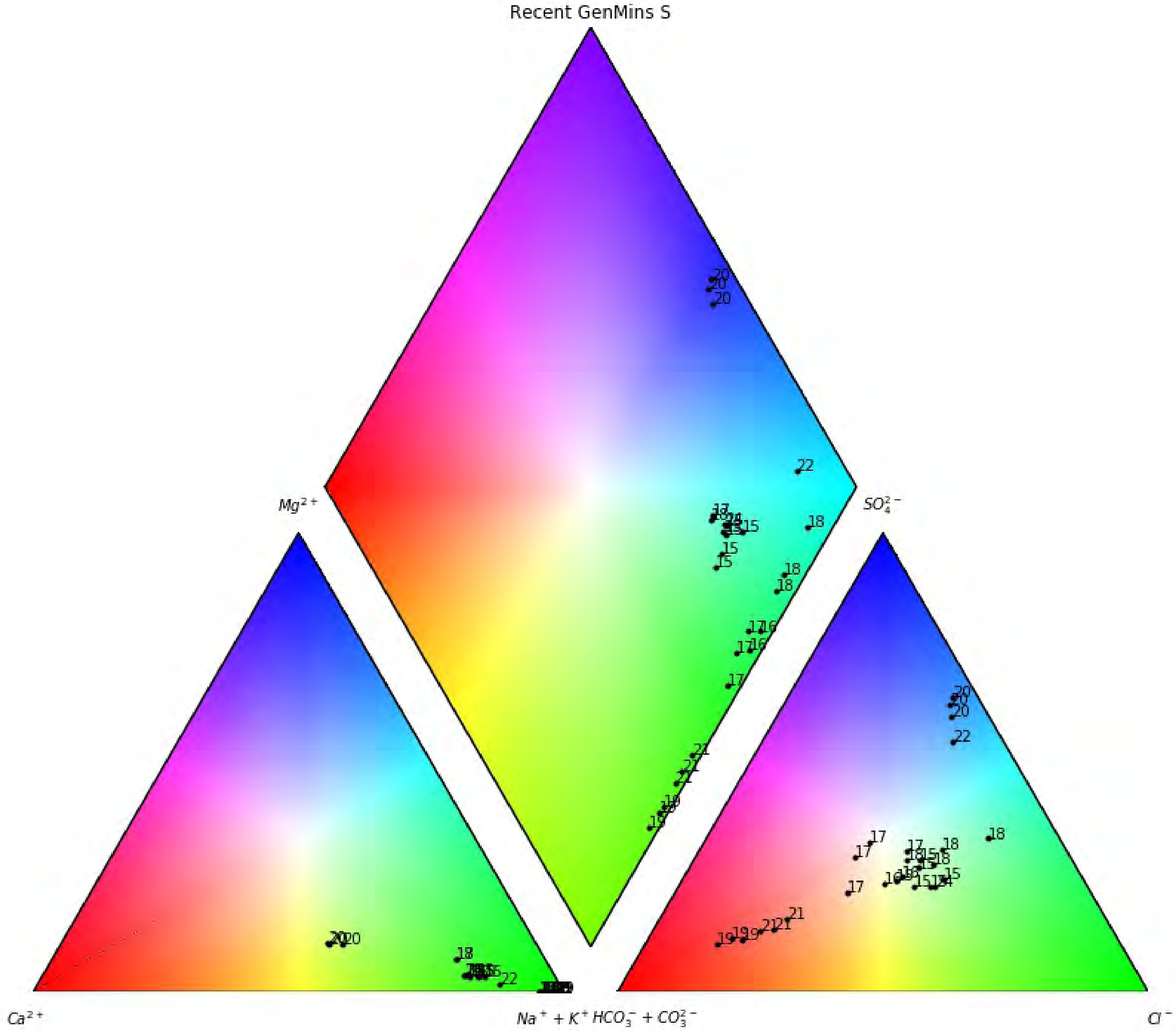
This Piper diagram is further explained in **Figure 6**.

Recent Data: North and Central (Piper only)



Note: The number on the diagrams correspond to sequential well numbers assigned to each of the wells as explained in the text. Data are for the period of 2005 to 2018.

Recent Data: South (Piper only)



Note: The number on the diagrams correspond to sequential well numbers assigned to each of the wells as explained in the text. Data are for the period of 2005 to 2018.

Appendix C:

Assessment of Water Level Decline, Hydrogeologic Conditions, and Potential Overdraft Impacts For Active BWD Water Supply Wells.

ENSI Draft dated 1/7/2019

January 7, 2019

Mr. Geoff Poole
General Manager, Borrego Water District
806 Palm Canyon Drive,
Borrego Springs, CA 92004

RE: Assessment Of Water Level Decline, Hydrogeologic Conditions, and Potential Overdraft Impacts For Active BWD Water Supply Wells

Dear Geoff,

The following draft Report was produced under our existing contract to provide technical support to BWD for to the Borrego Valley Groundwater Basin Groundwater Sustainability Plan Proposition 1 Grant Project. This Report completes Task 2 in combination with reports dated 9/12/2018 and 12/7/2018, and provides supporting data for Task 3 specific to the assessment of overdraft impacts on BWD's water supply.

Subsequent analyses are in process that will build from this Report to examine the effect of overdraft on BWD supply well production rates and water quality.

Thank you for your time and attention.

Sincerely,

Jay W. Jones
CA PG#4106
Environmental Navigation Services Inc.

OVERVIEW

The purpose of this Report is to assess groundwater elevation decline trends for the Borrego Water District's (BWD) nine water supply wells[1], examine well-specific hydrogeologic conditions at the well locations, and assess the potential impact of overdraft on future water production. Measured groundwater elevations at the nine BWD wells are reviewed in combination with model-predicted groundwater elevations to assess ongoing water level decline at the BWD wells. Site specific drilling logs, measured groundwater level data, and model-calculated groundwater elevation data are evaluated in the context of the hydrogeologic characterization developed in the USGS Model Report[2]. An analysis of potential aquifer productivity at BWD wells is then developed based on an evaluation of how aquifer transmissivity[3] changes as a function of water level using the aquifer geometry and hydraulic parameters from the USGS Model Report.

The overall intent of this analysis is to examine the potential impact of overdraft on BWD water supply wells and provide technical support to assess the uncertainty associated with water level trend analyses and predictions for individual BWD water supply wells. Specific objectives include:

1) Construct and evaluate hydrographs depicting measured groundwater levels and model-predicted groundwater levels at each well, and examine water level decline trends at each BWD water supply well.

2) Develop lithologic logs for each of the BWD wells as derived from driller's logs and available detailed geologic cross-sections and related studies. Use the interpreted logs to compare local well conditions to the larger-scale hydrogeologic parameters used in the USGS Model [USGS Model Report, 2015].

3) Compare the hydrographs and model-based water level predictions to the lithologic logs to provide an understanding of well-specific hydrogeologic conditions at BWD's nine water supply wells.

4) Use the model aquifer geometry and local hydraulic conductivity values to calculate aquifer transmissivity, a measure of aquifer productivity, for each BWD well location. Based on observed water level decline, calculate the change in transmissivity as a function of aquifer saturation to assess how overdraft will potentially affect BWD water supply well production.

[1] There are currently eight active water supply wells and one reserve well (see **Table 1**).
[2] [USGS Model Report, 2015] Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed, Michelle, Brandt, Justin, Martin, Peter, and Coes, A.L., 2015, Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California: U.S. Geological Survey Scientific Investigations Report 2015–5150, 135 p., http://dx.doi.org/10.3133/sir20155150
[3] Transmissivity is a hydraulic parameter defined as the product of the hydraulic conductivity times the aquifer thickness. As further described in this Report, decreases in transmissivity are occurring due to overdraft.

The Borrego Springs Subbasin (Subbasin) of the Borrego Valley Groundwater Basin has been declared by the California Department of Water Resources (DWR) to be in a state of critical overdraft and is subject to the Sustainable Groundwater Management Act (SGMA). Per SGMA "A basin is subject to critical overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts."[4] Pursuant to SGMA a Groundwater Sustainability Plan (GSP) is currently under development[5] for the Subbasin.

Water level and pumping rate measurements will provide the primary data to monitor overdraft and the effectiveness of pumping rate reductions under the GSP. The USGS's numerical model and supporting information contained in the USGS Model Report provide supporting insights specific to future groundwater conditions data to assess water level decline due to ongoing overdraft. The model was designed and calibrated to evaluate groundwater levels across the ~88 mi^2 Subbasin. It discretizes the aquifer system into three layers described as the upper, middle, and lower aquifers. Each of the model layers are composed of 2,000 x 2,000 ft cells (~92 acres/ 0.15 mi^2) that average hydrologic properties at a much larger scale than occurs at individual wells. As a result, approximations and averages are used at a scale broader than the immediate area surrounding individual BWD water supply wells. The analysis provided in this report is intended to be used, in part, to support the application of the model at the scale of the BWD wells.

Evaluation of the relationship between individual well production and BWD's water storage and distribution system is not included in this report. BWD's current water supply system consists of six pressure zones further described in a Dudek report entitled *Proposition 1 SDAC Grant Task 5 Water Vulnerability/New Extraction Well Site Feasibility Analysis* (dated 12/21/2018). Also included in the 12/21/2018 report is information regarding the physical condition of BWD's wells, evaluations of well longevity, and recommendations for well replacement.

Water quality has also been changing over time at BWD wells. This Report focuses on water production- for supporting details please refer to an ENSI Report entitled *Water Quality Review and Assessment: Borrego Water District (BWD) Water Supply Wells*, dated 12/7/2018.

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4 See: https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118/Critically-Overdrafted-Basins

5 The GSP is being developed by the Groundwater Sustainability Agency (GSA) that consists of the County of San Diego and the Borrego Water District. See overview at: https://www.sandiegocounty.gov/pds/SGMA.html

The following sections are included in this Report:

Section 2 of this Report provides an overview of aquifer conditions and includes hydrographs for each of the BWD wells. Water quality is not discussed- a review of water quality conditions for the BWD water supply wells is included in a separate ENSI report dated 12/7/2018.

Section 3 examines hydrogeologic conditions at each of the wells and compares the local, well-specific information to conditions described in the larger-scale groundwater model developed by the US Geological Survey. Generalized well logs are developed for each of the BWD wells based on driller's logs

Section 4 examines how the aquifer productivity will decrease as water levels decline due to critical overdraft. Here an analysis of the aquifer transmissivity, a measure of aquifer productivity, is used to examine how the wells will be affected over time under current rates of water level decline.

1.0 WELLS USED IN THIS ANALYSIS

The focus of this Report is on the assessment of eight active and one reserve BWD water supply wells (**Table 1, Figure 1**). The wells have been segregated by management areas as established in prior work by Dudek (North/Central/South; see the GSP for details).

TABLE 1

Management Area	Well Name	GSA GWM Well	Status	Year Installed	GPM	Static Water Level (ft)	Draw Down (ft)	GPM/Ft ***	Plant Efficiency ****	Well Depth (ft)
North	**ID4-4***	Yes	Active	1979**	395	205.4	63.5	6	71	802
	ID4-11	Yes	Active	1995	920	223.2	5.8	159	73	770
	ID4-18*	Yes	Active	1982	130	311.2	7.6	17	50	570
Central	**ID1-10***	Yes	Active	1972	317	213.9	11.5	28	54	392
	ID1-12	No	Active	1984	890	145.5	10.4	86	72	580
	ID1-16	Yes	Active	1989	848	230.9	24.3	35	71	550
	ID5-5	Yes	Active	2000	542	182.1	16.1	34	62	700
	Wilcox	Yes	Stand-by	1981	205	305.2	5.8	35	NA	502
South	**ID1-8**	Yes	Active	1972	448	71.2	47.7	9	51	830

Notes:
Data from 2018 Pump Check Results (see **Appendix A**)
*, wells being considered for replacement (currently three: ID4-4, ID4-18, and ID1-10)
**, ID4-4 was redrilled/deepened in 1979
***, gpm/ft calculated from Pump Check data
****, Plant Efficiency from Pump Check, in percent.
Values less than 60% are viewed to be of concern.

Note that BWD well locations do not fully represent hydrologic conditions within the Borrego Subbasin as they are located in populated areas within their historical service areas (or Improvement Districts [ID] as indicated by the well names) (**Figure 1**).

1.1 BWD Well Production and Demand

BWD currently serves approximately 1600 acre-feet of water per year (2017 Consumer Confidence Report[6] dated July 1, 2018). This is equivalent to a continuous pumping rate of 992 gpm. The total pumping capacity of the wells listed in **Table 1** is 4,695 gpm. Water supply wells are typically operated 8 to 12 hours per day so BWD's operating capacity is on the order of 1,565 to 2,348 gpm, approximately 1.6 to 2.4 times the current demand (992 gpm). This overview assessment focuses on BWD's water supply wells and does not account for the ability of BWD's water distribution system to store and transmit water to meet customer demand. Please refer to Dudek's 12/21/2018 Report for further system-specific details.

It is understood that well ID4-4 is in poor condition and will be replaced in 2019 at its existing location. It is likely that the new well will be more efficient and have a higher pumping capacity. It is also understood that well ID1-10 will be replaced in 2019 at new well location yet to be finalized but within the Central Management Area. Like ID4-4 it is being replaced due to it being in poor condition, and a replacement well will also be likely to be more efficient and have a higher pumping capacity.

Well ID4-18 is also reportedly in poor condition and is the lowest yielding BWD well per **Table 1**. However, it is understood that it currently serves a very small water demand in the northern portion of BWD's service area. Because it is able to meet the demand ID4-18 will likely not be replaced in the near future.

1.1.1 Future Water Demand

BWD's service area includes many undeveloped residentially- and commercially-zoned parcels that, when developed, will require water. Potential future water demands were assessed in a Dudek report entitled *BWD Theoretical Water Demand at Buildout of Present Unbuilt Lots Under County's Current Zoning in Borrego Springs*, dated October 4, 2016. The Report states:

"Under the County's current zoning there are 4,439 vacant and undeveloped parcels that could be converted to residential development and 526 vacant and undeveloped lots that could be converted to commercial, industrial, office space, rural commercial, open space, public agency, or public/semi-public facilities (County of San Diego 2011a). Because an undetermined number of lots do not have legal lot status and because many of the lots are not developable due to environmental and other physical constraints, it was assumed that development of approximately 3,000 residential units would approach maximum buildout of the Borrego Valley. To estimate increased demand for commercial and other user types, it was conservatively assumed that their

[6] See BWD website: http://nebula.wsimg.com/c30a61991a5160ddf5e577fe9f7b3c01?AccessKeyId=D2148395D6E5BC38D600&disposition=0&alloworigin=1

demand would increase proportionally to their existing percentage of the overall demand as growth occurs in Borrego Springs.

Full General Plan buildout of legal lots given constraints was presumed to add an additional 3,000 residential, 215 commercial, 108 public agency, 207 irrigation, and 179 multiple unit EDUs to the basin for a total of 6,811 EDUs at buildout of the Borrego Valley. A conservative estimate of future water demands was estimated by applying the current residential EDU water demand of 0.55 acre-feet per account. This results in a future estimated municipal water demand of 3,746 acre-feet per year, which is about 66% of the basin sustainable yield of 5,700 acre-feet per year[7]."

Dudek's report concluded with three findings that are copied below:

- *"Present County zoning for the BWD's service area may be unsupportable under SGMA constraints. Even with drastic reductions in residential EDU, it is uncertain that municipal demand can be met, given current competition with agriculture, recreation, and other water users of the basin, including potential environmental water necessary to maintain the groundwater system.*

- *Existing County General Plan assumptions need to be reevaluated given physical water constraints under SGMA.*

- *Any up-zoning in the BWD's service area would necessarily require as preconditions significant down-zoning of existing properties given physical constrains of available groundwater supply to meet municipal demand at buildout of Borrego Springs. Otherwise, an up-zoning without first meeting these preconditions would create a significant contingent liability for the BWD and its ratepayers as well as potentially difficult litigation risk due to the District's cost to purchase water and potential inability to provide potable water to the up-zoned property due to SGMA constraints. In other words, upfront mitigation for new development is required to offset the condition of overdraft in the BVGB."*

Clearly the estimated future demand cannot be met with BWD's current water supply as the total water demand could potentially triple. This Report will focus on BWD's existing wells independent of any SGMA considerations and defers to the GSP for further analysis of how population growth will be accommodated under SGMA.

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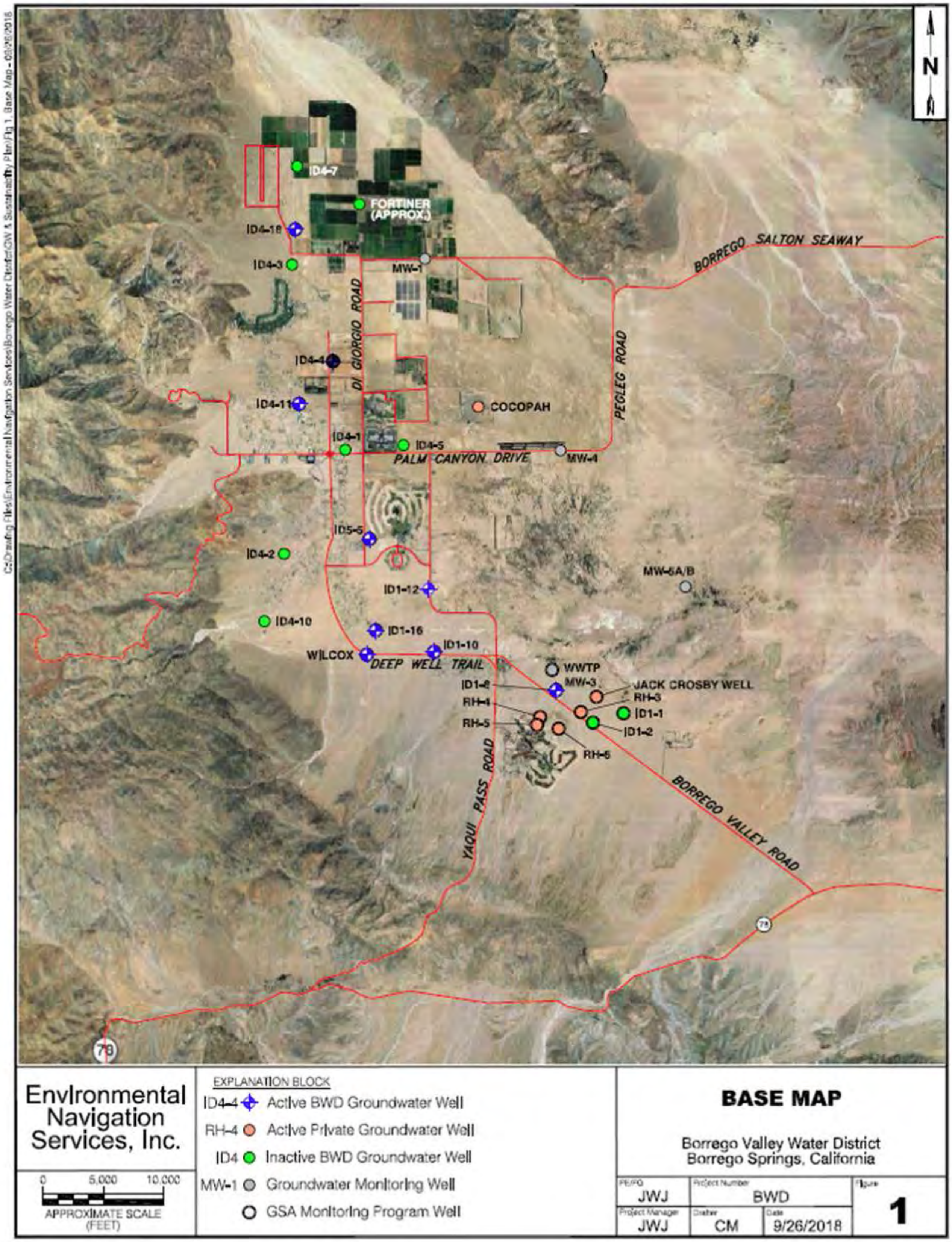
[7] Report Footnote 3: "*This estimate of the theoretical municipal water demand at buildout of present unbuilt lots under the County's current zoning in Borrego Springs is based on the current residential water use per EDU of 0.55 acre-feet per year, the existing distribution of user types, and an assumed additional 3,000 residential units at buildout. It is recognized that change in the water use per EDU and change in the distribution of user types will vary the actual municipal water demand."*



N
ID4-7
FORTINER (APPROX.)
ID4-18
ID4-3
MW-1
BORREGO SALTON SEAWAY
DI GIORGIO ROAD
PEGLEG ROAD
ID4-4
ID4-11
COCOPAH
ID4-1
ID4-5
PALM CANYON DRIVE
MW-4
ID5-5
ID4-2
MW-5A/B
ID1-12
ID4-10
ID1-16
ID1-10
WILCOX
DEEP WELL TRAIL
WWTP
ID1-8
MW-3
JACK CROSBY WELL
RH-3
RH-4
ID1-1
RH-5
ID1-2
RH-6
YAQUI PASS ROAD
BORREGO VALLEY ROAD
78
Environmental Navigation Services, Inc.
0 5,000 10,000
APPROXIMATE SCALE (FEET)
EXPLANATION BLOCK
ID4-4 Active BWD Groundwater Well
RH-4 Active Private Groundwater Well
ID4 Inactive BWD Groundwater Well
MW-1 Groundwater Monitoring Well
GSA Monitoring Program Well
BASE MAP
Borrego Valley Water District
Borrego Springs, California
JWJ
Project Number
BWD
Figure
1
Project Manager
JWJ
Drafter
CM
Date
9/26/2018

2.0 HYDROGEOLOGIC CONDITIONS AND CONCEPTUAL MODEL

This section provides an overview of the current hydrogeologic conceptual model for the Subbasin's aquifer system. More comprehensive presentations and discussions of hydrogeologic conditions are presented in the GSP.

Reports to date generally describe the Subbasin as consisting of three unconfined aquifers named the upper, middle, and lower aquifers. The upper and middle aquifers are the primary sources of water currently in use and are comprised of unconsolidated sediments. The lower aquifer sediments become consolidated with depth and have been subject to folding and faulting. The effects of overdraft are primarily seen in the upper aquifer as much of this portion of the aquifer system has been dewatered. It is generally understood that the productivity of the aquifer system decreases with depth from declines in both the hydraulic conductivity (the relative rate of flow to a well for a given amount of drawdown) and in the aquifer storativity (the amount of water that will be produced from the aquifer in response to a drop in water level).

The types and distribution of sediments that occur in the aquifer system are related to the geologic conditions that formed the sediments. The USGS Model Report generally depicts the Borrego Subbasin geology as initially described by Moyle, 1982[8]. The three aquifers were described by the USGS as follows (USGS Model Report, page 31):

"The upper aquifer is the regional water-table aquifer and consists of the saturated part of the alluvium (Quaternary gravels [Qg] of Dorsey, 2002). Historically, it has been the principal source of groundwater in Borrego Valley and yields as much as 2,000 gallons per minute (gal/min) to individual wells (Mitten and others, 1988[9]). The upper aquifer is composed of Holocene to Pleistocene age alluvial, fan, playa, and eolian deposits. These deposits are composed of unconsolidated sand, gravel, silt, and clay (Mitten and others, 1988). The upper aquifer ranges in thickness from 0 to 643 ft (table 2) and is thickest at the north end of the valley where Coyote Creek enters the basin. It thins to the southeast and is only about 50 ft thick near the Borrego Sink (Mitten and others, 1988) (fig. 10A).

The middle aquifer is composed of the upper part of Pleistocene age continental deposits. Moyle (1982) correlated the middle aquifer with the upper Palm Spring Formation/upper QTc. The middle aquifer yields moderate quantities of water to wells, but is considered a non-viable source of water south of San Felipe Creek because of its diminished thickness (Mitten and others, 1988). Descriptions on well logs penetrating these deposits indicate that the deposits range in size from

[8] Moyle, W. R., 1982, Water resources of Borrego Valley and vicinity, California; Phase 1, Definition of geologic and hydrologic characteristics of basin: U.S. Geological Survey Open-File Report 82–855, 39 p.

[9] Mitten, H.T., Lines, G.C., Berenbrock, Charles., and Durbin, T.J., 1988, Water resources of Borrego Valley and vicinity, California, San Diego County, California; Phase 2, Development of a groundwater flow model: U.S. Geological Survey Water-Resources Investigation Report 87–4199, 27 p.

gravel to silt with moderate amounts of consolidation and cementation and that the predominant grain sizes range from medium sand to clay (Moyle, 1982). The middle aquifer is as much as 908 ft thick (table 2) in the northern part of the valley, but it thins substantially in a southeasterly direction (Mitten and others, 1988) (fig. 10B).

The lower aquifer includes the combined deposits of the lower Palm Spring and Imperial Formations (Moyle, 1982; Henderson, 2001). The lower aquifer yields only small amounts of water to wells (Moyle, 1982); it is composed primarily of partly consolidated siltstone, sandstone, and conglomerate in the lower part of the continental deposits (Mitten and others, 1988). The separation of the middle and lower aquifers is based on drillers' log descriptions of "hard, dry, red clays" that extend over the southern half of Borrego Valley at increasing depth to the north. Drillers' logs indicate sediments above the red clays are easy to drill, whereas those below the red clay are hard to drill (Moyle, 1982). On the basis of the most recent interpretations of gravity data, this aquifer is as thick as 3,831 ft (table 2) and is thickest in the eastern part of the valley (figs. 9, 10B, 10C)."

Review of the USGS Model Report indicates that the aquifer details were developed for the model as follows:

- Began with the three-layer aquifer geometry primarily based on work done by Moyle (1982) and Mitten et al (1988).

- Reviewed 230 well and driller logs and interpreted sediment types and grain sizes from the logs. Based on the interpretation developed a data base with grain size distributions. "*Each lithologic log was divided into discrete binary texture classifications of either coarse-grained or fine-grained intervals on the basis of the description in the log (table 3)."*

- The hydraulic properties of each layer (upper/middle/lower aquifer) were then estimated based on grain sizes. "A *2-D geostatistical model, both incorporating kriging and cokriging methods, was used to interpolate*[10] *the percentage of coarse-grained deposits of the nearest wells onto a 2,000-ft grid across each aquifer for the entire study area.*" The results were used to create 14 roughly concentric zones per layer for model parameter estimation. The zones are vertically contiguous across the three layers in the model.

- Refinement of layers and hydraulic properties based on review of groundwater model calibration results where parameter refinement was done to improve the model's ability to match historical water levels.

[10] Ed: In simple terms a map was made by using known values of sediment grain size and estimating the value across the groundwater model grid. The estimates were determined using a multi-step process where each point estimate is a linear combination of nearby points. Please refer to the USGS Model Report for additional details.

In contrast to the USGS's geostatistical approach, hydrogeologic stratigraphic analysis was conducted as part of SDSU graduate student research for the Borrego Valley (Netto, 2001[11]). He has a different aquifer interpretation than that used in the USGS Model Report as follows (Netto, page 37):

"The conceptualization of hydrostratigraphic units described above is different from the previous conceptualization made by the USGS (Moyle, 1982), which has since been the basis for other groundwater modeling and water resource studies in Borrego Valley (DWR, 1984b; Mitten, 1988). Moyle (1982) described a three-aquifer system corresponding to the alluvium, upper Palm Spring Formation, and the combined lower Palm Spring and Imperial Formations, respectively. Each unit was described as uniform, with no variation of the physical characteristics within any of the three units. In this current study, the alluvium, comprising the upper aquifer of Moyle (1982), has been divided into three separate hydrostratigraphic units, each with varying physical characteristics based on the distribution of soil texture within the alluvium. The middle and lower aquifers of Moyle (1982), have been combined into one unit, partly because sufficient data is lacking to make clear distinction between separate hydrostratigraphic units within the Palm Spring Formation and potentially underlying Imperial Formation, and also because groundwater production from this unit is limited to relatively shallow portions of the Palm Spring Formation from a limited area in southern Borrego Valley. The current model has increased the definition of the hydrostratigraphy in the principal water bearing portions of the aquifer system, namely the alluvial aquifer."

Netto's conclusions further explain the difference in the hydrostratigraphic interpretation (page 136):

- *"The geologic materials found within the groundwater basin include Tertiary rocks, predominantly the Palm Spring formation, and Quaternary alluvium. The Quaternary alluvium has been divided into older, intermediate and younger alluvium and is mostly comprised of alluvial fan and intermittent stream deposits, as well as some lacustrine deposits found within the intermediate alluvium."*

- *"The aquifer system is comprised of four hydrogeologic units of Quaternary and Tertiary age. The uppermost three units are the Quaternary Alluvium, designated as younger, intermediate and older, each with varying hydraulic properties. The oldest and lowermost unit is the Tertiary Palm Spring Formation. The hydrogeologic units are underlain by the Cretaceous and older crystalline basement rocks."*

[11] Netto, S.P., 2001, Water Resources of Borrego Valley San Diego County, California: Master's Thesis, San Diego State University, 143 p.

- *"The Quaternary older alluvium is the principal water-bearing unit of the aquifer. It is relatively coarse grained and is thickest in the northern portion of the basin."*

The USGS Model Report includes multiple references to Netto (2001) but describes the work as a water resources study (page 9) and defers to Moyle (1982) as their primary guidance for the aquifer designations and interpretation. While a direct comparison of the two approaches has not been developed for this report, Netto's hydrogeologic cross-sections have been used to support review of the BWD well conditions by comparing the developed detailed geologic cross-sections and lithology maps to the driller's well logs.

The upper aquifer in the vicinity of the BWD water supply wells has been extensively dewatered as a result of ongoing overdraft. Thus, future water production will increasingly need to rely on the middle and lower aquifers. Historically the upper aquifer was the primary water source and most of the wells and drilling-related data have focused on the upper aquifer. As a result comparatively less data are available for the middle and lower aquifers.

A significant question specific to BWD wells is whether the water production from the sediments of the middle aquifer will decrease with depth, leading to lower water production rates as water levels decline with ongoing overdraft. The USGS Model is a finite element model that discretizes the aquifer using a square grid of cells, assigns one set of hydraulic properties per 92-acre cell, and assumes that each of the aquifer "blocks" per layer is homogeneous. Thus, the hydraulic properties within each layer do not vary with depth. **Section 3** includes an analysis of lithologic conditions at each of the BWD well used to assess potential variations within the aquifer system that may affect future well performance. Further refinement of the Subbasin-wide hydrostratigraphy and aquifer conditions is beyond the scope of this report.

2.1 Aquifer Properties Assigned to the Groundwater Model at BWD Wells

Aquifer properties assigned to each layer of the USGS Model at the nine BWD well locations have been compiled and provided to ENSI by Dudek staff (**Table 2**). The model discretizes the aquifer into 92-acre cells and the cell properties for each BWD well location include the hydraulic conductivity (ft/day) and specific yield (dimensionless). These values correspond to how quickly water will flow through the aquifer under a unit hydraulic gradient and the water volume (ft^3) that will be released from one-cubic foot of water subject to a one-foot water level drop, respectively. Lower values of either parameter correspond to lower production rates. The ratio of the parameters is indicative of how the well will produce water with increasing depth.

Table 2. Model Parameters at BWD Well Locations (per Modflow cell)

Parameter	ID4-4	ID4-11	ID4-18	ID1-10	ID1-12	ID1-16	ID5-5	Wilcox	ID1-8
Hydraulic Conductivity of Layer 1 (ft/day)	41.77	41.27	97.15	82.61	56.99	96.62	71.39	97.24	56.00
Hydraulic Conductivity of Layer 2 (ft/day)	3.92	4.49	5.87	5.26	5.67	6.35	5.13	6.15	1.15
Hydraulic Conductivity of Layer 3 (ft/day)	0.54	0.92	0.52	0.28	0.12	0.80	0.85	0.78	0.16
Specific Yield Layer 1	0.30	0.30	0.08	0.07	0.11	0.08	0.05	0.08	0.11
Specific Yield Layer 2	0.03	0.03	0.05	0.03	0.03	0.05	0.20	0.05	0.03
Specific Yield Layer 3	0.04	0.04	0.08	0.04	0.04	0.08	0.03	0.08	0.04
Thickness of Layer 1 (feet)	292	233	392	125	123	188	184	259	120
Thickness of Layer 2 (feet)	420	268	908	222	286	147	274	71	125
Thickness of Layer 3 (feet)	221	300	0	1516	1821	939	1509	601	1538
Elevation of Top of Layer 1 (Feet above MSL)	597	613	692	561	528	643	561	725	531
Elevation of Top of Layer 2 (Feet above MSL)	305	381	300	436	405	454	377	466	411
Elevation of Top of Layer 3 (Feet above MSL)	-114	113	-608	214	119	308	103	394	286
K layer 1: layer2	11	9	17	16	10	15	14	16	49
S layer 1: layer2	9.1	9.1	1.8	2.4	3.6	1.8	0.3	1.8	3.6
K layer 2: layer 3	7	5	11	19	49	8	6	8	7
S layer 2: layer 3	0.9	0.9	0.6	0.8	0.8	0.6	6.8	0.6	0.8

FIGURE 2

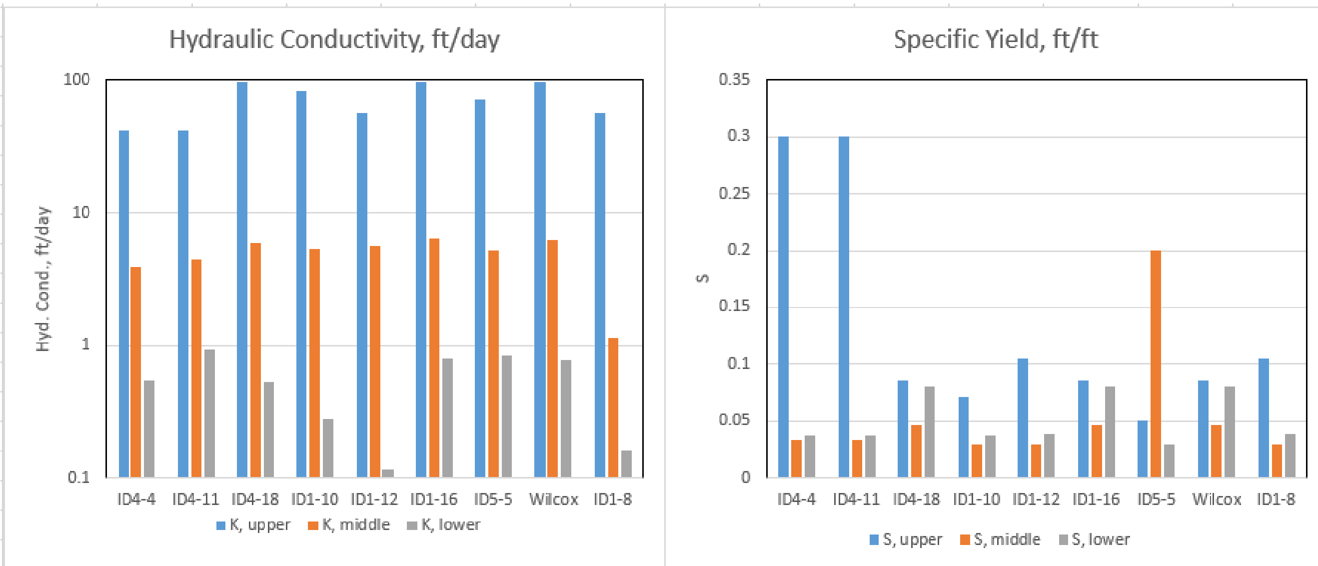


Figure 2 depicts the hydraulic parameters. Hydraulic conductivities consistently decrease with depth at all well locations. Here the values are shown on logarithmic scale because they decrease by factors of 10 from layer to layer. Specific yield values in the middle and lower aquifers are more similar in magnitude versus the upper aquifer and are shown linearly.

The aquifer parameter values are generally consistent with the conceptual model for the aquifer system where water production rates and the amount of groundwater in storage decrease with depth. Here, the sharp drop in hydraulic conductivity with depth at aquifer boundaries means that the wells, as simulated in the model based on their interpretation of well log data, will have decreasing production rates with depth. Further the model parameters illustrate that the loss of the upper aquifer because of overdraft is very significant in that the upper aquifer can support much higher production rates than the middle aquifer. Production from the middle aquifer, in turn, will be significantly better than expected from the lower aquifer.

Aquifer parameter measurements normally obtained through controlled aquifer testing are in short supply. The well-specific hydraulic parameters listed in **Table 2** were developed by the USGS based on interpretation of lithologic descriptions based on driller's logs and calibration of the numerical model. While the process likely results in reasonable estimates of the hydraulic parameters, none of the values are based on well-specific aquifer test results. The lack of well-specific hydraulic test data represents a major data gap toward the understanding of aquifer conditions with depth at BWD water supply wells.

2.2 BWD Water Supply Wells: Water Level Hydrographs and Observed Long-Term Water Level Decline

Observed groundwater elevations at the nine BWD wells and model-estimated groundwater elevations calculated as part of the Groundwater Model Update by Dudek are presented in hydrograph plots (**Figures 3 to 12**). Dudek's update used the calibrated USGS model (1945 to 2005) and incorporated additional hydrologic data to extend the model period through 2016.

In the larger perspective the model generally replicates the overall decrease in water levels and loss of groundwater from storage that has been and continues to occur in the Subbasin due to overdraft. The differences between the observed and modeled groundwater elevations over time are depicted for eight of the nine BWD water supply wells (**Figure 3**). Groundwater elevation decline observed at each of the BWD wells has ranged from 20 to 89 feet for each of the wells. The water level elevation decline rates observed in eight of the nine wells over the past decade range from 0.6 to 4.5 feet/year based on linear trends fitted to the water level data (**Table 3**). Well ID1-10 is an exception and has exhibited a rise in groundwater elevation over the past 10 years.

Comparison of the observed and model-calculated water level elevations can be used to support the use of the groundwater model at BWD well locations. The model works to provide a statistically-based 'fit' of observed and predicted water levels and tends to average conditions across the Subbasin. As a result, while the model provides a Subbasin-wide assessment of hydrologic conditions, local water level elevations calculated by the model can be higher or lower than those observed by water level elevations obtained by measurements at the wells. If the water level elevations calculated by the model are lower than observed, the model is said here to overestimate water level declines and thus overestimate overdraft. From a BWD management perspective this means that the use of the model is protectively conservative and allows for a margin of error. Conversely, if the model-calculated water levels are higher than those observed at a well the model is said to underestimate water level decline and overdraft. In both cases the understanding of model behavior can be used to support the localized use of the model.

The USGS Model was calibrated[12] by the USGS for the period of 1945 to 2010. It was updated by Dudek where the hydrologic parameters such as recharge and pumping were added for the

[12] Ed: Calibration specific to the hydrograph analysis refers to the process where the model parameters are adjusted to improve the match between observed and model-predicted water levels. It is a large-scale model so the calibration will locally over- and under-estimate water levels with to statistically obtain a 'best fit' across the Subbasin. As noted in the Model Report (page 99) "Although the model was designed with the capability of being accurate everywhere, the conceptual and numerical model still retains simplifications that could restrict appropriate use of the current model to regional and sub-regional spatial scales and within seasonal to inter-annual temporal scales. Potential future refinements and enhancements could improve the level of accuracy and the spatial and temporal resolution."

period of 2011 to 2016 without changing the aquifer parameters (hydraulic conductivity, specific yield, etc.). Nine wells were analyzed:

- The model overestimates water decline when compared to water level elevation measurements at five wells. The following wells are listed in the order of increasing magnitude: ID1-5, ID4-4, ID4-18, ID4-11, and ID1-8. Increasing trends were observed in four of these five wells. The exception, as illustrated by **Figure 3**, is ID4-4 where the difference between modeled and measured groundwater elevations started decreasing in 2014 and becoming more accurate over time.

- The model matches observed water level elevations reasonably well at ID1-12.

- The model underestimates water level decline over time at two wells; ID1-16 and Wilcox. Increasing trends over time were observed at these wells.

- Model-predicted and observed groundwater elevations have dissimilar trends at ID1-10, and the differences between observed and predicted groundwater elevations are at times greater than 50 feet so it has not been included in **Figure 3**. Measured groundwater elevations vary greatly over the monitoring period, observed water levels have been rising at ID1-10 since 2008, and groundwater model predictions of this variability has been poor (see **Figure 4**). The cause of the water level rise is not known. It is known that this well is in poor condition and it is scheduled to be replaced in 2019.

- All of the wells have experienced long-term water level decline that is generally captured by the model.

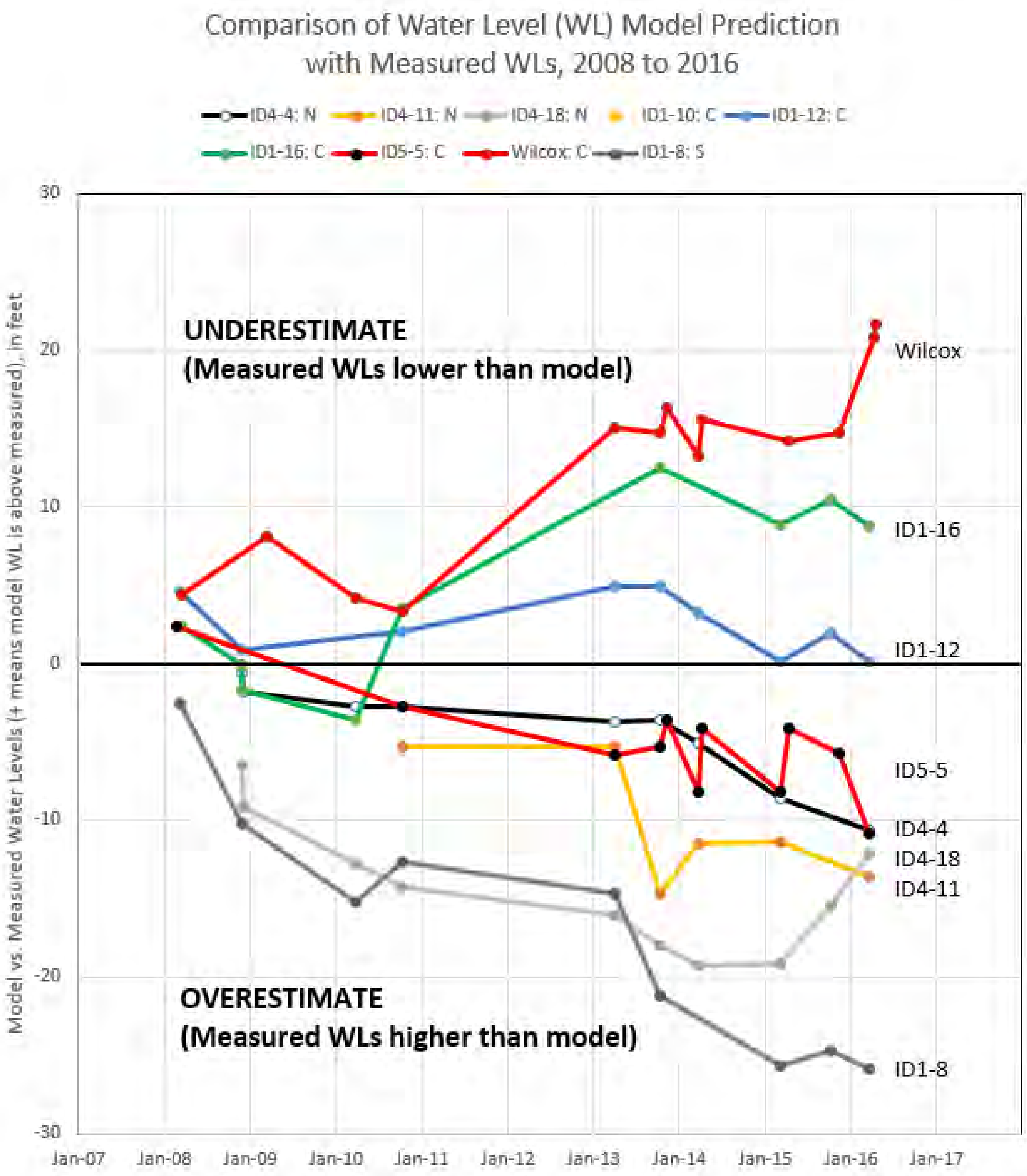
The differences between the observed and model-calculated water level elevations are described in this Section to provide a refined understanding of the model behavior. There are multiple factors included in the model including pumping rates, recharge rates, assumed aquifer geometry, and estimated hydraulic properties. As previously noted, the model parameters are based on a statistical fitting process, and differences will arise during the calibration process. Overall the model remains useful to understand the hydrology of the Subbasin and the differences do not negate the long-term observations of water level decline and overdraft impacts.

A series of Tables and Figures follow.

Figure 3 and **Table 3** summarize the comparison of the model-calculated water level elevations versus observed.

Figures 4 through **12** depict the observed and model-calculated water level elevations for each of the BWD wells. Please note that varying characteristics are highlighted among the figures.

FIGURE 3



Notes:

1. Overestimates mean that the model calculations lead to more overdraft than is being observed. This may provide a factor of safety for the well operation.
2. ID1-10 is not shown because results show the model water levels are higher than observed by 60 to 40 ft (See **Figure 4**)

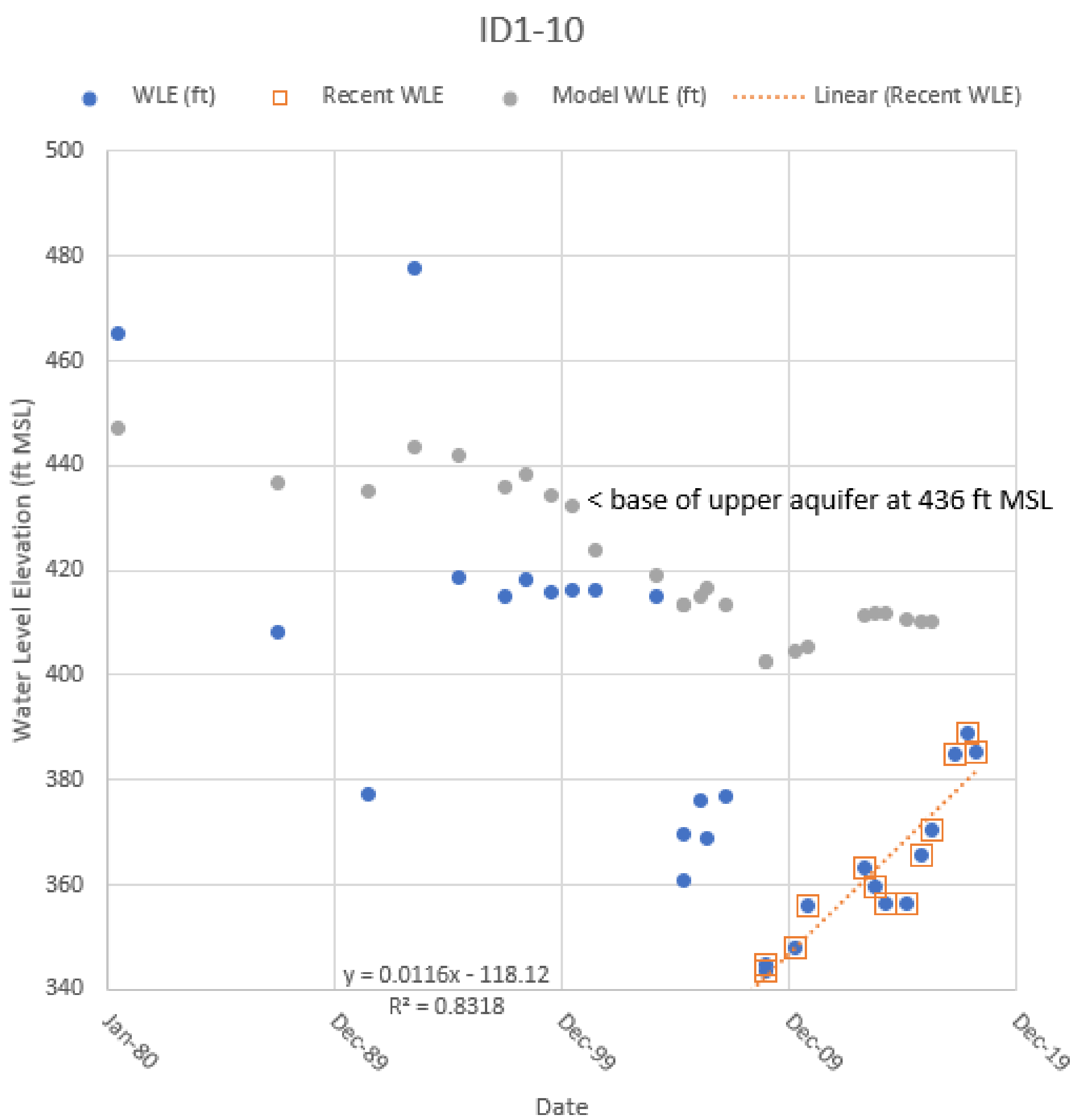
TABLE 3

Well ID	Long-term Measured Water Level Decline[1] (ft)	Measured Water Level Decline Rate (period in yrs)[2] ft/yr	Model Predictions versus Observed Water Levels **Overestimate:** **Model water level elevations are lower than observed (overestimates overdraft).** **Underestimate:** **Model water level elevations are higher than observed.**
ID4-4 (Fig 5)	74[3] (1980**)	-2.0 (7.3 years)	Model Overestimates water level decline. 2017- 2018 water level data show sharp drop after model period (not included in trend calculation)
ID4-11 (Fig 6)	56 (1995)	-1.0 (5.5 years)	Model Overestimates water level decline. Difference is increasing from 2010-2016.
ID4-18 (Fig 7)	89 (1987)	-2.6 (9.3 years)	Model Overestimates water level decline. Rates of water level decline are similar for model and observations.
ID1-10 (Fig 4)	80 (1980**)	+4.4 (9.3 years)	Indeterminate. Highly variable water levels are observed together with poor model calibration. Cause of variability is unknown. Observed water levels have risen.
ID1-12 (Fig 8)	58 (1987)	-1.4 (10 years)	Model predicted water levels match well with observed water levels.
ID1-16 (Fig 9)	53 (1991)	-0.6 (10 years)	Model Underestimates water level decline.
ID5-5 (Fig 10)	20 (2004)	-1.0 (10 years)	Model Overestimates water level decline.
Wilcox (Fig 11)	26 (2000)	-0.9 (10 years)	Model Underestimates water level decline.
ID1-8 (Fig 12)	20 (1980)	-4.5 (2.5 years)	Model Overestimates water level decline. Difference between observations and model trend is decreasing.

Notes:

1) Since well installation. The year of well installation is indicated in (parentheses). Wells ID4-4 and ID1-10 scheduled to be replaced in 2019.
2) Based on linear regression of observed water levels to calculate the annual decline rate over the time period as indicated.
3) Period ending 2016. Recent WL data obtained from the well during and not included in this analysis (see **Figure 5**).

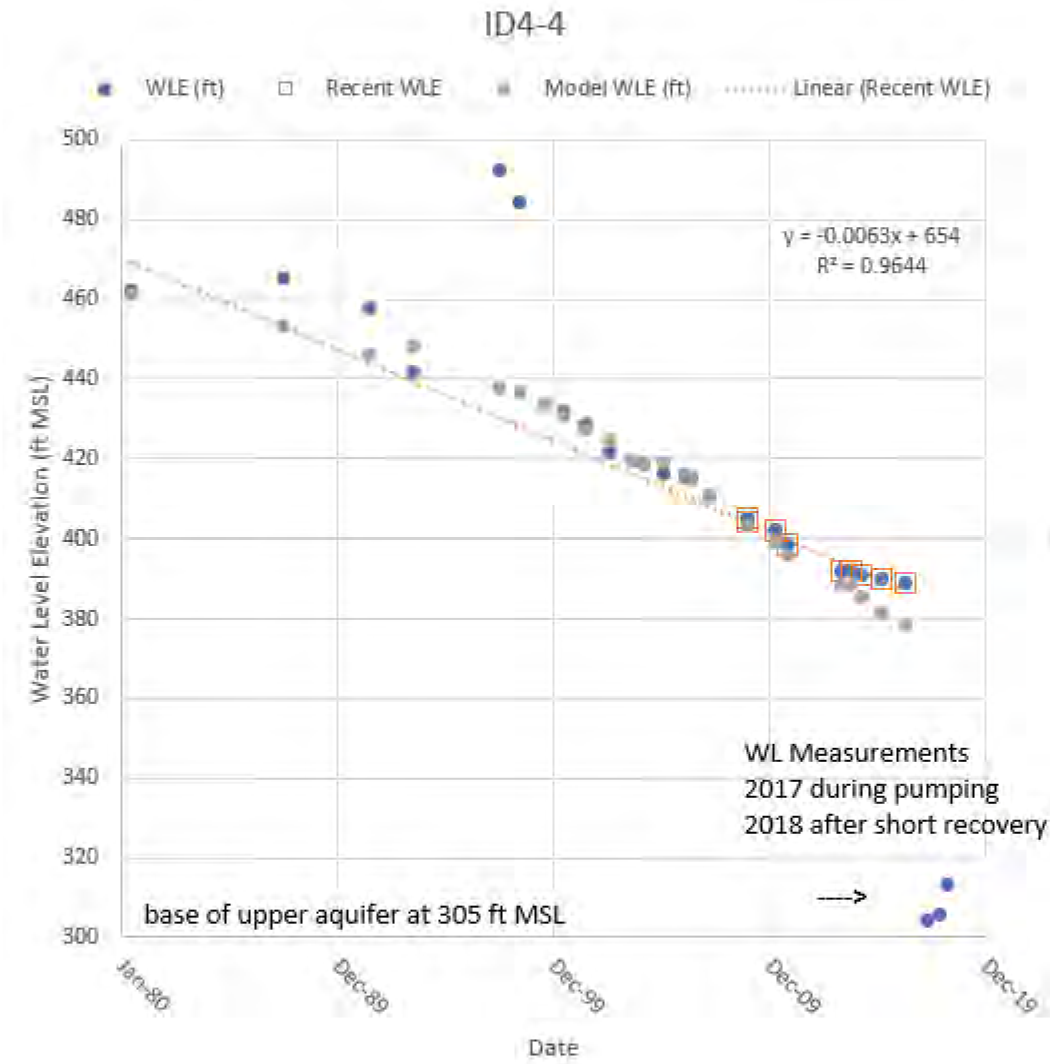
FIGURE 4. ID1-10 Hydrograph (Well in poor condition, to be replaced in 2019)



Notes:

1. Trend shown for recent measured groundwater elevation highlight the disparity with model predicted groundwater elevations. Measured and model-calculated groundwater elevations both show a rise in water levels over the past 10 years. Causes of observed groundwater elevation variability and rise have not been examined or determined.
2. Upper aquifer has been dewatered.

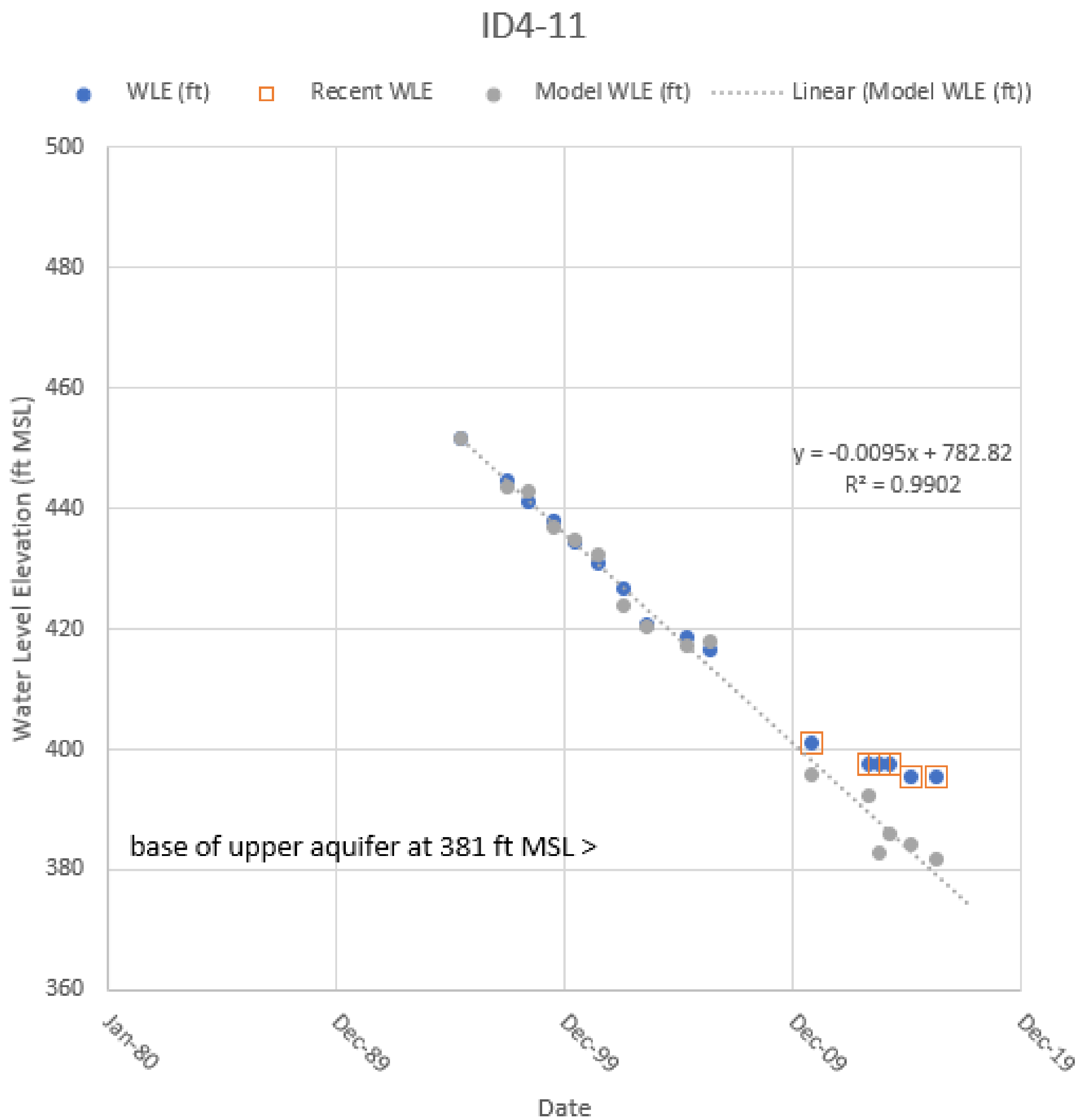
FIGURE 5. ID4-4 Hydrograph (Well in poor condition, to be replaced in 2019) Current water level decline is 2.0 ft/yr.



Notes:

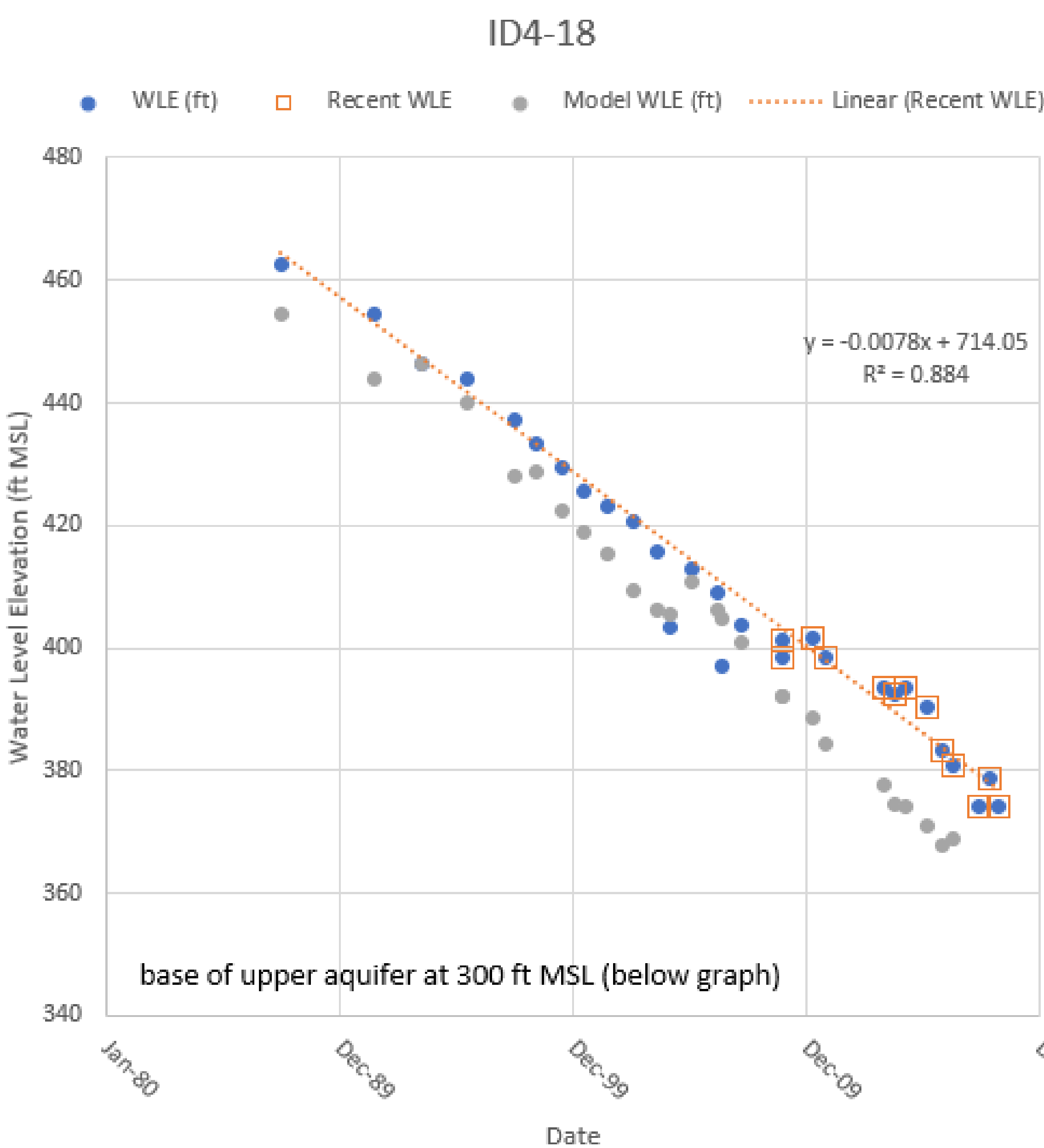
1. Model predicted groundwater elevations are lower than measured groundwater elevations observed 2008-2014. The rate of decline is also less.
2. Linear regression shown for recent data (in red squares) to highlight data versus model since 2010.
3. Upper aquifer remains viable; however, water level measurements in 2017 and 2018 are affected by pumping and likely overestimate the depth to water and water level decline.

FIGURE 6. ID4-11 Hydrograph
Current water level decline is 1.0 ft/yr.



<u>Notes:</u>
1. Model predicted groundwater elevations are lower than measured groundwater elevations, 2009-2016. Model predicted rate of drawdown from 2009-2016 shown by the linear regression line is also greater than currently measured rate of drawdown.
2. Upper aquifer has been dewatered in model simulation but measured groundwater elevations indicate the upper aquifer has not yet been completely dewatered.

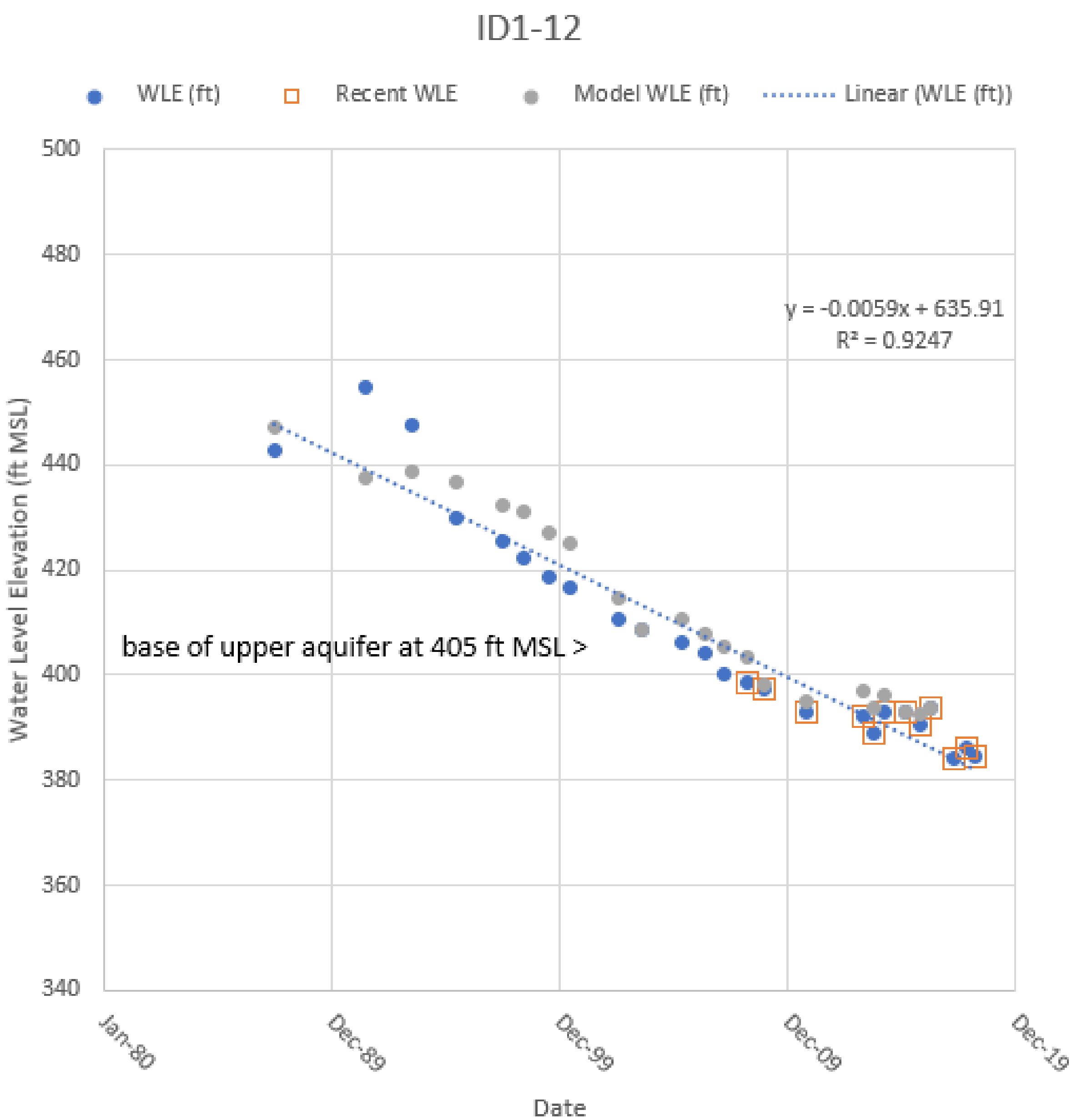
FIGURE 7. ID4-18 Hydrograph
Current water level decline is 2.6 ft/yr.



Notes:
1. Model predicted groundwater elevations are lower than measured groundwater elevations from 1995-2016. Trend shown for recent groundwater elevations (shown as squares).
2. Rates of groundwater elevation decline for predicted and measured data are similar.
3. Upper aquifer remains saturated (approximately 75 ft of saturated thickness remains).

FIGURE 8. ID1-12 Hydrograph

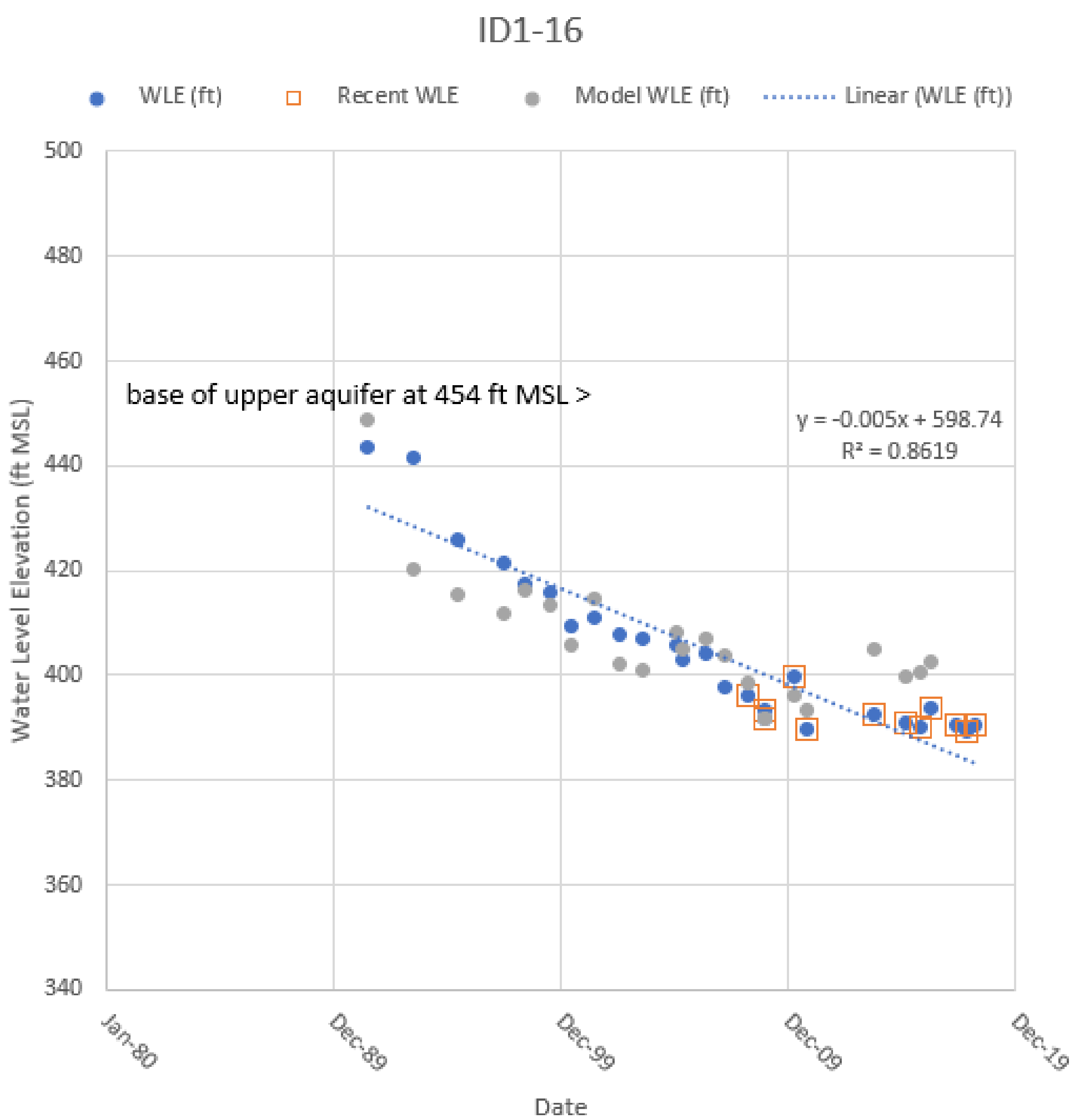
Current water level decline is 1.4 ft/yr.



Notes:

1. Linear regression trend shown for all measured groundwater elevations. Model match is reasonably good.
2. Upper aquifer dewatered during USGS model calibration period that ended in 2010.

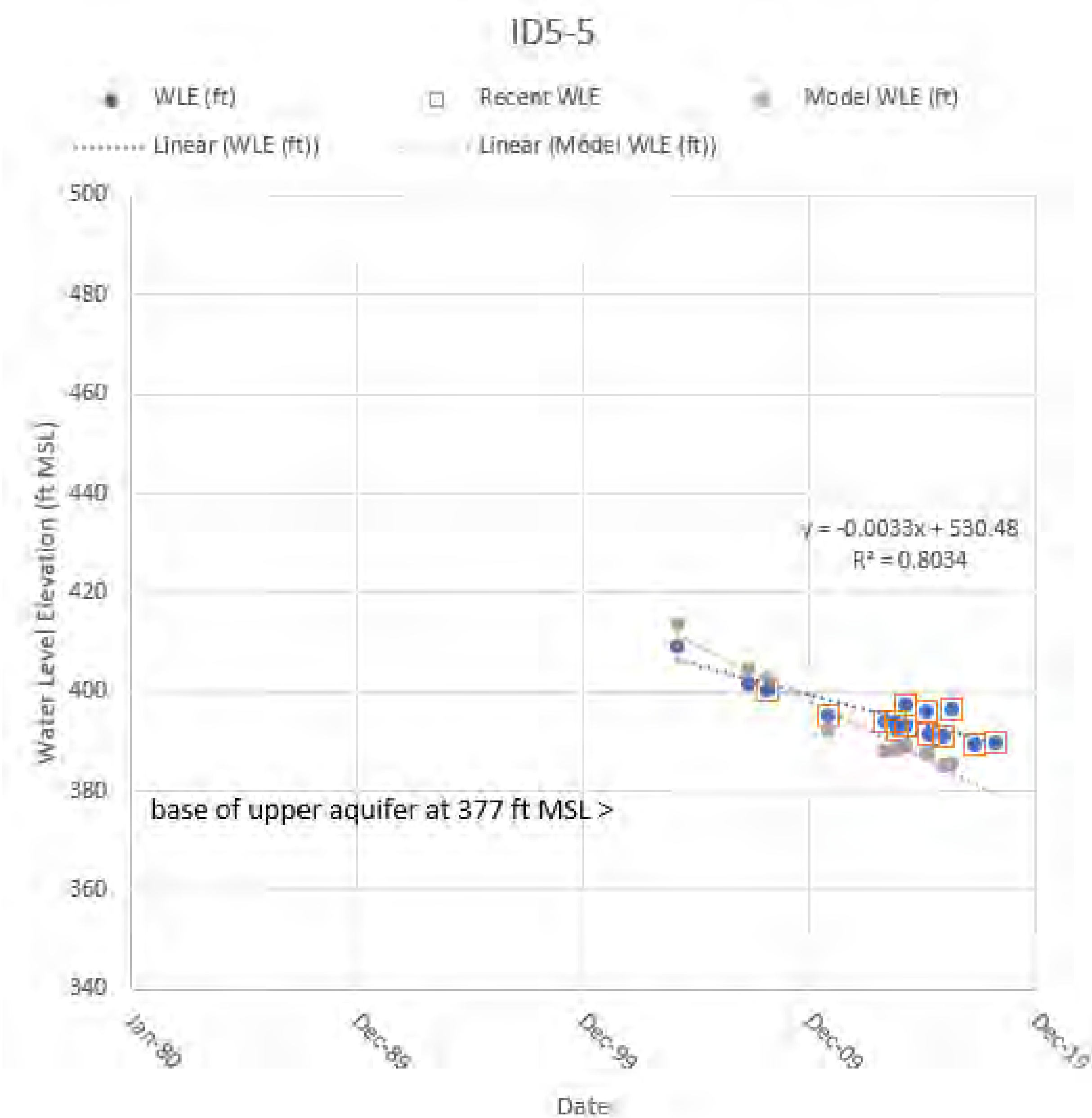
FIGURE 9. ID1-16 Hydrograph
Current water level decline is 0.5 ft/yr.



<u>Notes:</u>
1. Since 2014 indicate the model predicted groundwater elevations are higher than observed. Linear trend shown for all observed water levels.
2. Upper aquifer dewatered over 30 years ago.

FIGURE 10. ID5-5 Hydrograph

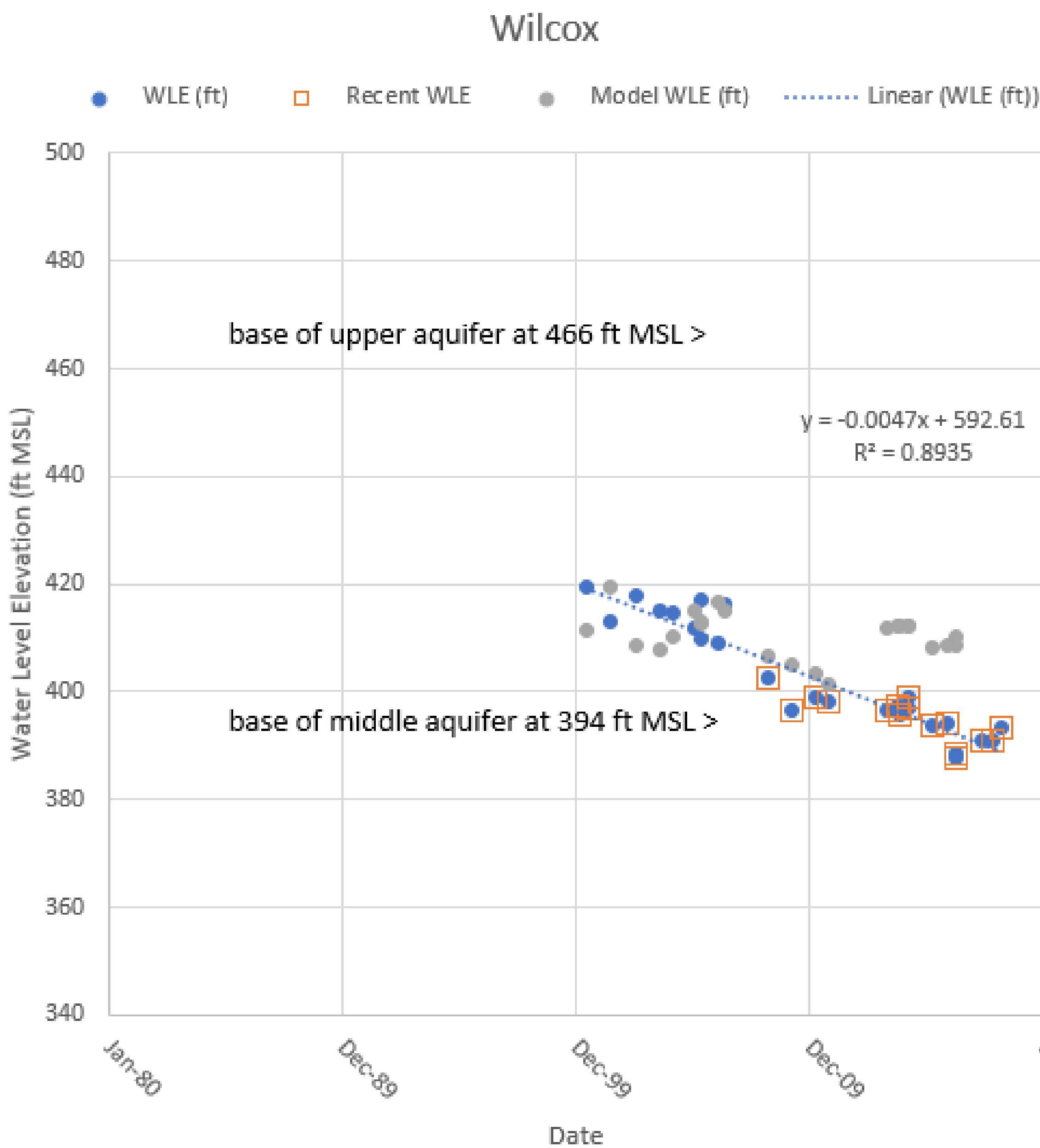
Current water level decline is 1.0 ft/yr.



Notes:

1. Model predicted groundwater elevations are lower than observed.
2. Model predicts that the upper aquifer will soon be dewatered. Observed water level data also support the upper aquifer will be dewatered but not as rapidly as calculated by the model. Linear trends have been fit to both to illustrate the relative rates.

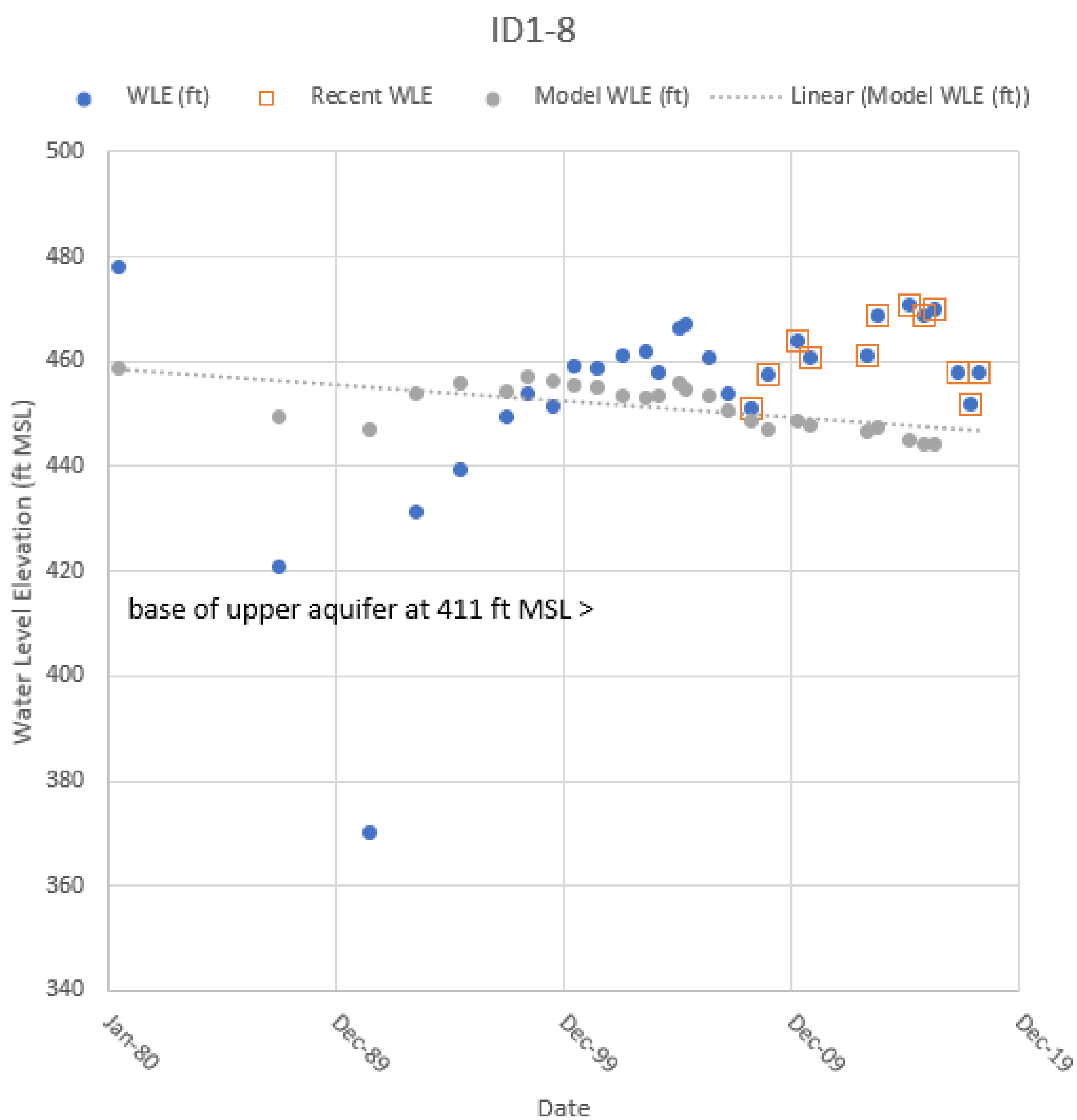
FIGURE 11. Wilcox Hydrograph
Current water level decline is 0.9 ft/yr.



Notes:

1. Model predicted groundwater elevations over the past decade are higher than the observed groundwater elevations and thus underestimate the measured rate of groundwater elevation decline.
2. Upper aquifer dewatered many decades ago. Middle aquifer dewatered in ~2015. Thus, remaining production is from the lower aquifer.

FIGURE 12. ID1-8 Hydrograph
Current water level decline is 4.5 ft/yr.



Notes:
1. Model predicted groundwater elevations do not include the rise or variability in measured groundwater elevations observed over the past decade. The model-calculated groundwater levels predict consistent groundwater drawdown instead of the groundwater level recovery observed from approximately 2000 to 2014.
2. Water levels remain within the upper aquifer.

3.0 BWD WATER SUPPLY WELLS: INTERPRETED HYDROGEOLOGY FROM DRILLER'S LOGS

The description of drill cuttings and drilling observations by the well drillers included in the well completion reports for each of the nine BWD wells were used to develop hydrogeologically-interpreted well logs. Though the observations are subjective and the quality and type of the observations can vary from driller to driller, the results were reviewed from a hydrogeologic perspective and used to develop generalized lithologies for each of the wells. It is recognized that the interpretations are subjective and are provided here as the logs are currently the only means to be able to review well-specific hydrogeologic conditions. Hydrogeologic conditions and well construction details are graphically presented (**Figures 13-21**).

The primary purpose of this review is to compare the large-scale aquifer conditions used in the model to the stratigraphic features observable in the driller's logs. The stratigraphic interpretations have also proven useful toward evaluation of the behavior of the groundwater model.

Figures 13 to 21 depict the lithologic and well construction information for each of the BWD wells in the context of USGS and SDSU stratigraphic interpretations.

The figures depict:

- Well construction and screen intervals.
- Lithologies based on a hydrogeologic interpretation of the driller's log for each well. None of the wells were geophysically logged and all observations were as reported by the drillers. The reported lithologies vary among drillers so the logs have been reviewed and described and interpreted herein using more consistent terms.
- Depths where USGS Model Aquifer Boundaries occur (from **Table 2**).
- Depths of Hydrogeologic boundaries and aquifer units as described by Netto (2001)
- Select historical water level data to illustrate overdraft impact. Please refer to **Figures 4** to **12** for specific hydrograph data for each of the wells.
- Projected water level decline. Two values are shown that correspond to a rate of 1 to 3 feet/year over 20 years, roughly in the currently-observed range for the BWD wells. The projected water level decline depicted on **Figures 13** to **21** are shown for general illustration and are not directly linked to current observations.

The lithology reported in each well log has been compared to the aquifer units and groundwater flow parameter that were incorporated into the groundwater model for the cell where each well is located in the model (see **Table 4**). The actual likely contact elevation is estimated based on the driller's log, and review of nearby logs that have been depicted in cross-sections developed by Netto (2001). **Table 4** also provides for a review of the model's aquifer discretization and parameterization and ties those findings with the hydrograph findings in **Section 2**.

TABLE 4

Well ID	Upper Aquifer Base: Model (ft, msl)	Upper Aquifer Base: Well Log (ft, msl)	ELEVATION DIFFERENCE, (Model Estimate- Well Log) For Upper Aquifer Base (ft)	Middle Aquifer Base Per Model (ft, msl)	Middle Aquifer Base Per Well Log (ft, msl)	ELEVATION DIFFERENCE, (Model Estimate - Well Log) For Middle Aquifer Base (ft)	Middle Aquifer Thickness: Log versus model (+value is thicker)	UPPER AQUIFER	MIDDLE AQUIFER	COMMENT
ID4-4	300	321	-21	-115	-163	48	69	Nearly Dewatered. Lithology log indicates base is 21 feet higher than model.	Lithology log indicates middle aquifer is thicker than model estimate.	The model's understimate of middle aquifer thickness will lead to slight overestimate of water level decline. NOTE: Lithology log indicates confined aquifer conditions may have occurrred until recently.
ID4-11	381	335	46	113	-195	308	262	Nearly Dewatered. Lithology log indicates base is 46 feet lower than model.	Lithology log indicates middle aquifer is much thicker than model estimate.	The model's understimate of middle aquifer thickness will lead to an overestimate of water level decline. NOTE: Lithology log indicates confined aquifer conditions occur.
ID4-18	300	282	18	-608	Not encountered in 700' deep well bore.	Not Calculated	very deep	Remains Viable. Lithology log indicates base is 18 feet lower than model.	Base of middle aquifer not indicated in lithology log (very deep or log lacks detail necessary to identify base).	Thicker upper aquifer than used by model will lead to an overestimate of water decline.
ID1-10	408	423	-15	219	216	3	18	Dewatered. Lithology log indicates base is 15 feet higher than model.	Lithology log indicates middle aquifer is slightly thicker than model estimate (by 18 ft).	Rising water levels and poor model match.
ID1-12	405	385	20	118	-65	183	163	Dewatered. Lithology log indicates base is 20 feet lower than model.	Lithology log indicates middle aquifer is much thicker than model estimate.	The model's understimate of middle aquifer thickness will lead to an overestimate of water level decline. NOTE: Lithology log indicates confined aquifer conditions may have occurred until recently.
ID1-16	454	197	257	308	Not encountered in 700' deep well bore.	Not Calculated		Dewatered. Lithology log indicates base is very deep- 257 feet lower than model.	Lithology log indicates middle aquifer is much thicker than model estimate. However extreme lack of fine-grained materials in the driller log suggests that the log is incomplete.	Very thick upper aquifer observed in lithology log versus model will lead to an overestimate of water decline by the model. Uncertainty: Assumes the drillers log accurately reflects lithology.
ID5-5	375	Not Analyzed		Not Analyzed				Nearly Dewatered.		Driller's log grossly generalized, of limited use, not analyzed.
Wilcox	466	550	-84	394	200	194	278	Dewatered. Lithology log indicates base is 84 feet higher than model (has no effect on model).	Lithology log indicates middle aquifer is much thicker than model estimate. However, the sediments were observed to be consolidated and may have low hydraulic conductivity like the lower aquifer.	The model's understimate of middle aquifer thickness will lead to an overestimate of water level decline. Uncertainty: the presence of consolidated sediments will lower hydraulic conductivity and cause the model to underestimate water level decline.
ID1-8	410	310	100	290	-33	323	223	Remains Viable. Lithology log indicates base is much lower than in the model by 100 feet.	Lithology log indicates middle aquifer is also thicker than model estimate. Clay at base of middle aquifer may cause confined aquifer conditions to occur within lower portion of well.	Very thick upper aquifer observed in lithology log versus model will lead to an overestimate of water decline by the model. Will also mean that the well production from the more prolific upper aquifer will be maintained for a longer duration.

NOTE:

(shaded) Indicates a well where the model-calculated water levels may overestimate water level decline.

ID4-4 (to be replaced, currently scheduled for 2019)

Comparison of model-predicted and measured water levels at Well ID4-4 (**Figure 4**) shows that the model overestimated water level decline from 2010 to 2016 by approximately 10 feet.

Upper aquifer has been dewatered so water production is now from the middle and lower aquifers. By apparent USGS criteria, review of the lithologies supports that the model over estimates middle aquifer base elevation by 48 feet, thereby underestimating middle aquifer thickness and over estimating lower aquifer thickness greater by 48 feet respectively. Because the model assigns a middle aquifer hydraulic conductivity value that is 11 times greater than lower aquifer hydraulic conductivity, the underestimate of the middle aquifer thickness will lead to slight overestimate of water level decline at well.

Review of the SDSU stratigraphy interpretation the upper aquifer thickness is underestimated by 600 feet. By this criterion the model would lead to an overestimate of water level decline at the well.

The lithology log indicates that confined aquifer conditions may have occurred until recently.

ID4-11

Comparison of model-predicted and measured water levels at Well ID4-11 (**Figure 5**) shows the model overestimated water level decline from 2010 to 2016 by approximately 15 feet.

Upper aquifer, as defined by the USGS model, is dewatered at this point in time and water production is now from the middle and lower aquifers. The model overestimates middle aquifer base elevation by 308 feet, thereby underestimating middle aquifer thickness and overestimating lower aquifer thickness greater by 308 feet, respectively. Because the model assigns a middle aquifer hydraulic conductivity value that is 5 times greater than the lower aquifer the model's underestimate of middle aquifer thickness will lead to an overestimate of water level decline at the well.

Review of the SDSU stratigraphy interpretation supports that the model under estimates upper aquifer thickness by approximately 600 feet. By SDSU criteria, hydraulic conductivity values in the model are further underestimated. leading to a greater overestimate of water level decline at the well.

The lithology log indicates that confined aquifer conditions may have occurred until recently.

ID4-18 (being considered for replacement)

Comparison of model-predicted and measured heads at Well ID4-18 (**Figure 6**) indicate that from 2010 to 2016 the model overestimated water level decline. The difference is decreasing and the model estimate is improving toward the end of the model update period (2016).

The upper aquifer remains partially saturated and currently viable. Review of the lithologic log indicates that the model slightly underestimates the thickness of the upper aquifer. This will lead to a slight underestimate of water level decline at the well. Should the upper aquifer be dewatered water production will be primarily from the middle aquifer.

A pilot borehole was drilled when the well was constructed in 1982. The well was not completed between 560 and 699 feet bgs likely because of better production from the upper aquifer at that time. The sediments encountered at depth may prove to be reasonably productive.

ID1-10

Comparison of model-predicted and measured water level elevations at Well ID1-10 indicate both are rising with time since 2009. Observed water levels are approximately 60 feet below modeled water level elevations and rising much faster than model-predicted heads during this period (**Figure 3**). Overall comparison shows high observed water level variability and poor model performance.

The upper aquifer is dewatered at this point in time. Model contacts (top and bottom of the middle aquifer) are close to drillers log based on apparent USGS criteria. Review of SDSU stratigraphic criteria supports that the model underestimates the upper aquifer thickness by approximately 140 feet. If so, the model will overestimate water level decline at the well.

ID1-12

Model-predicted and measured water level elevations at Well ID1-12 are reasonably similar and indicate the model is performing well.

The upper aquifer as defined by USGS model was dewatered in the mid-2000s. The well currently produces water from the middle and lower aquifers. Review of the lithologic log supports that the elevation of the base of the middle aquifer is higher by 183 feet versus the model and 163 feet thicker. The review also supports that the well may not be completed in the lower aquifer. If so, the model underestimates the contribution of the middle aquifer. Since the model assigns a hydraulic conductivity value for the middle aquifer that is 47 times greater than that of the lower aquifer the model, the lithology review suggest that the model has the potential to overestimate water level decline at this well. The lithology log also indicates confined aquifer conditions may have occurred until recently.

Review of SDSU stratigraphic criteria suggest that the model underestimates the thickness of the upper aquifer by over 400 feet. If the SDSU criteria are appropriate, the model underestimates hydraulic conductivity and will over estimate water level decline. However, current model-predicted heads and measured heads match closely at Well ID1-12 (**Figure 7**) so these effects are not being realized.

ID1-16

Model-predicted head and measured water level elevations at Well ID1-16 indicate that model predicted water levels are higher than observed. Data obtained for 2013 through 2016 support that the model performance is improving (**Figure 8**).

The upper aquifer has been dewatered for decades. The well currently produces water from the middle and lower aquifers.

The driller’s log for the 705' boring is very generalized and does not report encountering any silt or clay. Hence the boring does not appear to have encountered the lower aquifer. In contrast the model predicts the base of middle aquifer at 225 ft MSL. Review of the lithology log indicates middle aquifer is much thicker than model estimate. If so the model-predicted water levels will be higher than observed; however, the conspicuous lack of silt and clay in the driller log suggests that the log is incomplete.

By SDSU criteria, the model underestimates the thickness of the upper aquifer by approximately 380 feet. If SDSU's criteria is appropriate this would lead to a greater under estimated of hydraulic conductivity in the model and a greater under estimate of drawdown.

ID5-5

Driller's log is grossly generalized and has limited useful information.

Water production will soon be from the middle and lower aquifer as the upper aquifer is nearly dewatered.

Wilcox

Comparison of model-predicted and measured water level elevations at the Wilcox well indicate that model underestimates water level decline in recent years by approximately 20 feet (**Figure 10**).

Water production is from the lower aquifer- the upper aquifer had been dewatered prior to the time of well installation and the middle aquifer dewater in ~2015.

Review of the lithologic log indicates that the elevation of the base of the middle aquifer base is underestimated by 194 feet leading to a thicker middle aquifer than assumed by the model. Because the model assigns a hydraulic conductivity value for the middle aquifer that is 8 times greater than that of the lower aquifer the model may calculate more water decline than observed at this well if the middle aquifer has not yet dewatered.
By SDSU criteria the model under estimates upper aquifer thickness by approximately 180 feet. If SDSU's criteria is appropriate this would lead to a greater underestimate of hydraulic conductivity in the model and a similar effect on the model calculations.

ID1-8

Comparison of model-predicted and measured water level elevations at Well ID1-8 indicate that model overestimates water level decline in recent years by approximately 25 feet (Figure 10).

The upper aquifer remains viable in this well; however, the current rate of water level decline is 4.5 ft/year and an estimated saturated thickness of 47 feet remains per the model-estimated aquifer base. Significant upper aquifer water production remains in this well but the upper aquifer is likely to become dewatered as a result of ongoing overdraft.

Both the upper and middle aquifer thicknesses per lithologic log review are significantly greater that estimated in the model. The model assigns a hydraulic conductivity value for the upper aquifer that is 49 times greater than that of the middle aquifer, and assigns a middle aquifer hydraulic conductivity value that is 7 times greater than that of the lower aquifer. As a result, the well will be more prolific than calculated in the model and thus the model may be overestimating water level decline at this well.

The driller's log makes little reference to lithification/density of sediments making the stratigraphic assignment of the base of the middle aquifer tenuous. The base of middle aquifer as designated by the model is interpreted by SDSU as the top of the Palm Springs Formation. In contrast the USGS Model Report (see **Section 2**) indicates that they correlated the middle aquifer with the upper Palm Spring Formation. If so, this would suggest the middle aquifer is much thinner. Overall the comparison highlights the difficulty in the aquifer interpretations based on geologic boundaries.

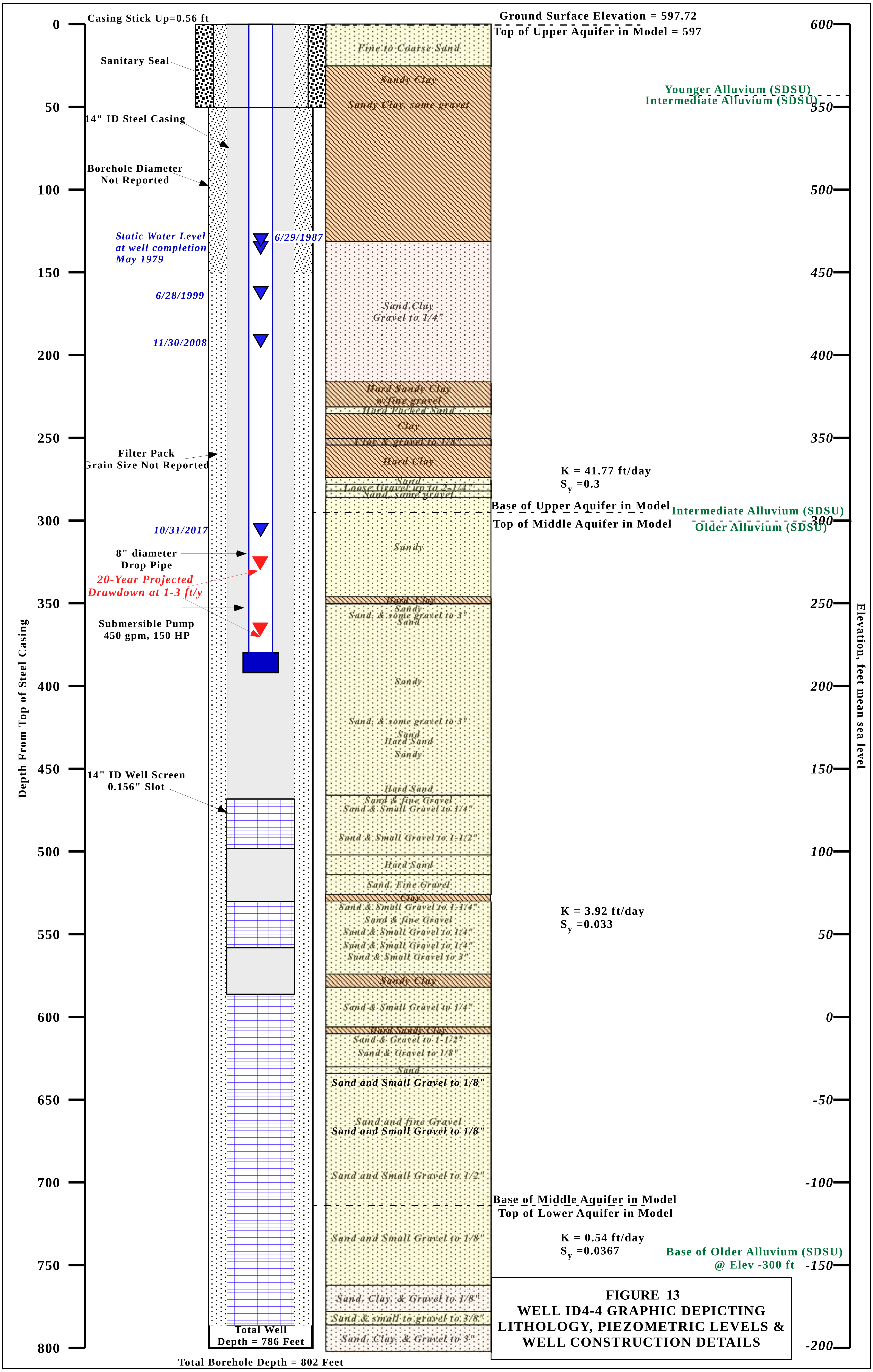


FIGURE 13
WELL ID4-4 GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

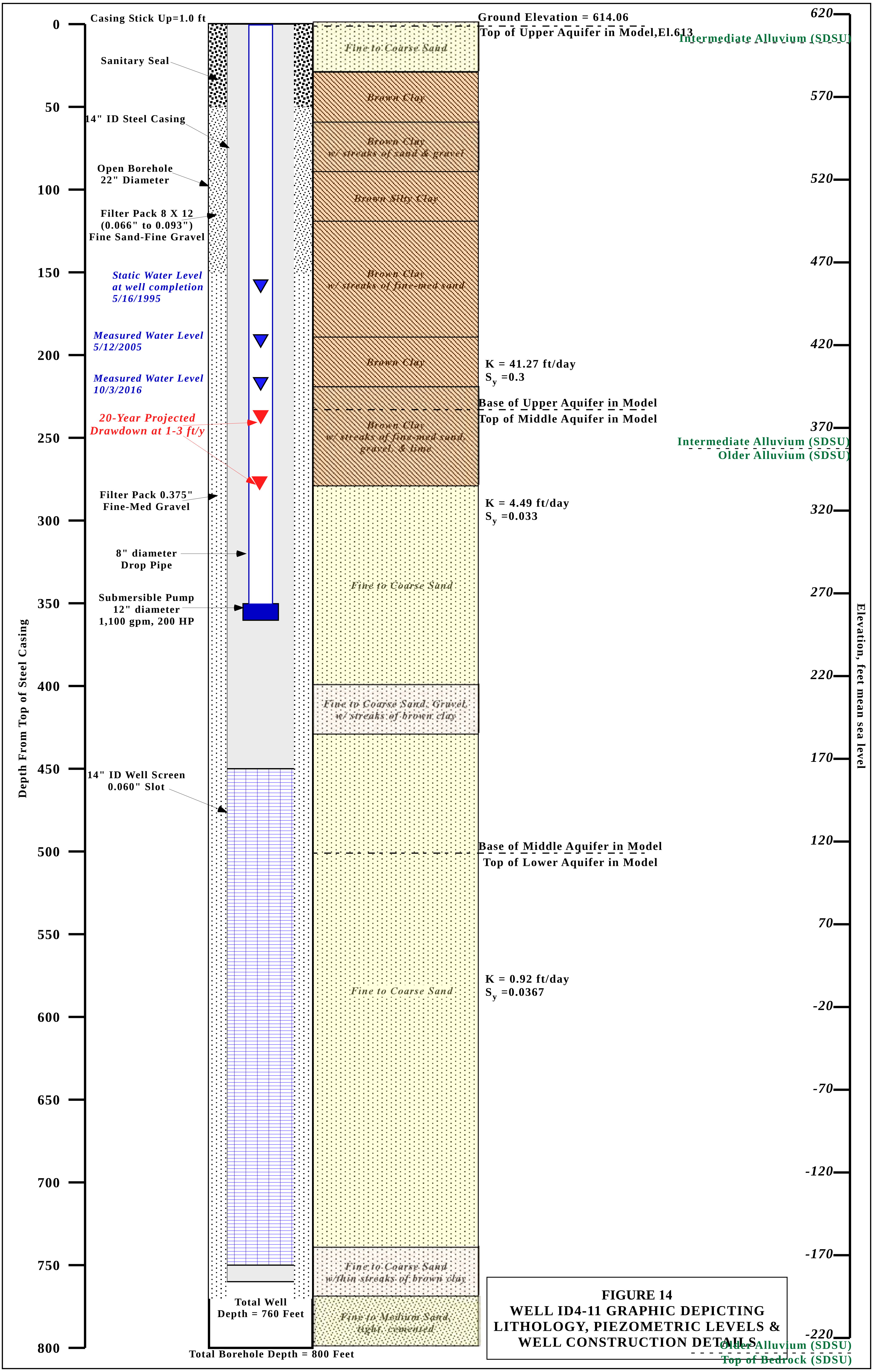


FIGURE 14
WELL ID4-11 GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

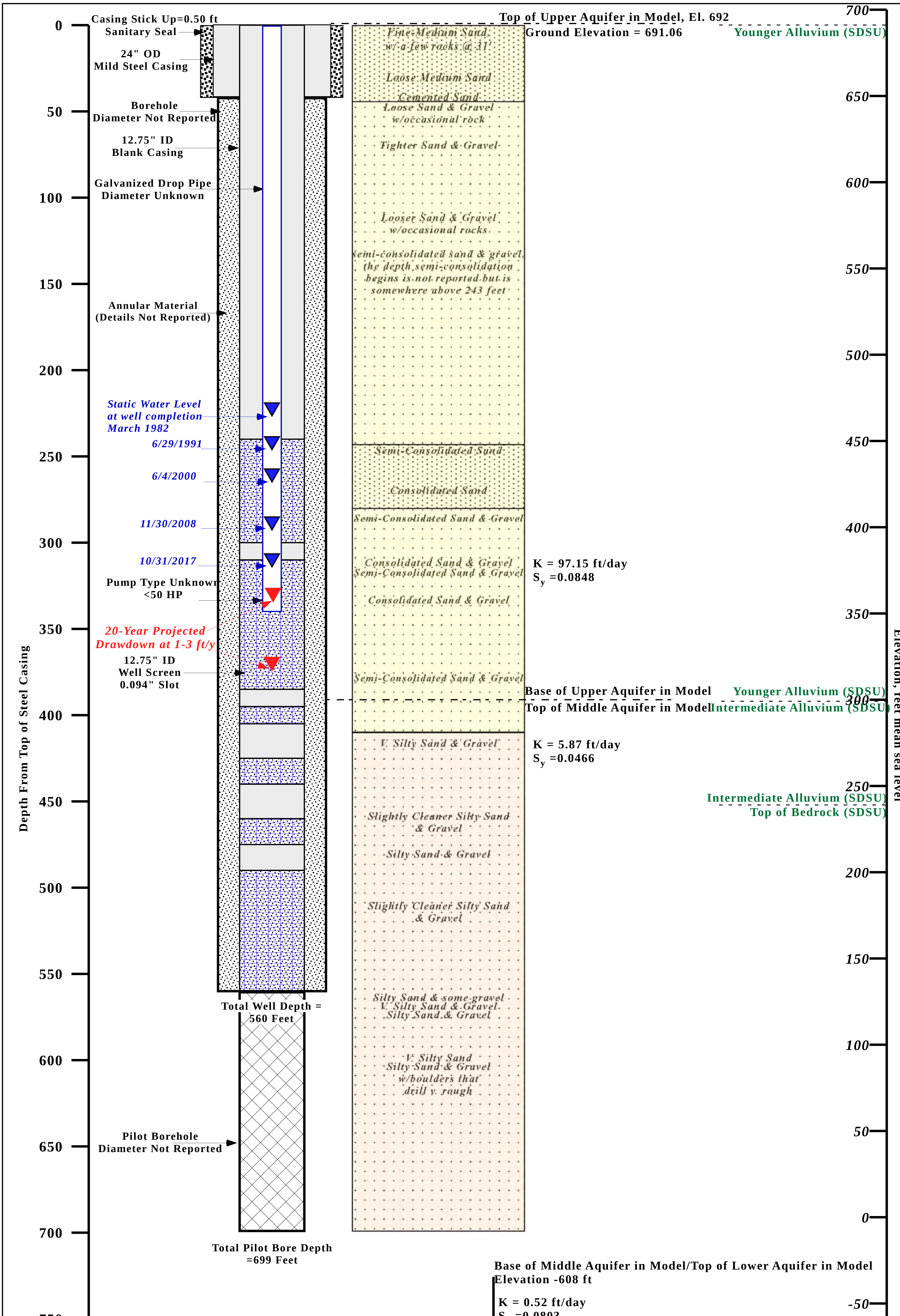


FIGURE 15
WELL ID4-18 GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

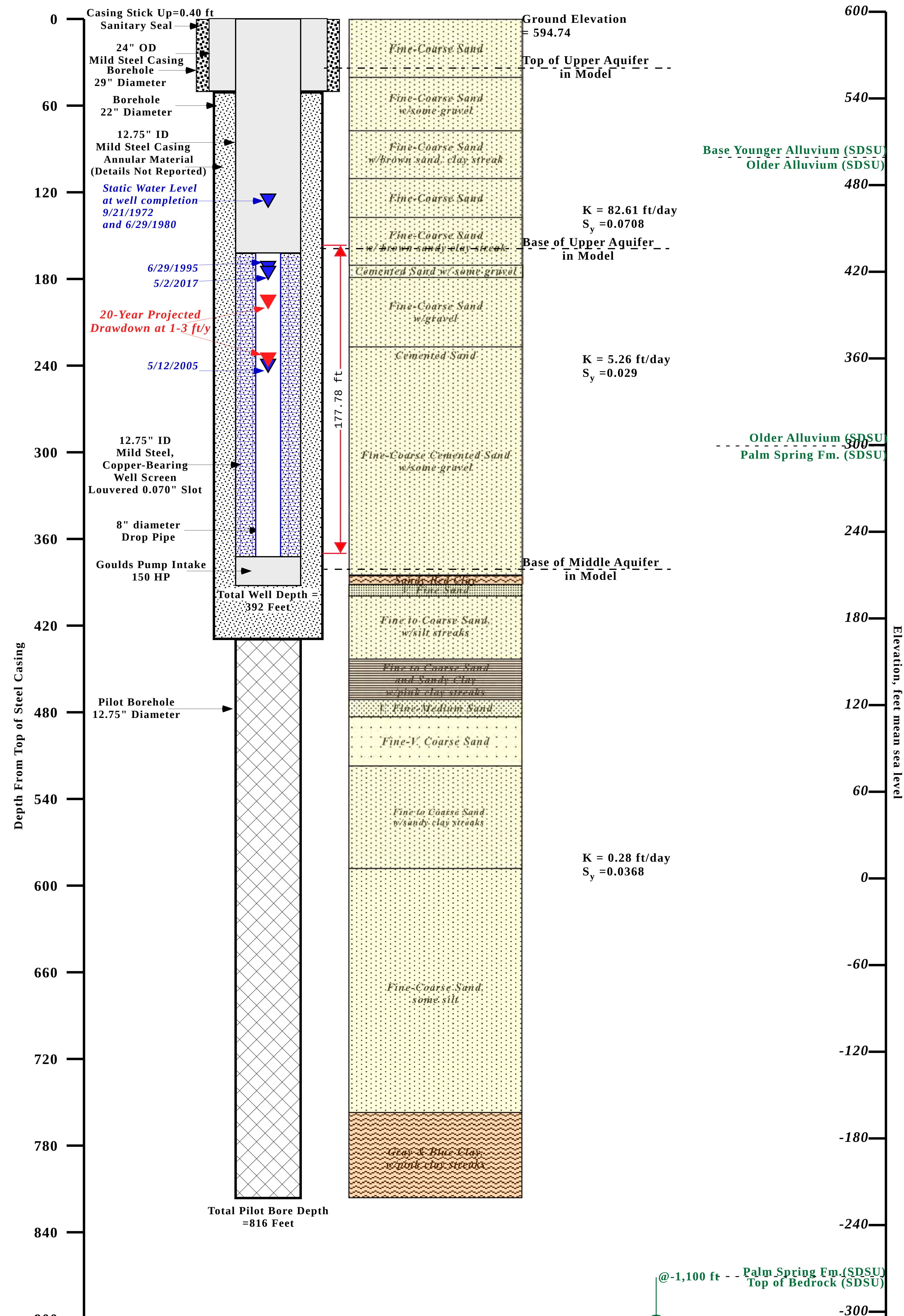


FIGURE 16
WELL ID1-10 GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

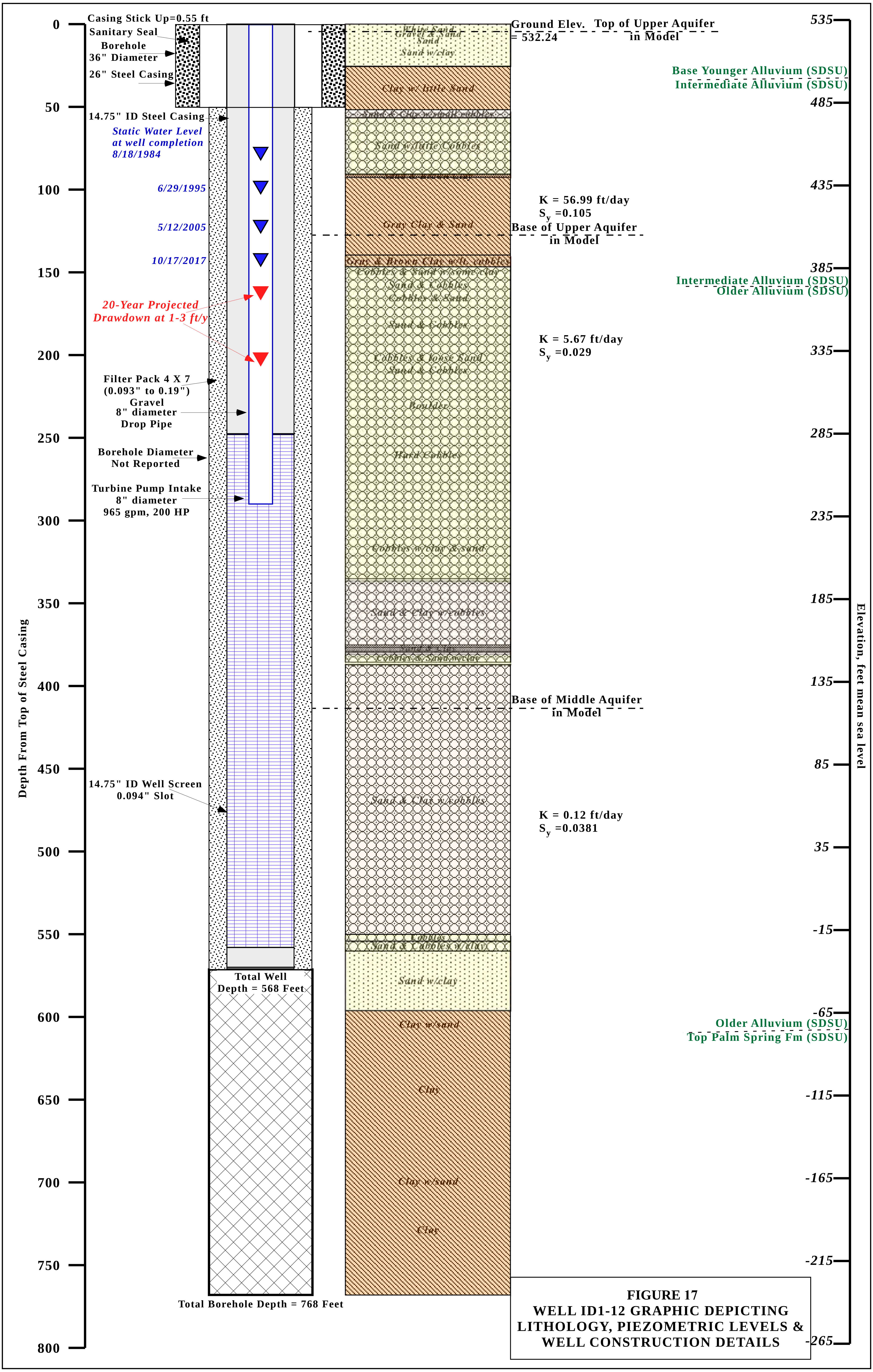


FIGURE 17
WELL ID1-12 GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

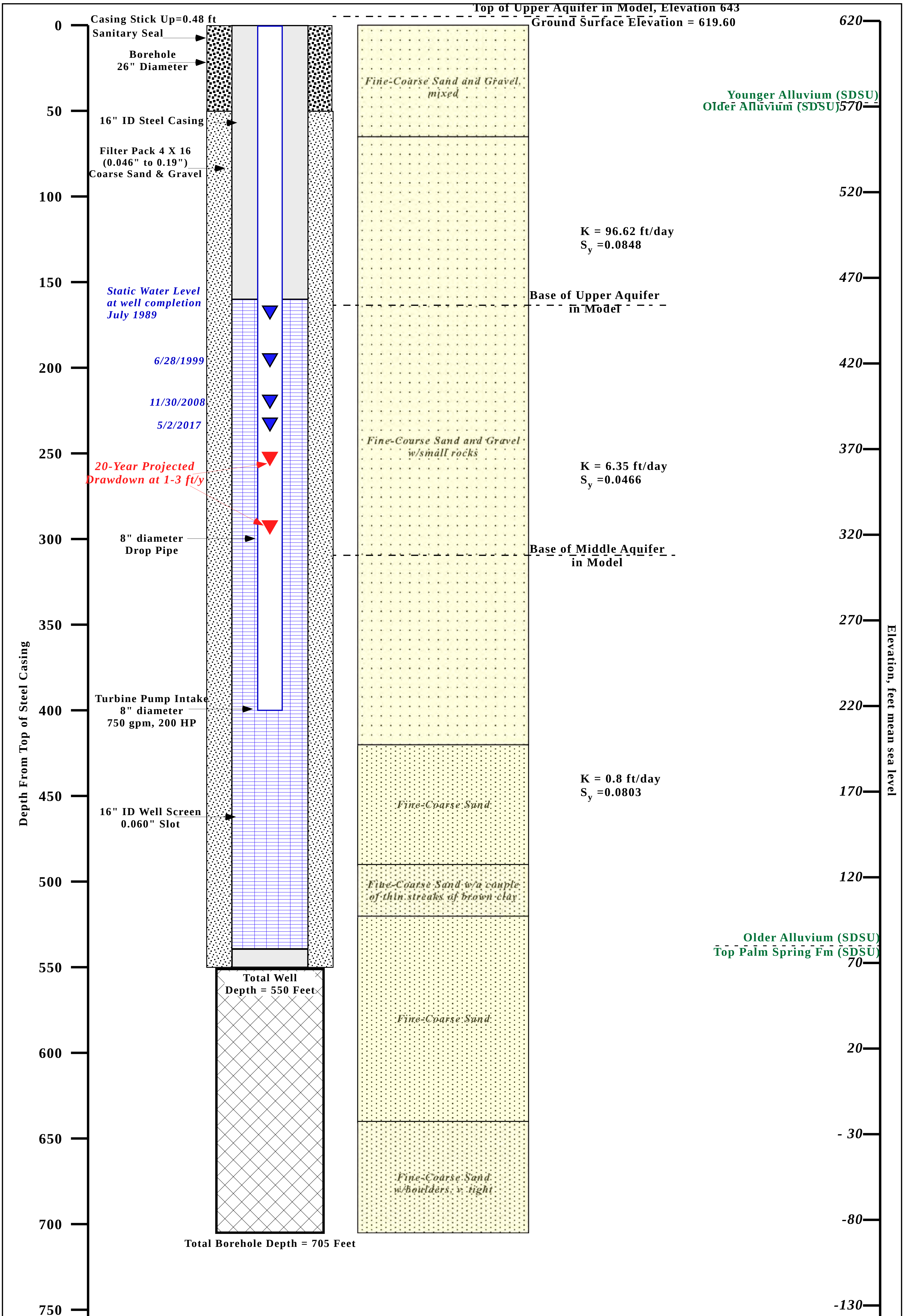


FIGURE 18
WELL ID1-16 GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

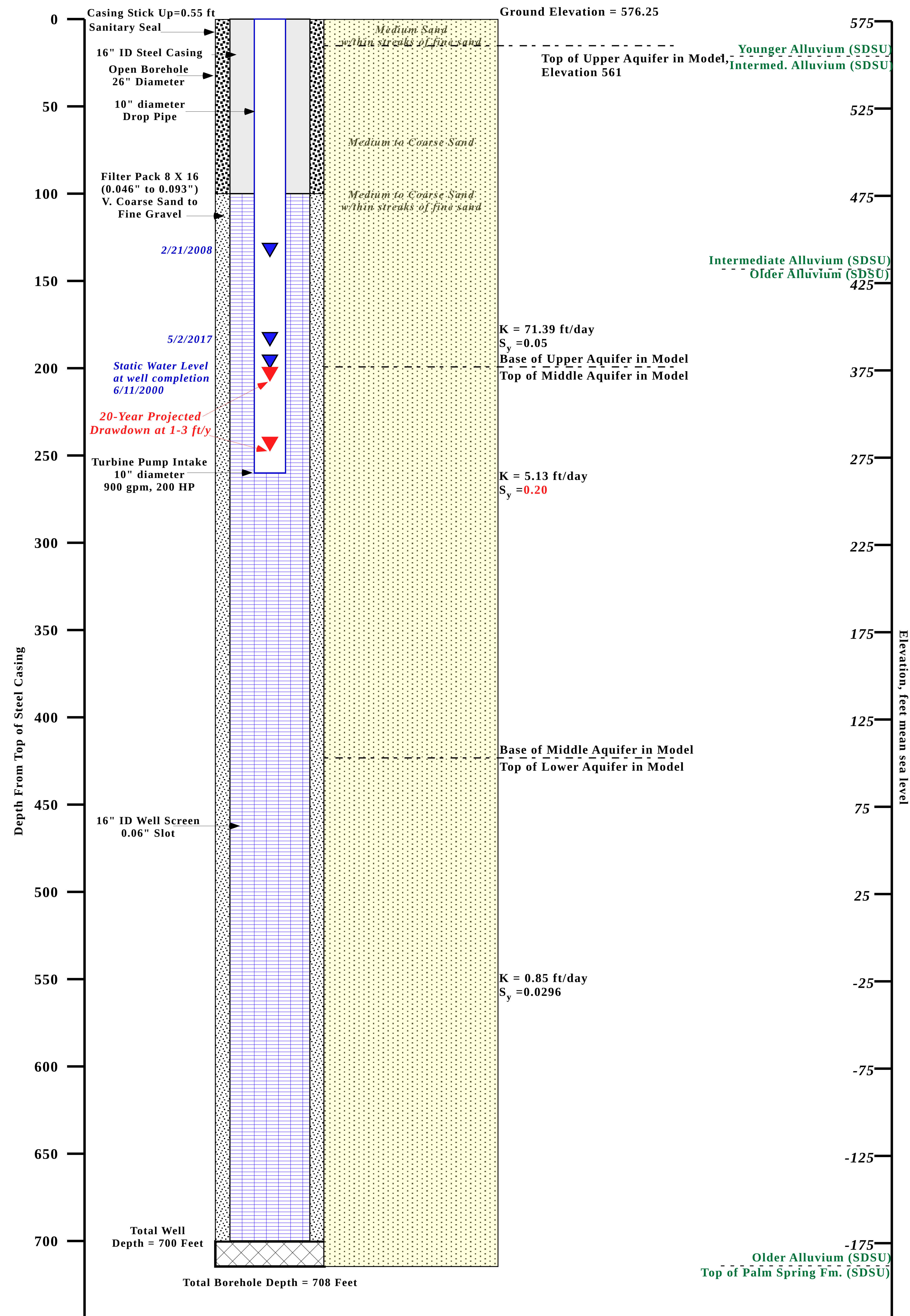


FIGURE 19
WELL ID5-5 GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

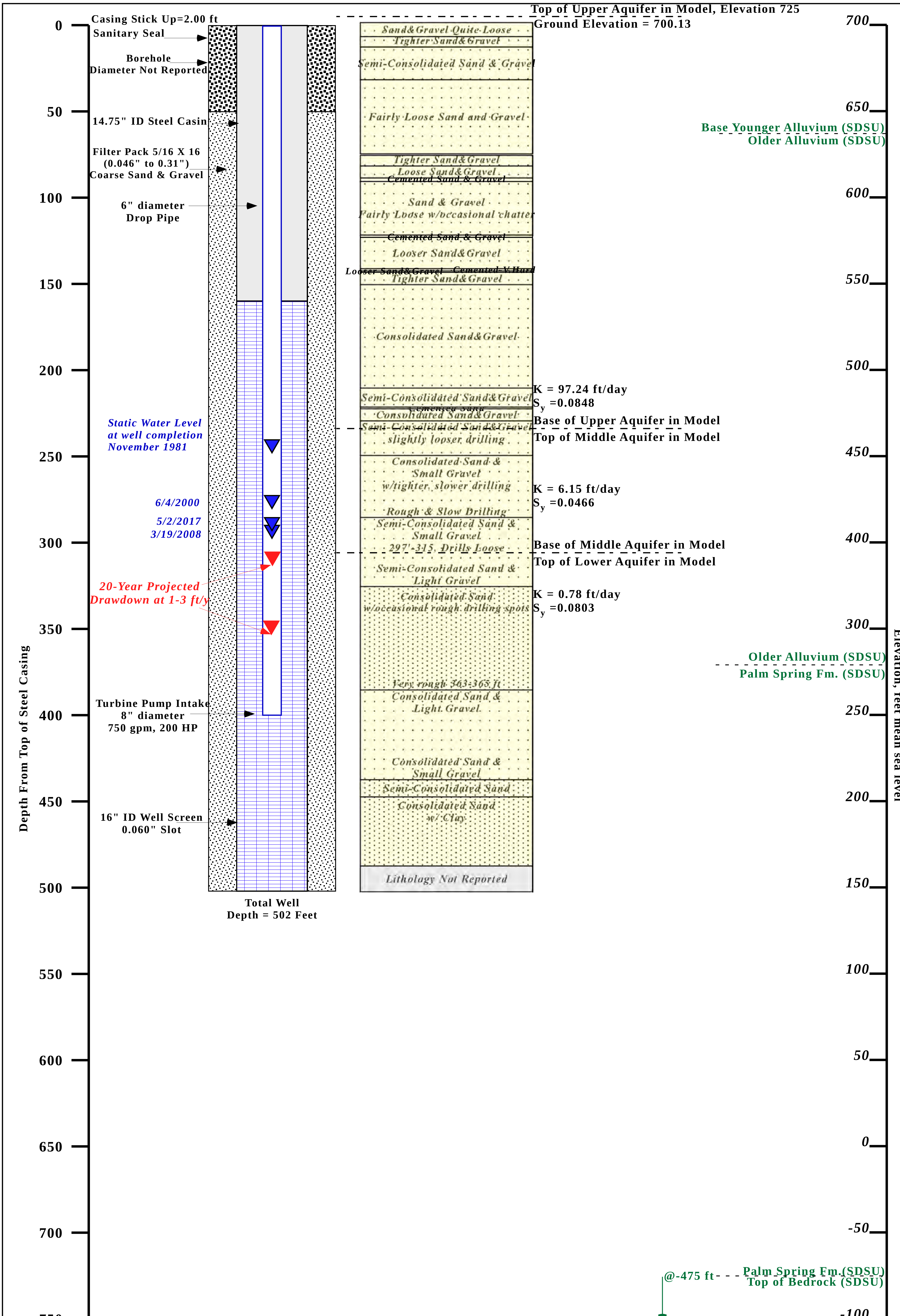


FIGURE 20
WILCOX WELL GRAPHIC DEPICTING LITHOLOGY, PIEZOMETRIC LEVELS & WELL CONSTRUCTION DETAILS

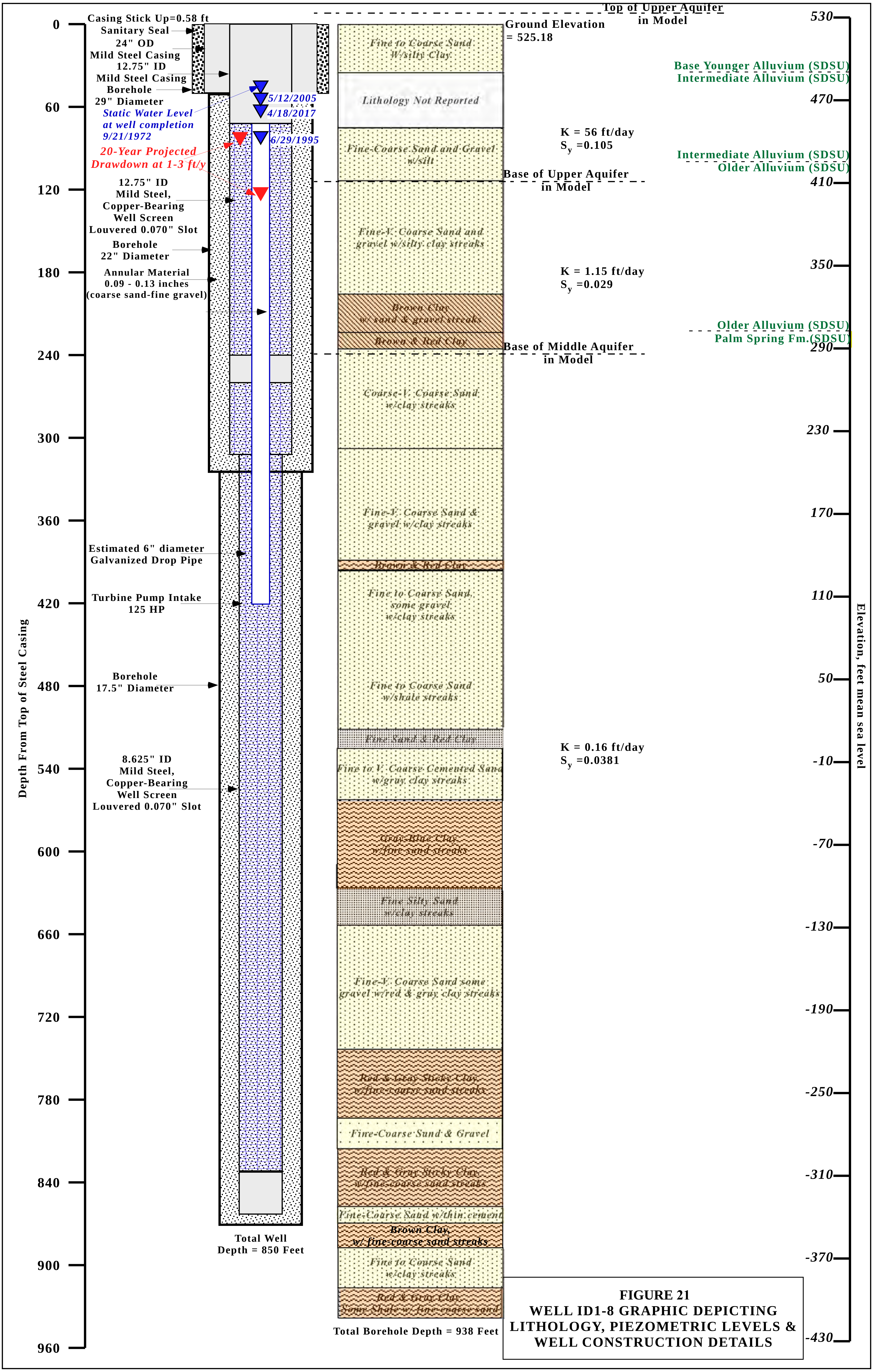


FIGURE 21
WELL ID1-8 GRAPHIC DEPICTING
LITHOLOGY, PIEZOMETRIC LEVELS &
WELL CONSTRUCTION DETAILS

4.0 EFFECT OF CONTINUED OVERDRAFT (LONG-TERM WATER LEVEL DECLINE) ON AQUIFER CONDITIONS AT BWD WELLS

The long-term ability of a well to produce water is directly related to the saturated thickness and hydraulic conductivity of the aquifer where a well is constructed. A parameter known as transmissivity, T, is used to support numerical estimates of aquifer productivity and in well hydraulics. It is the product of the saturated thickness (b, in feet) multiplied by the hydraulic conductivity (K, in ft/day), or K*b. The higher the value of T, the greater will be the amount of water that can flow through an aquifer and enter a water supply well. Declining water levels cause the aquifer transmissivity to decrease as a function of the saturated thickness as there is simply less water flowing through an aquifer and into a well. T, for a layered aquifer, is the sum of the transmissivities of each of the layers.

Transmissivity calculations were conducted for each of the wells based on current water levels, the aquifer layer elevations developed by the USGS for use in the model, and the hydraulic conductivity at the well. Future water levels were then calculated based on current rates of water level decline observed at each of the wells as depicted in the well hydrographs in **Section 2.2**. While not a direct assessment of well yields, the calculations provide insight regarding how overdraft will affect long-term well yield.

TABLE 5

	Well	delWL, ft/yr	K, upper ft/day	b, upper ft	K, middle ft/day	b, middle ft	K, lower ft/day	b, lower ft	rated gpm
NMA	**ID4-4***	2.0	41.77	8	3.92	420	0.54	72	395
	ID4-11	1.0	41.27	12	4.49	268	0.92	252	920
	ID4-18	2.6	97.15	74	5.87	170	0.52	0	130
CMA	**ID1-10***	1.0	82.61	0	5.26	171	0.28	0	317
	ID1-12	1.4	56.99	0	5.67	265	0.12	147	890
	ID1-16	0.6	96.62	0	6.35	83	0.80	230	848
	ID5-5	1.0	71.39	13	5.13	225	0.85	276	542
	Wilcox	0.9	97.24	0	6.15	0	0.78	192	205
SMA	**ID1-8**	4.5	56.00	47	1.15	102	0.16	498	448
			provisional estimate (after well replacement)						

The calculations for each of the wells are based on the saturated sediment thickness based on the depth of each of the wells. As illustrated by **Figure 2** and the values in **Table 5**, the hydraulic conductivities (K, in ft/day) decrease from the upper to the middle aquifer, and again from the middle to the lower aquifer. The aquifer thicknesses (b, in ft/day) vary depending on aquifer geometry and degree of overdraft. Note that the upper aquifer has been substantially dewatered in all but 2 of the wells, and the middle aquifer has been dewatered at the Wilcox well. The results of the calculation are shown in graphical form in **Figures 22** and **23**, below, and further discussed in **Section 5** and in **Table 6**.

FIGURE 22

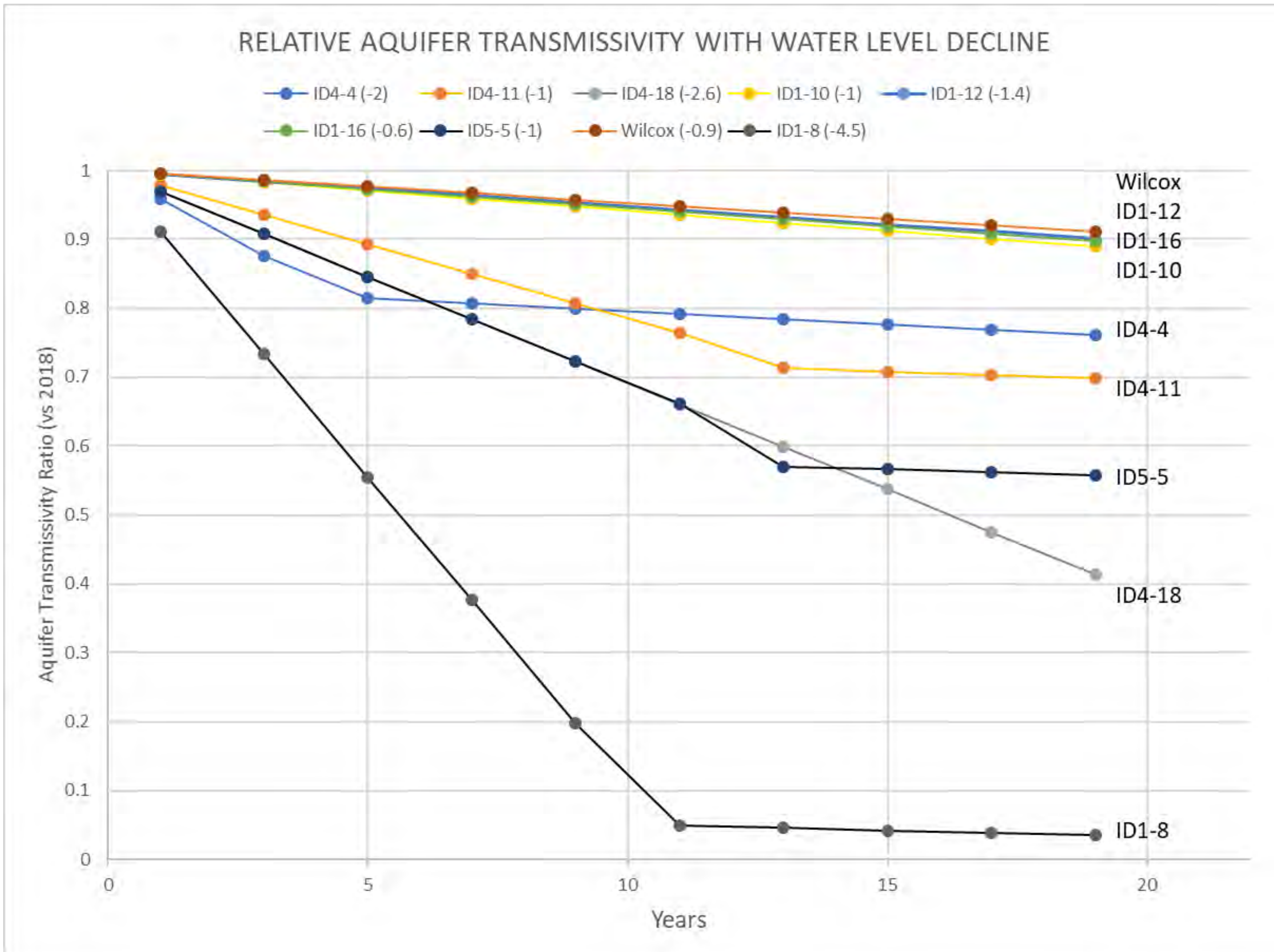


Figure 22 depicts the change in transmissivity over time expressed as a ratio, starting at a value of 1 and decreasing. The annual rate of water level decline is noted for each well in the chart labels, was assumed constant, and ranges from 0.6 to 4.5 ft/year. A future water level decline rate of 1.0 ft/year is provisionally assumed for the ID1-10 replacement well. Three behaviors can be noted:

- Linear decrease (Wilcox, ID1-12, ID1-16, and ID1-10) to approximately 90% of initial. Water levels remain within an aquifer layer so T decreases linearly with water levels. For example, a 10% decrease in water level equates to a 10% decrease in T.

- T decreases linearly but at a much higher rate (ID4-18). Here the more prolific upper aquifer is being dewatered so the impact on T is more severe, decreasing to approximately 40%.

- The decrease in T after the upper aquifer is dewatered changes. This is observed in ID4-4, ID5-5, and ID1-8 after 5, 13, and 11 years, respectively.

FIGURE 23

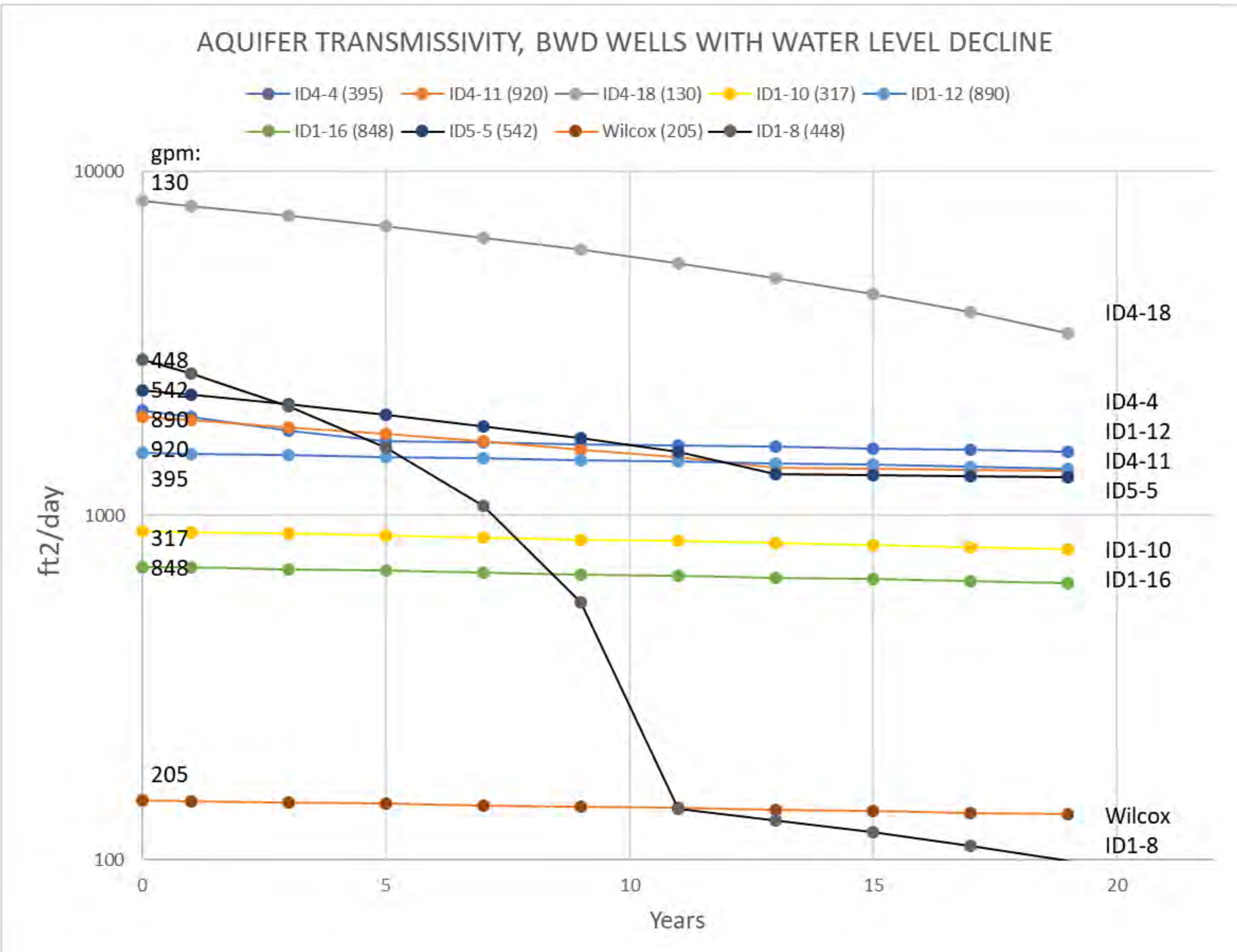


Figure 23 shows the magnitude of the changes in Transmissivity over time at the various well locations. The changes in the magnitude of T per well are depicted in **Figure 22.** Significant changes occur when an aquifer that provides water to a well is dewatered. The chart illustrates the following:

- Well ID1-8, where water levels are declining 4.5 ft/year, is severely affected by overdraft. For reference it is currently rated at 448 gpm and the Wilcox well is at 205 gpm.

- Dewatering of the more prolific, higher permeability upper aquifer is having a significant effect on ID4-18, and a lesser effect on ID5-5.

- The calculated T values do not necessarily reflect the observed well performance as the well conditions are not accounted for. The gpm ratings are indicated along the left side of the chart. ID4-18, a well reportedly in poor condition, is located in an area of high T but has a relatively poor production rate.

Long-term overdraft has led to the loss of the upper aquifer as a source of water for many of the BWD wells, and the upper aquifer will become dewatered over the next 20 years at the currently-observed rates of water level decline in all but one of the wells (ID4-18 is the exception). Fortunately, the middle aquifer has proven to be a reliable source of water with sufficient production rates to meet current BWD demand.

Water supply well production rates are expected to decrease as a result of ongoing water level decline. The greatest impact occurs when the upper aquifer is dewatered as indicated by the four wells (ID4-4, ID4-11, ID5-5, and ID1-8) where the upper aquifer is projected to become dewatered as best illustrated in **Figure 22**. For reference the hydraulic conductivity of the Upper Aquifer included in the model ranges from 9 to 49 times that of the Middle Aquifer. This means relative to potential aquifer productivity that a 10-foot thick layer of the Upper Aquifer is equivalent to a 90- to 490-foot thick layer of the Middle Aquifer.

Where the upper aquifer has already been dewatered (e.g. Wilcox, ID1-12, ID1-16, and ID1-10) transmissivities decrease by approximately 10% and the wells are relatively unaffected. ID1-8 is especially affected because of water levels that are falling at a rate of 4.5 ft/yr. **Figure 23** shows the calculated values of transmissivity over time. Review of the results supports that the magnitudes of transmissivity are in a range where the wells should remain productive, with the exception of ID1-8.

The transmissivity values are used to provide an approximate measure of the potential decrease in well productivity. The flow rates are adjusted based on the change in transmissivity presented in **Figure 22** and the calculations presented in **Table 6**.

TABLE 6

	NMA			CMA					SMA
Well:	**ID4-4***	**ID4-11**	**ID4-18**	**ID1-10***	**ID1-12**	**ID1-16**	**ID5-5**	**Wilcox**	**ID1-8**
Rated Flow, gpm	395	920	130	317	890	848	542	205	448
% T at 10 years	80%	80%	70%	95%	95%	95%	70%	95%	15%
Adjusted Rate, gpm	316	736	91	301	846	806	379	195	67
% T at 20 years	75%	70%	40%	90%	90%	90%	55%	90%	5%
Adjusted Rate, gpm	296	644	52	285	801	763	298	185	22
	* Poor condition wells scheduled to be replaced in 2019.								
	Evaluation of Pumping Rate at 1600 AFY Demand (992 gpm continous pumping rate)								
	TOTAL	% loss	**8 hr/day**	versus demand	**12 hr/day**	versus demand			
Flow Rate, gpm	4695		1565	158%	2348	237%			
Adjusted Rate, 10 yrs	3737	20%	1246	126%	1868	188%			
Adjusted Rate, 20 yrs	3347	29%	1116	112%	1673	169%			

The calculations presented in **Table 6** assume that the current well performance depends solely on the model-calculated transmissivities. Individual well performance depends on multiple factors aside from the transmissivity. These include whether a well is properly functioning and hydraulically efficient, the heterogeneity of sediments in the vicinity of a well, and how the well and aquifer will respond to pumping. While multiple assumptions and approximations are involved in the calculations, they do provide insight regarding how the well productivity can be expected to change over time as water levels decline. Here periods of 10 and 20 years are included for general comparison. Two total well pumping rate values are presented as a range based on an operating schedule of either 8 or 12 hours/day. Review of the results supports:

- Current flow rates provide 158 to 237 percent of current demand capacity, assuming that all of the wells are in production and that the flows can be managed by BWD's water storage and distribution system.

- After 10 years the wells provide 126 to 188 percent of current demand capacity- a reduction of approximately 20% from current capacity.

- After 20 years the wells provide 112 to 169 percent of current demand capacity- a reduction of approximately 29% from current capacity.

- Production rates of Wells ID4-18 and ID1-8 significantly diminish. These wells are likely to be no longer cost-efficient to operate.

This analysis indicates that while combined pumping capacity of the wells will support BWDs' current demand, the reserve capacity of the water supply is diminishing and at least two of the wells may no longer be cost effective to operate. Pumping (lift) costs will also increase as water levels fall. Some of the impacts on reserve capacity may be offset, depending on timing, by pumping rate reductions required under the GSP.

The transmissivity-based production rate analysis does not account for the physical condition of the wells and is based on the aquifer properties for three distinct aquifer layers as describes in the USGS groundwater model. Well conditions are known to be poor at ID4-4, ID1-10, and ID4-18 and their production rates as tested (see **Table 6**) likely underestimate potential well performance. Wells ID4-4 and ID1-10 are scheduled to be replaced in 2019 and both will be completed in the middle and possibly lower aquifers depending on the results of drilling and testing. For additional details please refer to Dudek's report entitled *Proposition 1 SDAC Grant Task 5 Water Vulnerability/New Extraction Well Site Feasibility Analysis* (dated 12/21/2018). Also included in the 12/21/2018 report is information regarding the physical condition of BWD's wells, evaluations of well longevity, identifies six pressure zones used in BWD's water supply system, and supporting details and recommendations for well replacement.

The foregoing analysis examines the total well production and does not include the ability of BWD's pipeline and storage system to deliver the water. Review and analysis of ongoing well testing and water level monitoring will be necessary to track the performance of the wells relative to the approximations and estimates developed for this report.

5.0 SUMMARY

The Borrego Water District (BWD) actively operates eight water supply wells and has a ninth in reserve. Of concern is the impact of continued overdraft to BWD's ability to reliably produce drinking water. Overdraft is being addressed under the Sustainable Groundwater Management Act (SGMA) by the development and implementation of a Groundwater Sustainability Plan (GSP) as previously explained in this report. The combined production from these wells is sufficient to meet the current water demand provided the water can be delivered via BWD's water storage and distribution system. Two wells (ID4-4 and ID1-10) are in poor condition and scheduled for replacement in 2019. The new wells will improve the reliability of the water supply and will likely increase BWD's available pumping capacity.

Long-term overdraft has affected all of the BWD water supply wells and water level decline is ongoing. Current rates of water level decline at BWD wells range from 0.6 to 4.5 ft/year. BWD water supply wells are becoming increasingly reliant on water produced from deeper, less productive sediments. This results in wells that become less productive and to have increased pumping costs as water levels decline. Conceptually the aquifer system consists of three units termed the upper, middle, and lower aquifers. Of these the upper aquifer has historically water proven to be the most prolific since it generally consists of coarse-grained alluvial sediment with hydraulic conductivities roughly 10 times higher than the middle aquifer. Much of the upper aquifer has been dewatered forcing well production to become dependent on the middle and lower aquifers.

Calculations presented in **Section 4** support that the combined well production has the potential to continue to be able to support the quantity of water necessary for BWD's current water supply demands over the next 10 to 20 years. While the middle aquifer and lower aquifers are less prolific than the upper aquifer, BWD water supply wells are currently able to maintain pumping rates ranging from 130 to 920 gpm. Future water production rates are projected to decrease approximately 20 to 30 percent over the next 10 to 20 years based on current rates of water level decline.

Note that this analysis does not consider the potential impact of overdraft on water quality or future water demand related to undeveloped properties in the Borrego Valley. Please refer to the GSP and a separate ENSI report dated 12/7/2018 included within the GSP that provide an assessment of how groundwater quality is being affected by overdraft and land use. As noted in **Section 1.1.1**, the future water demand due to undeveloped parcels as currently zoned and/or entitled may prove to be unsupportable under SGMA constraints. Evaluation of future water demands will be addressed under SGMA will be included in the GSP.

This report examines the model results and aquifer conditions at the scale of BWD water supply wells. This was done by comparing the current model results at BWD water supply wells together with review of driller's logs and the aquifer boundaries and parameters included in the model construction.

Analyses are presented in this report to:

1) Compare observed and modeled water level decline at BWD wells (**Section 2**). Hydrographs depicting groundwater levels measured over time at each of the BWD water supply well were developed and presented in this report. Water level observations are the primary measure of overdraft.

2) Examine available lithologic data from BWD wells to assess the performance of the large-scale groundwater model relative to local conditions (**Section 3**). Hydrogeologic evaluation of driller's logs and review of available detailed geologic cross-sections and structure maps were conducted to establish stratigraphic conditions at each BWD water supply well. The model was developed to address groundwater conditions across the 88 mi^2 Subbasin and necessarily requires that aquifer conditions be assessed at a relatively large scale as compared to hydraulic conditions that occur at the scale of individual wells.

3) Evaluate potential changes in aquifer productivity, as measured by aquifer transmissivities used in the model, in the vicinity of BWD wells as a function of water level decline (**Section 4**).

The overall goal of the GSP is to attain a sustainable hydrologic condition where water extracted from the aquifer system is replenished by recharge and thus eliminate long-term overdraft within the Borrego Subbasin. The analyses of this report assume that current water level decline rates observed at BWD wells will continue over the next 20 years. Overdraft will affect all of the wells, with the most significant loss in production occurring in a subset of the wells when the upper aquifer is dewatered. As water production shifts to the middle aquifer the well capacities decrease and production rates are expected to generally decrease to varying degrees as a function of water level.

Among the findings of this report include:

1. Hydrograph Analyses

- Current rates of water level decline range from 0.9 to 4.5 ft/yr. The highest rate is observed at ID1-8 where nearby Ram's Hill wells are being operated. On average the other wells are experiencing a decline of approximately 1.3 ft/year (ranging from 0.6 to 2.6 ft/year).

- The upper aquifer as defined in the groundwater model has been dewatered in 4 of the 9 BWD wells (**Table 5**). Where the upper aquifer remains saturated three of the wells have residual saturations of 8 to 13 feet and will soon be dewatered. The upper aquifer in the other 2 wells may remain viable with 47 and 74 feet of remaining saturations, respectively.

- From a BWD perspective, overestimated water level decline by the groundwater model is preferred at it provides a factor of safety to the use of the model for water supply management. This applies to four wells: ID4-4, ID4-11, ID4-18, and ID5-5. A fifth well, ID1-8, is being overestimated by the model but review of the well conditions supports that conditions may change.

- Underestimated water level decline is of concern from BWD water supply management perspective. This applies to two wells- Wilcox and ID1-16. The Wilcox well is currently inactive and available for reserve capacity.

- The model prediction closely matches current hydrographs at ID1-12.

- The model behavior at ID1-10 is not understood and the observed water levels are very dissimilar to the model predictions. The model and well conditions are similar so it is suspected that the model behavior is not related to the aquifer properties used in the model. ID1-10 is in poor condition and scheduled to be replaced in 2019.

  In terms of the use of the groundwater model for prediction of BWD well water elevations in the GSP, the overall rate of water level decline determined by the model is similar to what has been observed in all wells except for ID1-10. There are differences between observed and model-calculated water levels (as illustrated by **Figure 3)** that will need to be monitored. While the model may be recalibrated or refined in the future, it remains useful for evaluation of BWD's water supply wells provided the differences between observed and model-calculated water levels are considered.

2. Lithologic Review

- There is evidence based on review of the lithologic logs that the model may underestimate the thickness of the upper aquifer at six of the water supply wells (**Table 7**). If this is the case, the model may be using lower hydraulic conductivity for the sediments that occur in the vicinity of the water supply wells. This will cause the model to overestimate the rate of water level decline where the upper aquifer has not yet been dewatered.

- Comparison of local hydrogeologic conditions to the generalized hydrogeologic conditions incorporated into the broader scale groundwater model indicates that there is considerable uncertainty associated with the designation of hydrogeologic units. For example, the aquifer system is described as unconfined in the USGS Model. However, the driller's log review supports that fine-grained strata that could well be confining units occur in ID4-11 and ID1-12. If so, future performance of these wells may vary from what would be predicted for wells pumping from a confined aquifer.

  Of the BWD wells, ID4-11 and ID1-12 have the highest specific capacity (159 and 86 gpm/ft, see **Table 1**). A high specific capacity indicates a high performance well. Review of lithologic logs suggest confined aquifer conditions occur instead of the unconfined conditions assumed in the model. The well performance will likely change if water levels drop sufficiently to cause the aquifer to be dewatered to a depth that occurs below the confining layer.

- The local stratigraphy inferred from the driller's logs can differ significantly from the regional model aquifer boundaries. The discrepancies observed between the model and the drilling logs were used to evaluate whether the model, as configured, has the potential to over or under estimate water level elevation decline (**Table 5**). Where the model-predicted water levels are lower than observed, review of the lithologic logs support that higher hydraulic conductivities may occur than incorporated by the model.

- The assessment of the model based on the well hydrostratigraphy compared favorably with the independent review of the hydrographs (**Table 6**). Since there are multiple parameters such as pumping and recharge rates that can affect the model, the well log review provides confirmation of the potential predictive bias of the model. For general reference the well logs use a range of 1 to 3 ft/year to graphically depict potential water level decline over the next 20 years.

- Wells ID4-4, ID4-11, ID1-12 are expected to have the least decline in well performance as drawdown continues over the next 20 years (**Table 5**)

- Wells ID4-18, ID1-16, and the Wilcox Well are expected to have a greater decline in well performance as drawdown continues over the next 20 years (**Table 5**).

- Future hydraulic performance at Wells ID1-8, ID1-10, and ID5-5 is subject to high uncertainty. Inconsistencies between USGS and SDSU interpretations of stratigraphic conditions lead to different conclusions at Wells ID1-8 and ID1-10. Lithologic descriptions reported by the drilling contractor at Well ID5-5 are too generalized to develop a meaningful assessment.

- Measured aquifer parameters have not been measured in many locations within the Subbasin. Measured aquifer parameters via aquifer testing and vertical flow meter profiling at BWD water supply wells would be expected to reduce uncertainty by better refining model calibration and drawdown prediction. The primary benefit would be to provide BWD a better understanding of how well yield will decline as drawdown continues.

TABLE 7

Well ID	Upper Aquifer Status as Defined by USGS Model Geometry (as of 4/2018)	Model Prediction vs Observed Water Levels (Table 3)	Lithologic Review (Section 3)	20 Year Model-Projected Transmissivity Change at Well (Section 4)	20-Year Projection of Future Aquifer Condition	Summary of Assessment
					Unconfined or Confined/Leaky?	
ID4-4 (TBR)	8 ft of saturated fine-grained sediments remain.	Model overestimates water level decline	Model overestimates water level decline	Moderate Reduction (~75%). Upper aquifer dewaters at ~ 5 years.	Confined until recently. Clay reported at base of upper aquifer as defined in the model.	Production supported by potentially high yielding upper aquifer basal sediments; however, a marked change in model well performance may occur as the aquifer is dewatered over the next ~5 years. Well performance will then likely decline relatively slowly. Lithologic logs indicate fine-grained, low permeability sediments that may have acted as a confining layer. Well is scheduled to be replaced so testing will provide more certain understanding of potential well production.
ID4-11	12 ft of saturated fine-grained sediments remain. Nearly dewatered.	Model overestimates water level decline	Model overestimates water level decline	Moderate Reduction (~70%). Upper aquifer as defined by the model dewaters at ~ 13 years.	Confined/Leaky; moderate change in well yield unless water level drops below confining layer.	Lithologic log indicates that well performance will likely decline relatively slowly as next 20 years will bring a slow dewatering of a fine-grained, low permeability sediments that may act as a confining layer. Local conditions likely are confined now and will remain so assuming 1-3 ft/yr drawdown. Middle aquifer permeability may be significantly greater and support more production versus the value assigned in the model as the driller's log shows sediment texture is fairly coarse-grained.
ID4-18 (PTBR)	74 ft of saturated sediments remain	Model overestimates water level decline	Model overestimates water level decline	Reduces to ~40% as upper aquifer dewaters. T remains fairly high if upper aquifer remains vialble.	Unconfined	Well performance may decline roughly in half as the thickness of the better yielding sediments are dewatered and reduced by roughly half over the next 20 years. Anticipate that the pump intake will need to be lowered as static groundwater levels drop to or below the current pump intake.
ID1-10 (TBR)	Dewatered in late '90s.	Uncertain, note that water levels are rising	Model and Lithology are Similar	Gradual Reduction (90%)	Unconfined. Well is realtively shallow and currently has about 175 ft of wetted screen. Accelerated water level decline of 2 to 3 ft/yr would be significant impact to water production.	Well performance may decline gradually as wetted screen length diminishes with drawdown over 20 years. No key high yield zones identified in well log, but limited well depth and screen length puts well at risk of decreased production. This assessment is subject to a fair degree of uncertainty as groundwater levels have been on the rise and the cause of that rise has not yet been evaluated. Well is scheduled to be replaced so testing will provide more certain understanding of potential well production.
ID1-12	Recently dewatered.	Model provides reasonable prediction of measured heads.	Model overestimates water level decline	Gradual Reduction (90%)	Unconfined. Confining layer will soon be dewatered. Underlying sand and cobbles may have greater K than the model assumes.	Well performance may significantly change over the 20 year projection if the area around the well changes from a confined condition to an unconfined condition. The lithologic log shows ~200 feet of coarse grained sediments with little clay underlain by ~220 feet of coarse grained sediments with clay. The occurence of realtivley productive sediments at depth suggests water level decline over the next 20 years will not greatly impact well performance.
ID1-16	Dewatered.	Model underestimates water levels versus observed.	Uncertain: Driller's log lacks fine-grained sediments	Gradual Reduction (90%)	Unconfined. However conditions are uncertain due to the conspicuous absence of silts and clays in the driller's log	Well performance may decline gradually on the order of 10 to 30% as aquifer thickness is reduced 20 to 60 ft over the next 20 years. While the driller's log indicates that the lower aquifer will support water production as well as the middle aquifer, this assessment is uncertain as the driller's log suspiciously lacks fine-grained sediments.
ID5-5	13 ft of saturated sediments remain	Model overestimates water level decline	No Data	Reduces to ~55% as upper aquifer dewaters in ~ year 13. T of middle aquifer remains sufficient to support well production.	Unconfined. However, the lithologic log lacks details	Though driller's log is grossly simplified and provides little information, neaby SDSU stratigraphic analysis suggests good permeability and over 500 ft of middle aquifer thickness to support water production.
Wilcox	Dewatered prior to 2000. Middle aquifer dewatered in ~2015.	Model underestimates water levels versus observed.	Uncertain: Middle auifer may be thicker than modelled but sediments are consolidated and may be lower K	Gradual Reduction (90%). Water coming from Lower Aquifer so pumping rate expected to be relatively low.	Unconfined. Presence of consolidated and semi-consolidated sediments may lead to semi-confined/leak auifer conditions.	Production is from the lower aquifer. Well currently has about 200 ft of wetted screen. Well performance may decline gradually as the wetted screen length diminishes due to overdraft. No key high yield zones identified in well log, but limited well depth puts well at risk to production loss due to overdraft.
ID1-8	47 ft of saturated sediments remain	Model overestimates water level decline	Model overestimates water level decline	Sharp Reduction (to 5%) when upper aquifer dewaters in ~ year 11. Water will then be coming from middle aquifer so pumping rate expected to be sufficient to support the well.	Unconfined. Realtively thick clay layers at depth suggest the Lower Aquifer will transition to leaky or confined aquifer conditions.	Model anticipates a significant drop in K when the upper aquifer dewaters. Lithologic log and SDSU analysis suggests thicker and more permeable conditions where the well is screened. By the model's critieria, the upper aquifer may be dewatered in ~11 years with a sharp reduction in well productivity. Lithologic log data and SDSU analyses suggest the upper aquifer is thicker which suggests production will not be impacted as severely.

Notes: TBR= to be replaced; PTBR = potentially to be replaced (see text)

3. Relative Aquifer Productivity (Transmissivity as function of water level decline)

- Well production is directly related to the aquifer transmissivity. Calculations presented in **Section 4** provide insight regarding the effect of water level decline on the aquifer transmissivity at each well. The USGS model parameters including aquifer thickness and hydraulic conductivity were employed in the calculations. The well production capacity is compared to a baseline demand of 1600 AFY and a range is presented where the wells are operated from 8 to 12 hours/day. Review of the results supports:

    - Current flow rates provide 158 to 237 percent of current demand, assuming all of the wells are in operation fully connected into BWD's water storage and distribution system.
    - After 10 years the wells provide 126 to 188 percent of current demand, decreasing to 118 to 169 percent after 20 years. Assuming current rates of water level decline and overdraft, BWD's production capacity potentially decreases by 29% - roughly by a third, over the next 20 years.
    - Production rates of Wells ID4-18 and ID1-8 significantly diminish. These wells may prove to not be cost-efficient to operate.

  The transmissivity analysis indicates that while combined the pumping capacity of the wells will support BWDs' current demand, the reserve capacity of the water supply is diminishing and two of the wells may no longer be useful. The reduced production capacity of BWD water supply wells will likely be offset by pumping rate reductions will be required under the GSP. On the other hand, much of BWD's service area remains undeveloped and a significantly increased water demand may be realized due to population growth (see **Section 1.1.1**).

- Three conditions occur at BWD wells that depend on whether the transmissivity calculations indicate that the upper aquifer has been or will be dewatered (see **Figure 22**).

    - Where the upper aquifer has been dewatered and production comes from a single deeper aquifer, aquifer productivity declines linearly. A linear decrease occurs in four wells (Wilcox, ID1-12, ID1-16, and ID1-10).
    - In one case (ID4-18) the upper aquifer remains sufficiently saturated to remain viable. In this case the transmissivity decreases linearly but at a much higher rate (ID4-18).
    - In four cases the upper aquifer is dewatered over the next 20 years, resulting in a distinct decrease in aquifer transmissivity. This is observed in ID4-4, ID5-5, and ID1-8 after 5, 13, and 11 years, respectively.

6.0 RECOMMENDATIONS

This analysis of aquifer conditions based on observed conditions at BWD wells revealed there are potentially significant differences in hydrogeologic stratigraphy, groundwater flow parameters, and groundwater level decline rates among the wells. The analyses provided in this report highlight how a large-scale groundwater model necessarily approximates and averages aquifer properties across the Subbasin. Identified differences between broad scale model conditions and site-specific well conditions are intended to be used to identify how the differences may impact BWD's management decisions. For example, identification of overestimated model-predicted groundwater elevation decline at a given well location provides BWD management with a factor of safety when assessing model results for an individual well. Conversely, model-predicted drawdown rates that underestimate observed well specific conditions serves notice to BWD management the need to more carefully monitor conditions at specific wells and to develop contingency plans should the well performance be adversely impacted by overdraft conditions. While the model provides insights toward future water level conditions, the ultimate test of the whether overdraft has been controlled by pumping reductions will come from water level measurements.

Going forward it is understood that at least two new wells will be installed by BWD. Accordingly, it is to BWD's advantage to improve their understanding of well-specific conditions and potential overdraft impacts through ongoing site characterization. Opportunities to do so include:

- Conduct detailed geologic sampling and geophysical logging during future well installation and construction to improve the current interpretation of aquifer conditions at water supply well locations.

- Conduct aquifer testing at new water supply wells to optimize pump selection and to quantitatively measure basic groundwater modeling input parameters. Use nearby wells to the extent possible as potential observation wells so that an extended aquifer volume may be tested and groundwater storage parameters used in the model can be directly estimated.

- When accessible, conduct video logging of wells to assess the physical condition of the well casing and screen. Also evaluate the extent and type of microbial biomass that may be accumulating in the wells.

- Conduct vertical flow meter tests in new and existing water wells to quantitatively characterize how well yield changes with depth and to support selection of pump size and pump depth. Combine these data with ongoing specific capacity testing (measurement of flow rates versus drawdown) to project long-term well performance as a function of water level decline.

- If the model is updated consider re-discretization of the model in the areas of critical to BWD water production by adding layers to the model and locally increasing the number of nodes and this decreasing the nearby cell sizes. Also consider the use of an irregular grid using MODFLOW-USG, an unstructured grid version of MODFLOW.

- The USGS Model Report states that 230 well logs were reviewed and analyzed to provide averaged lithologic properties per aquifer layer (i.e. upper, middle, and lower). Consider re-analyzing the USGS' lithologic texture data using a 3-dimensional approach to examine potential changes with depth. When news wells are drilled and tested, jointly interpret the geologic and geophysical logs, and well hydraulic test findings to the prior lithologic texture data analysis.

- Consider detailed subsurface analysis of each of the well areas to further evaluate whether confined aquifer conditions occur locally. The primary reason for this is that the effect of pumping will be seen further from wells under confined aquifer conditions and well interference may become a complicating factor in the assessment of water level decline under the GSP. Geophysical techniques such as seismic reflection may prove applicable.

- Compile and review BWD's well testing information, such as flow and pump test records, and assess changes over time that may be related to water level decline due to overdraft. Specific capacity data may provide additional insights relative to how production rates have decreased as a result of overdraft.

7.0 REFERENCES

All references are included as footnotes or within the text.

APPENDIX A

WELL TESTING REPORT
by
PUMP CHECK Pumping Systems Analysis, Riverside, CA
April 24, 2018

PUMP CHECK
PUMPING SYSTEMS ANALYSIS • RIVERSIDE CA, SINCE 1958
P.O. Box 5646 Riverside, CA 92517 (951) 684-9801 Fax (951) 653-1950

April 24, 2018

Greg Holloway
Borrego Water District
P.O. Box 1870
Borrego Springs, CA 92004

Dear Greg:

Congratulations! The pump and motor work performed at **ID 1 Well 12** has resulted in a reduction of 163.5 kWh's per acre foot water pumped. Based on the acre feet water pumped last year by ID 1 Well 12, **the annual savings will be 50,750 kWh's.**

This is enough energy saved (kWh's) to power 4.8 average household for one year.
(National average for electricity consumed per household 10,500 kWh's per year. Source: U.S. Department of Energy, Table 1.5 Energy Consumption, Expenditures and Emissions Indicators, 2012, www.energy.gov).

And

Reduce Green House CO2 gases by 46.9 tons annually.
(National average emissions factor for electricity is 1.85 pounds CO2 per kilowatt-hour. Source: Energy Information Administration. Electric Generator Report 2013, Table 8.2, www.eia.doe.gov).

Continued regular pump testing keeps you aware of the water table and pump operating conditions. This also provides current information for pump redesign when necessary. By tracking pump wear and potential saving from pump replacement, you can determine the most cost effective time to replace a pump. Pumping cost reduction is a major benefit of regular pump testing.

Please call me at (951) 684-9801 if you have any questions.

Sincerely,

Jon Lee

PUMP CHECK

Pumping Systems Analysts

Hydraulic Test Report

Since 1958

(951) 684-9801 • Lic. 799498 • Fax (951) 684-2988

Borrego Water District
5037 Borrego Springs Road

Test Date: 03/16/2018
Pump type: DWT
Plant: ID 1 Well #8

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	Byron Jackson	SERIAL:	841L0168
MOTOR:	Newman	SERIAL:	S20046807
H.P.	125	LAT/LON:	33.12.191n116.18.860w
METER:	6578837	REF #:	PC 1222

TEST RESULTS

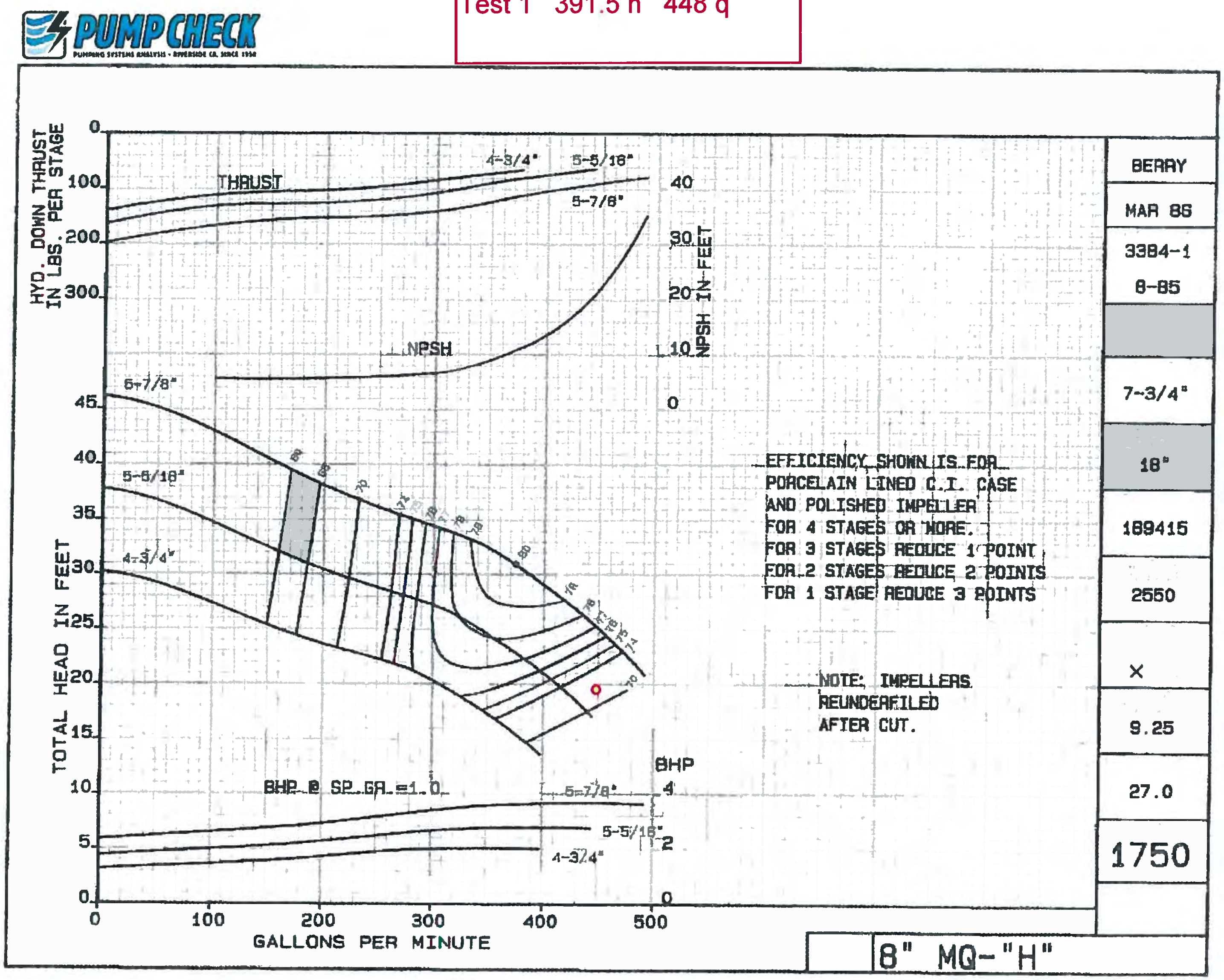
	TEST 1
Discharge, PSI	118.0
Discharge head, feet	272.6
Standing water level, feet	71.2
Drawdown, feet	47.7
Pumping water level, feet	118.9
Total pumping head, feet	391.5
Gallons per minute flow	**448**
Gallons per foot of drawdown	9.4
Acre feet pumped per 24 hours	1.977
KW input to motor	64.7
HP input to motor	86.7
Motor load, % BHP	63.1
Measured speed of pump, RPM	1788
KWH per acre foot	785.2
Overall Plant efficiency in %	**51.0**

Test 1 was with this pump operating to waste as found at the time of the test.

The available water measurement location does not meet recommended industry standards. We recommend 8-10 diameters of straight pipe for the ideal test location.

If you have any questions please contact Jon Lee at (951) 684-9801.

ID 1 Well #8 3/16/2018
Test 1 391.5 h 448 q



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Borrego Water District
4201 Borrego Springs Road

Test Date:	03/16/2018
Pump type:	DWT
Plant:	ID 1 Well #10

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	Aurora	SERIAL:	V81-726831
MOTOR:	Newman	SERIAL:	S20066201
H.P.	150	LAT/LON:	33.12.708n116.20.812w
METER:	6695547	REF #:	PC 1186

TEST RESULTS

	TEST 1
Discharge, PSI	133.0
Discharge head, feet	307.2
Standing water level, feet	213.9
Drawdown, feet	11.5
Pumping water level, feet	225.4
Total pumping head, feet	532.6
Gallons per minute flow	**317**
Gallons per foot of drawdown	27.5
Acre feet pumped per 24 hours	1.399
KW input to motor	59.0
HP input to motor	79.1
Motor load, % BHP	48.2
Measured speed of pump, RPM	1787
KWH per acre foot	1011.9
Overall Plant efficiency in %	**53.9**

Test 1 was with this pump operating to waste at the time of the test.

The airline length was calibrated at 352.5'.

The available water measurement location does not meet recommended industry standards. We recommend 8-10 diameters of straight pipe for the ideal test location.

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Borrego Water District		Test Date:	03/16/2018
3352 Borrego Valley Road		Pump type:	DWT
		Plant:	ID 1 Well #12

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	No Data	SERIAL:	N/A
MOTOR:	Newman	SERIAL:	S21612703
H.P.	200	LAT/LON:	33.13.571n116.20.897w
METER:	6695546	REF #:	PC 1221

TEST RESULTS

	TEST 1	TEST 2
Discharge, PSI	215.0	226.0
Discharge head, feet	496.7	522.1
Standing water level, feet	145.5	
Drawdown, feet	10.4	9.3
Pumping water level, feet	155.9	154.8
Total pumping head, feet	652.6	676.9
Gallons per minute flow	**890**	**844**
Gallons per foot of drawdown	85.5	90.8
Acre feet pumped per 24 hours	3.932	3.732
KW input to motor	152.2	152.0
HP input to motor	203.9	203.7
Motor load, % BHP	93.8	93.7
Measured speed of pump, RPM	1788	
KWH per acre foot	929.1	977.6
Overall Plant efficiency in %	**71.9**	**70.9**

Test 1 was the normal operation of the pump at the time of the test. The other results were obtained by throttling the pump discharge.

The available water measurement location does not meet recommended industry standards. We recommend 8-10 diameters of straight pipe for the ideal test location.

The airline length was calibrated at 303.4'.

If you have any questions please contact Jon Lee at (951) 684-9801.

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Borrego Water District
951 Rangor Way

Test Date:	03/16/2018
Pump type:	DWT
Plant:	ID 1 Well #16

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	Layne & Bowler	SERIAL:	801084
MOTOR:	US	SERIAL:	V047590079-0005-R0007
H.P.	150	LAT/LON:	33.12.993n116.21.744w
METER:	6695579	REF #:	PC 1219

TEST RESULTS

	TEST 1
Discharge, PSI	134.0
Discharge head, feet	309.5
Standing water level, feet	230.9
Drawdown, feet	24.3
Pumping water level, feet	255.2
Total pumping head, feet	564.7
Gallons per minute flow	**848**
Gallons per foot of drawdown	34.9
Acre feet pumped per 24 hours	3.748
KW input to motor	127.9
HP input to motor	171.4
Motor load, % BHP	109.5
Measured speed of pump, RPM	1785
KWH per acre foot	818.9
Overall Plant efficiency in %	**70.6**

Test 1 was with the VFD operating at 60.0 Hz to waste at the time of the test.

The airline length was calibrated at 402.5'.

The available water measurement location does not meet recommended industry standards. We recommend 8-10 diameters of straight pipe for the ideal test location.

If you have any questions please contact Jon Lee at (951) 684-9801.

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Borrego Water District
1775 Borrego Springs Road

Test Date: 03/16/2018
Pump type: DWT
Plant: ID 4 Well #4B

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	Goulds	SERIAL:	N/A
MOTOR:	US	SERIAL:	Y017664360-0005M0003
H.P.	100	LAT/LON:	33.16.627n116.22.463w
METER:	6561482	REF #:	PC 1180

TEST RESULTS

	TEST 1	TEST 2
Discharge, PSI	148.0	161.0
Discharge head, feet	341.9	371.9
Standing water level, feet	205.4	
Drawdown, feet	63.5	60.1
Pumping water level, feet	268.9	265.5
Total pumping head, feet	610.8	637.4
Gallons per minute flow	**395**	**380**
Gallons per foot of drawdown	6.2	6.3
Acre feet pumped per 24 hours	1.743	1.679
KW input to motor	64.0	63.9
HP input to motor	85.8	85.6
Motor load, % BHP	81.8	81.7
Measured speed of pump, RPM	1788	
KWH per acre foot	881.0	913.5
Overall Plant efficiency in %	**71.0**	**71.4**

Test 1 was the normal operation of the pump at the time of the test. The other results were obtained by throttling the pump discharge.

The airline length was calibrated at 388.5'.

If you have any questions please contact Jon Lee at (951) 684-9801.

PUMPCHECK

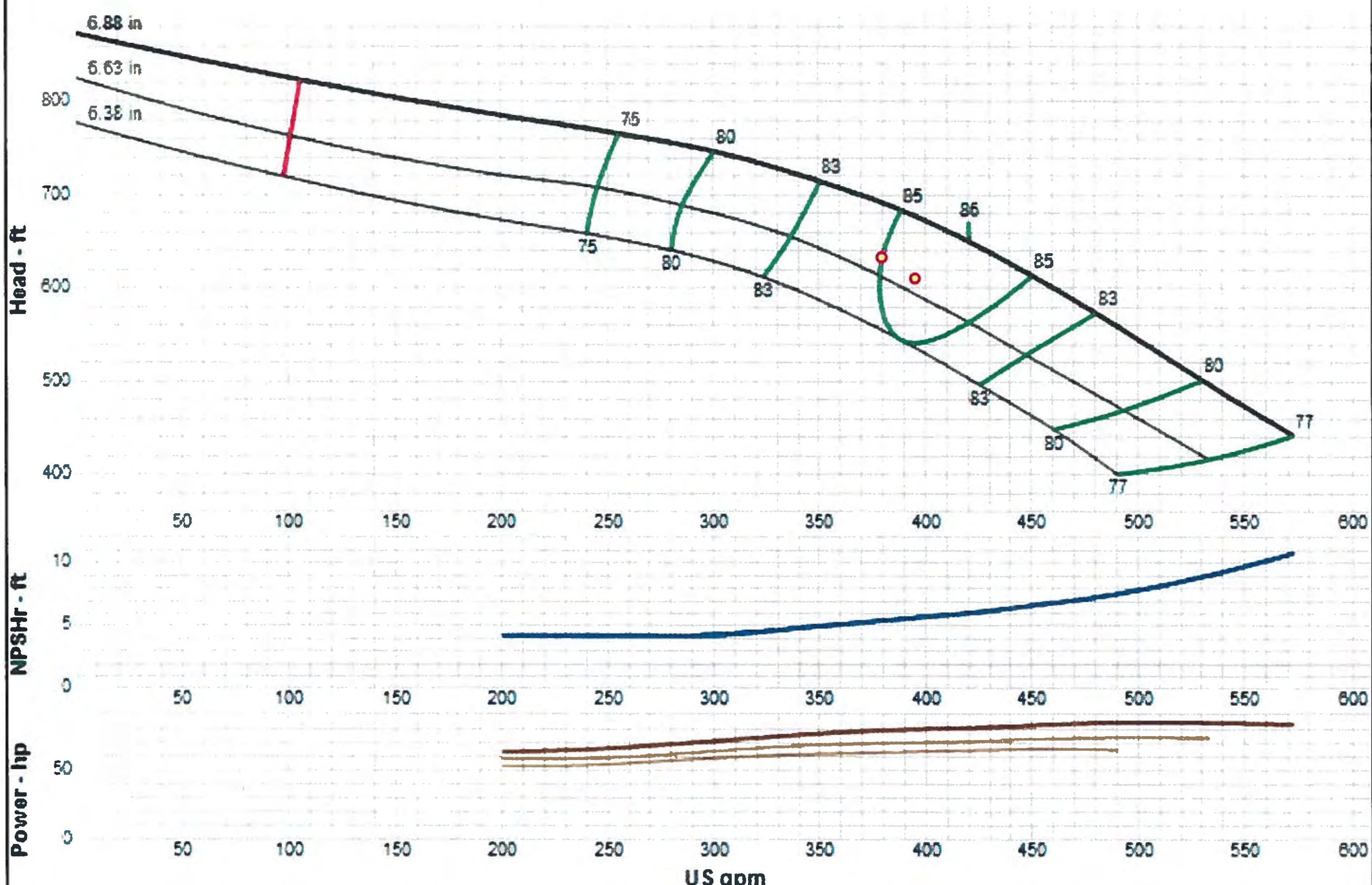
xylem
Let's Solve Water

ID4 Well #4B 3/16/2018
Test 1 610.8 h 395 q
Test 2 637.4 h 380 q

PERFORMANCE CURVE

Quote Number: 9001-170503-053
Product Name: DWT - Deep Well Lineshaft Turbine
Product Id: GWT_DWT

BORREGO WD ID4 WELL 4
HIDDEN VALLEY PUMP SYSTEMS, INC



Sizing Criteria

Series	GWT_DWT	Max Power on Design Curve	83.7 Hp
Size	9RCLC	Max Power on Max Imp Trim	83.7 Hp
Additional Size	9RCLC	Flow at BEP	420 USGPM
Speed	1770	Head at BEP	650 ft
Number of Stages	16	NPSH Required	0 ft
Stages	16 Stages	Specified NPSH Avail.	34 ft
Frequency	60 Hz	NPSHaMargin	2 ft
Impeller Trim	6.88 inch	Min Flow	105 USGPM
Additional Impeller Trim	6.88 inch	Flow on Max Imp Trim @ Max Power	530 USGPM
Impeller Maximum Trim	6.88 in inch		
Specified Flow	420 USGPM	Shut-Off Head	872 ft
Specified Head	0 ft	Shut-Off Disc Pressure	377 psi
Flow at Design	420 USGPM	Fluid Type	Water
Head at Design	872 ft	Temperature	70 F
Head at Design	872 ft	Allowable Sphere Size	0.75 inch
Run-Out Flow	0 USGPM	Exact Bowl Diameter	9.25 inch
Run-Out Head	0 ft	Curve ID	E6409CFPC2
Efficiency at Design	0	Thrust K Factor [lb/ft]	4.9
Best Efficiency	86	Add Thrust K Factor [lb/ft]	4.9
Driver Size	100 Hp	Max Lateral	0.88 inch

PUMP CHECK

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Borrego Water District
2201 Diegueno Road

Test Date: 03/16/2018
Pump type: DWT
Plant: ID 4 Well #11

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	Goulds	SERIAL:	N/A
MOTOR:	US	SERIAL:	X07X125R612R4
H.P.	250	LAT/LON:	33.16.047n116.23.004w
METER:	6695581	REF #:	PC 1183

TEST RESULTS

	TEST 1	TEST 2
Discharge, PSI	131.0	140.0
Discharge head, feet	302.6	323.4
Standing water level, feet	223.2	
Drawdown, feet	5.8	4.7
Pumping water level, feet	229.0	227.9
Total pumping head, feet	531.6	551.3
Gallons per minute flow	**920**	**819**
Gallons per foot of drawdown	158.6	174.3
Acre feet pumped per 24 hours	4.065	3.621
KW input to motor	126.7	126.6
HP input to motor	169.8	169.6
Motor load, % BHP	65.3	65.3
Measured speed of pump, RPM	1785	
KWH per acre foot	748.1	839.2
Overall Plant efficiency in %	**72.7**	**67.2**

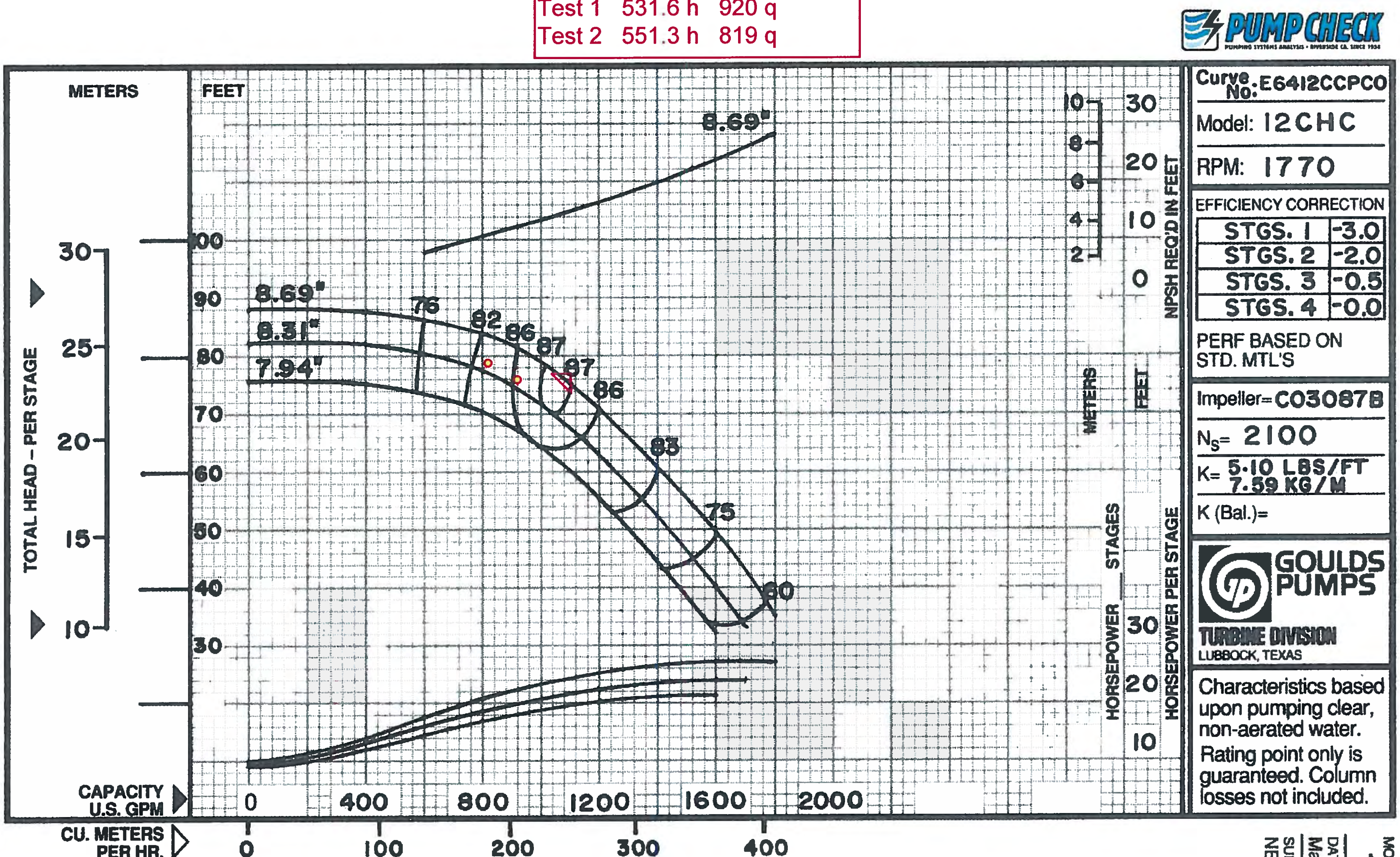
Test 1 was the normal operation of the pump at the time of the test. The other results were obtained by throttling the pump discharge.

The airline length was calibrated at 283.3'.

The available water measurement location does not meet recommended industry standards. We recommend 8-10 diameters of straight pipe for the ideal test location.

If you have any questions please contact Jon Lee at (951) 684-9801.

ID 4 Well #11 3/16/2018
Test 1 531.6 h 920 q
Test 2 551.3 h 819 q



C12CHC

MODEL 12CHC
DATE March 1995
SUPERCEDES NEW

PUMP CHECK

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Borrego Water District
111 Indian Head Ranch Road

Test Date: 03/16/2018
Pump type: SUB
Plant: ID 4 Well #18

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	Goulds	SERIAL:	N/A
MOTOR:	Franklin	SERIAL:	16J19-15-16154A
H.P.	40	LAT/LON:	33.18.404n116.23.087w
METER:	6597551	REF #:	PC 1181

TEST RESULTS

	TEST 1	TEST 2
Discharge, PSI	110.0	126.0
Discharge head, feet	254.1	291.1
Standing water level, feet	311.2	
Drawdown, feet	7.6	6.5
Pumping water level, feet	318.8	317.7
Total pumping head, feet	572.9	608.8
Gallons per minute flow	**130**	**109**
Gallons per foot of drawdown	17.1	16.8
Acre feet pumped per 24 hours	0.573	0.482
KW input to motor	27.8	27.6
HP input to motor	37.3	37.0
Motor load, % BHP	82.0	81.4
Measured speed of pump, RPM	n/a	
KWH per acre foot	1164.6	1375.0
Overall Plant efficiency in %	**50.3**	**45.3**

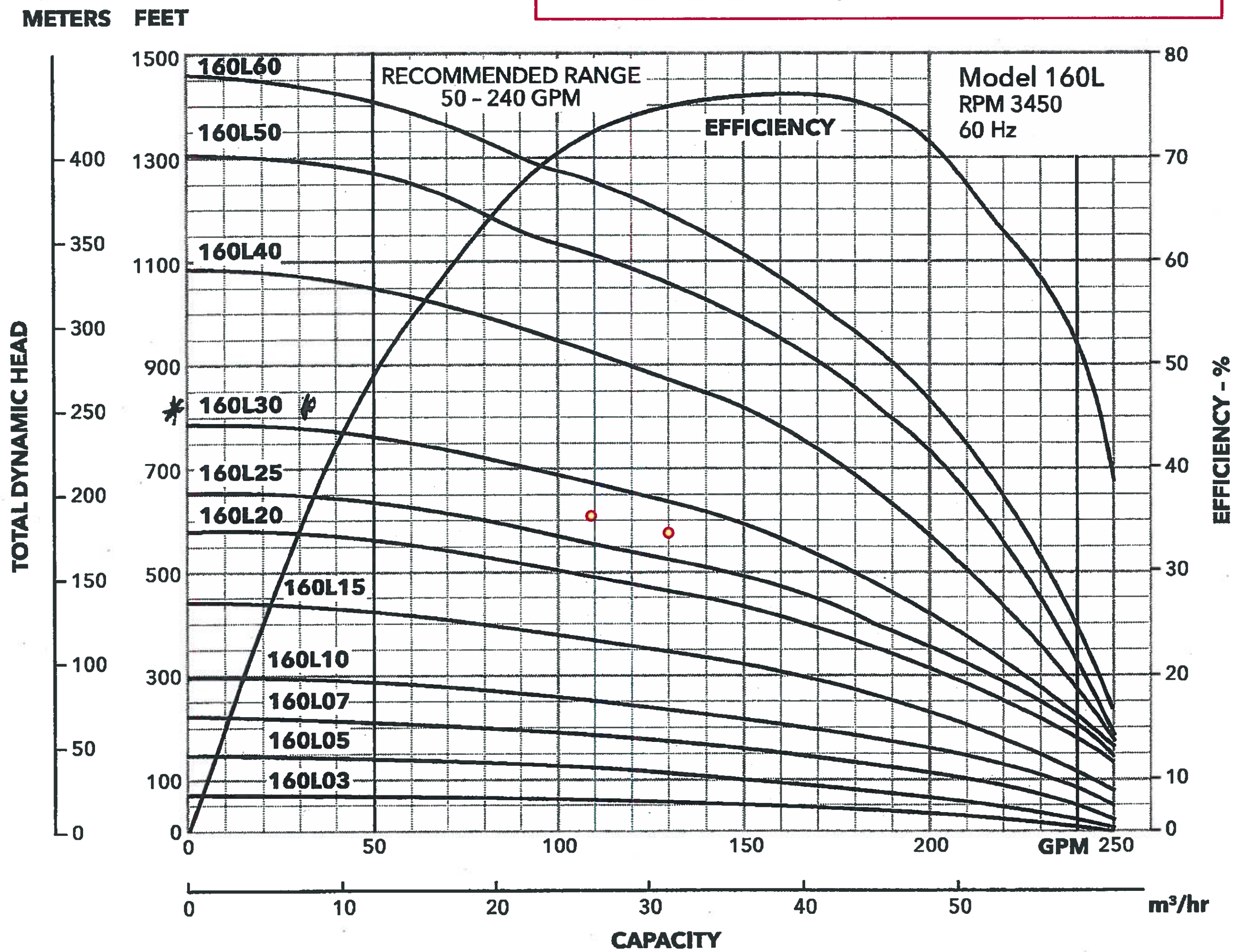
Test 1 was the normal operation of the pump at the time of the test. The other results were obtained by throttling the pump discharge.

If you have any questions please contact Jon Lee at (951) 684-9801.

PUMP CHECK

MODEL 160L

ID4 Well #18 3/16/2018
Test 1 572.9 h 130 q
Test 2 608.8 h 109 q



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Borrego Water District
3003 Lofter Drive

Test Date: 03/16/2018
Pump type: DWT
Plant: ID 5 Well #5

A test was made on this well pump and the following information was obtained.

EQUIPMENT

PUMP:	Goulds	SERIAL:	N/A
MOTOR:	US	SERIAL:	C09-6349-M01
H.P.	200	LAT/LON:	34.14.222n116.21.857w
METER:	6697749	REF #:	PC 3557

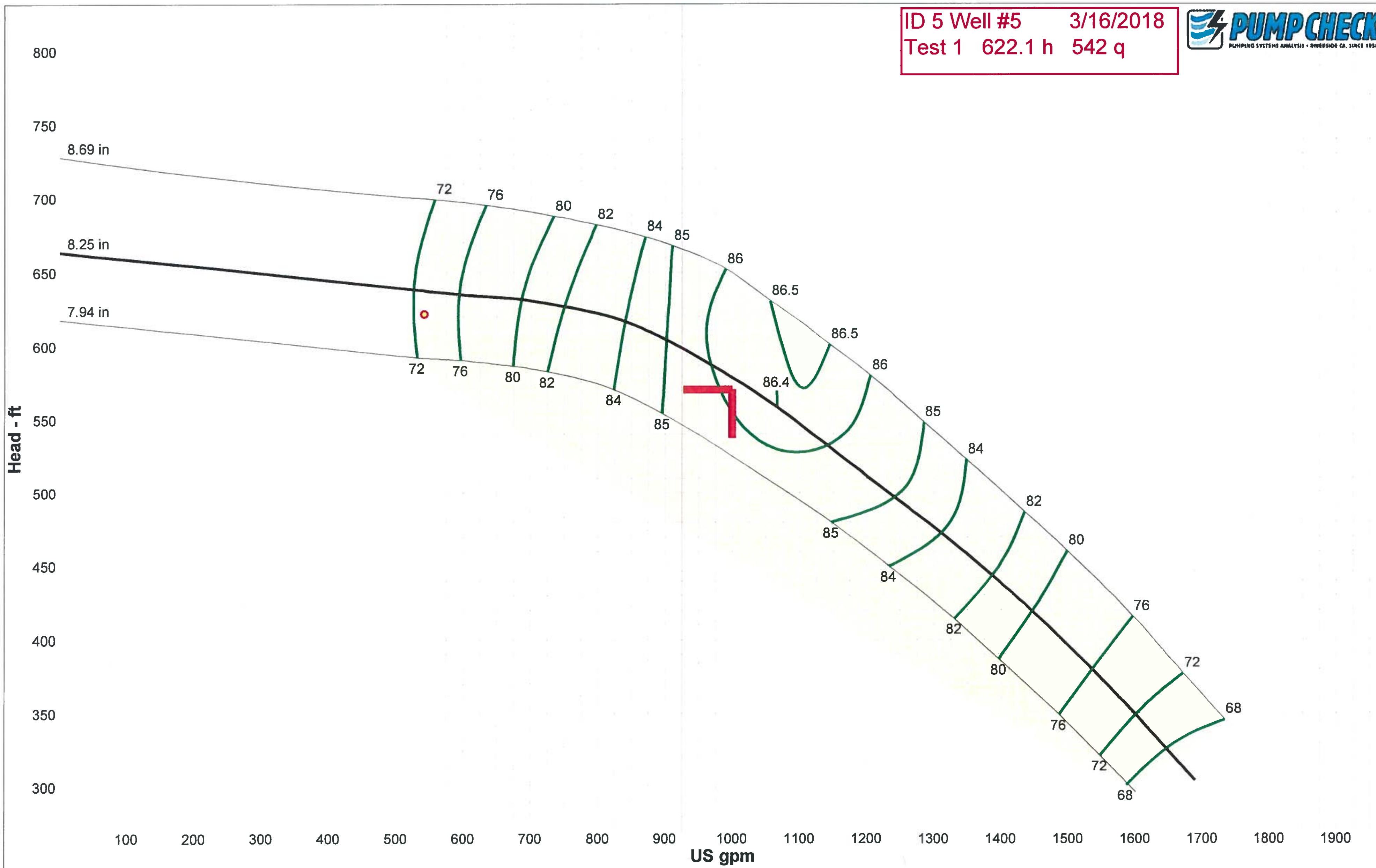
TEST RESULTS

	TEST 1
Discharge, PSI	183.5
Discharge head, feet	423.9
Standing water level, feet	182.1
Drawdown, feet	16.1
Pumping water level, feet	198.2
Total pumping head, feet	622.1
Gallons per minute flow	**542**
Gallons per foot of drawdown	33.7
Acre feet pumped per 24 hours	2.395
KW input to motor	102.4
HP input to motor	137.2
Motor load, % BHP	64.2
Measured speed of pump, RPM	1781
KWH per acre foot	1026.3
Overall Plant efficiency in %	**62.0**

Test 1 was the normal operation of the pump at the time of the test.

The airline length was calibrated at 258.3'.

If you have any questions please contact Jon Lee at (951) 684-9801.



Suction Size-8",10" Discharge Sizes-6",8",10". Curves are certified for water at 60°F only. Consult factory for performance with any other fluid.

Company: Borrego Water District
Name: ID 5 Well #5
4/1/2013

Turbine 60 Hz
Catalog: goulds lineshaft .60, Vers 3.36
Lineshaft - 1800
Design Point: 1000 US gpm, 570 ft

Size: 12CHC 8 stage
Speed: 1770 rpm
Dia: 8.25 in
Curve: E6412CCPC4

GOULDS WATER TECHNOLOGY
a xylem brand

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Borrego Water District
3816 Borrego Springs Road

Test Date: 03/16/2018
Pump Type: DWT
Plant: Wilcox Well

A test was made on this deep well turbine pump and the following information was obtained.

EQUIPMENT

Pump:	Goulds	Serial:	88583
Engine:	Cummins	Serial:	45848487
HP:	130	Lat/Lon:	33.12.660n116.21.887w
Meter:	Diesel	Ref #:	PC 1218

TEST RESULTS

	TEST 1
Discharge, PSI	94.0
Discharge head, feet	217.1
Standing water level, feet	305.2
Drawdown, feet	5.8
Pumping water level, feet	311.0
Total pumping head, feet	528.1
Gallons per minute flow	**205**
Gallons per foot of drawdown	35.3
Acre feet pumped per 24 hours	0.906
Measured speed of engine, RPM	1810
Measured speed of pump, RPM	1645

Test 1 was the normal operation of the pump at the time of the test.

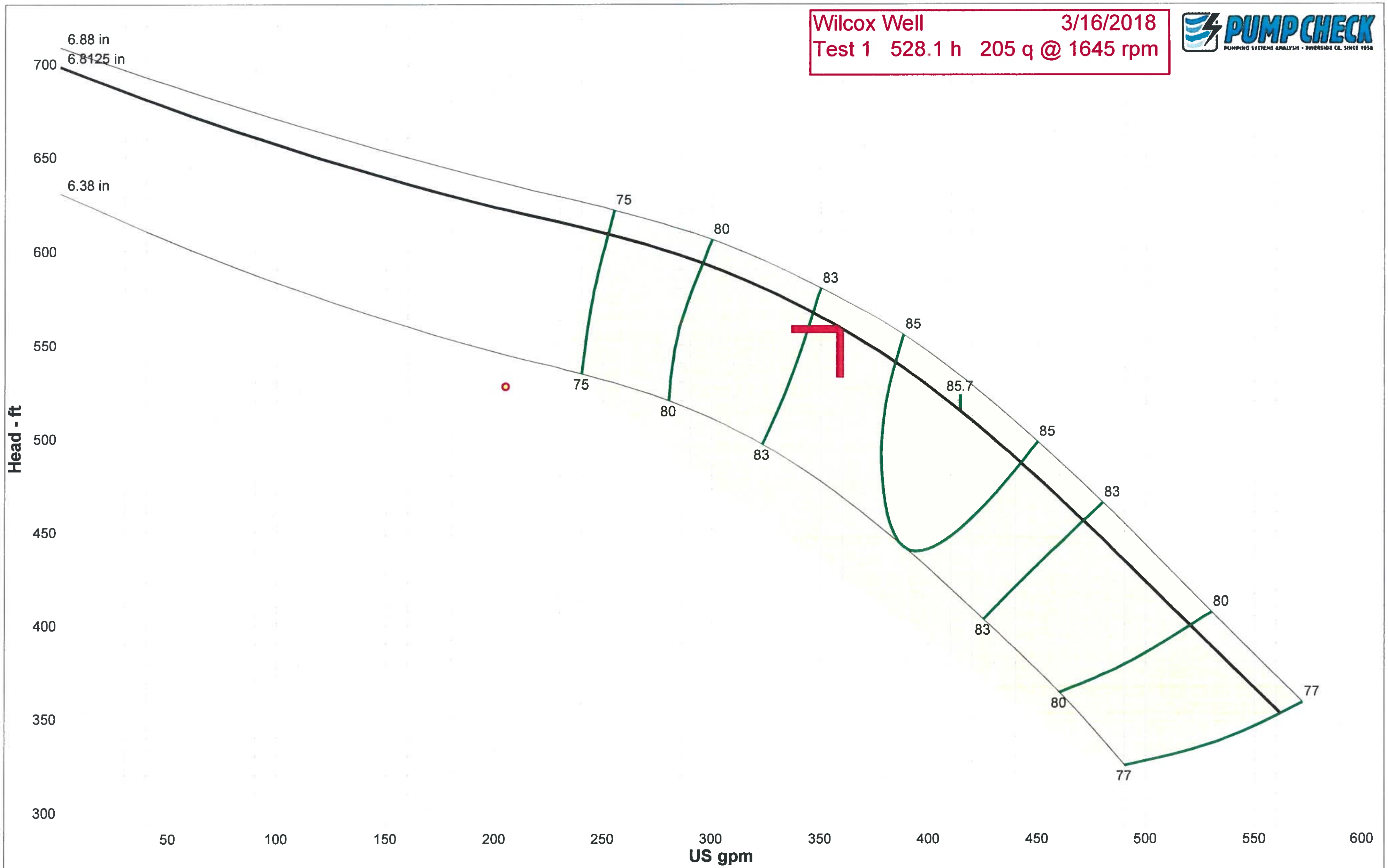
The airline length was calibrated at 397.6'.

The available water measurement location does not meet recommended industry standards. We recommend 8-10 diameters of straight pipe for the ideal test location.

If you have any questions please contact Jon Lee at (951) 684-9801.

P.O. Box 5646, Riverside, California 92517

"Pump Testing, The Service That Pays For Itself"



Suction Size-6" Discharge Sizes-5",6",8". Curves are certified for water at 60°F only. Consult factory for performance with any other fluid.

Company: Borrego Water District
Name: Wilcox Well
4/1/2013

Turbine 60 Hz
Catalog: goulds lineshaft .60, Vers 3.36
Lineshaft - 1800
Design Point: 359 US gpm, 558 ft

Size: 9RCLC 13 stage
Speed: 1770 rpm
Dia: 6.8125 in
Curve: E6409CFPC2

GOULDS WATER TECHNOLOGY
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APPENDIX B

Copies of Well Drilling Logs
For BWD Wells

RM114

ROSCOE MOSS COMPANY

4360 WORTH STREET
LOS ANGELES, CAL.

l No. 8 Drilled for DiGiorgio Corporation
ne (Borrego Springs Water Company)
ress P. O. Box B
Borrego Springs, California 92004
cation

rted Work July 20, 1972
mpleted Work August 2, 1972
tal Depth Drilled 938 Feet
tal Depth Completed -0-
lled By Hydraulic, Reverse Rotary Hydraulic Rotary

	DIAMETER	FROM	TO
PILOT BORE	12-1/4 in.	0 ft.	ft.
	29 in.	0 ft.	50 ft.
CONDUCTOR BORE	in.	ft.	ft.
	in.	ft.	ft.
COMPLETED WELL BORE	in.	ft.	ft.
	in.	ft.	ft.
	in.	ft.	ft.

CASING AND SCREEN SCHEDULE

Conductor Casing

aterial Mild Steel
iameter (OD) (ID) 24 in. Wall Thickness 1/4 in.
nstalled From 0 ft. To 50 ft.
emented From 2 ft. To 50 ft.

Well Casing

DIAMETER (ID) (OD)	WALL	MATERIAL	FROM	TO
		]		
None				

Screen

Type None
Material

DIAM. (ID) (OD)	WALL	NO. PERF. PER ROW	ROWS PER FOOT	SIZE	FROM	TO

Formation: Mention size of water gravel —

ft.	to	ft.	
0		35	~~Fine to coarse sand with~~ silty clay
75		108	Fine to coarse sand and gravel with silt
108		190	Fine to coarse sand and gravel with silty clay streaks
190		218	Brown clay with sand and gravel streaks
218		230	Brown and red clay
230		302	Boarse to very coarse sand with clay streaks
302		383	Fine to coarse sand and gravel ~~wstj~~ with clay strks
383		390	Brown and red clay
390		465	Fine to coarse sand, some gravel with clay streaks
465		505	Fine to coarse sand with shale streaks
505		519	Fine sand and red clay
519		546	Fine to very coarse cemented sand with grey clay streaks
546		610	Grey blue clay with fine sand streaks
610		627	Fine to coarse sand with grey clay streaks
627		654	Fine silty sand with clay streaks
654		745	Fine to very coarse sand some gravel with red & grey clay streaks
745		795	Red & grey caly with fine to coarse sand streaks, some gravel
795		817	Fine to coarse sand and gravel
817		859	Red and gray sticky clay with fine to coarse sand streaks

Formation: Mention size of water gravel —

ft.	to	ft.	
~~859~~		~~871~~	~~Fine to coarse sand~~ with thin cemented streak some clay

Completed Work August 2, 1972

Total Depth Drilled 938 Feet

Total Depth Completed -0-

Drilled By Hydraulic, Reverse Rotary Hydraulic Rotary

	DIAMETER	FROM	TO
PILOT BORE	12-1/4 in.	0 ft.	ft.
	29 in.	0 ft.	50 ft.
CONDUCTOR BORE	in.	ft.	ft.
	in.	ft.	ft.
COMPLETED WELL BORE	in.	ft.	ft.
	in.	ft.	ft.
	in.	ft.	ft.

CASING AND SCREEN SCHEDULE

Conductor Casing

Material Mild Steel

Diameter (OD) (ID) 24 in. Wall Thickness 1/4 in.

Installed From 0 ft. To 50 ft.

Cemented From 2 ft. To 50 ft.

Well Casing

DIAMETER (ID) (OD)	WALL	MATERIAL	FROM	TO
	None			

Screen

Type None

Material

DIAM. (ID) (OD)	WALL	NO. PERF. PER ROW	ROWS PER FOOT	SIZE	FROM	TO

Water level when first started Test ______ ft.

Draw down from standing level ______ ft.

No. of gallons per minute pumped when Test first started ______

No. of gallons per minute pumped when Test completed ______

Draw down at completion of Test ______ ft.

Hours Testing Well ______

No. of tons gravel installed ______

Gravel size: From ______ in. To ______ in. (Screen Size)

From		To	
	" "		" and gravel streaks
218	" "	230	" Brown and red clay
230	" "	302	" Boarse to very coarse
	" "		" sand with clay streaks
302	" "	383	" Fine to coarse sand and
	" "		" gravel ~~wak~~ with clay strk
383	" "	390	" Brown and red clay
390	" "	465	" Fine to coarse sand, som
	" "		" gravel with clay streaks
465	" "	505	" Fine to coarse sand with
	" "		" shale streaks
505	" "	519	" Fine sand and red clay
519	" "	546	" Fine to very coarse cem-
	" "		" ented sand with grey clay
	" "		" streaks
546	" "	610	" Grey blue clay with fine
	" "		" sand streaks
610	" "	627	" Fine to coarse sand with
	" "		" grey clay streaks
627	" "	654	" Fine silty sand with clay
	" "		" streaks
654	" "	745	" Fine to very coarse sand
	" "		" some gravel with red &
	" "		" grey clay streaks
745	" "	795	" Red & grey caly with fine
	" "		" to coarse sand streaks,
	" "		" some gravel
795	" "	817	" Fine to coarse sand and
	" "		" gravel
817	" "	859	" Red and gray sticky clay
	" "		" with fine to coarse sand
	" "		" streaks

Formation: Mention size of water gravel —

From		To	
~~859~~	ft. to	~~871~~	ft. ~~Fine to coarse sand~~
	" "		" with thin cemented streaks
	" "		" some clay
871	" "	889	" Brown clay with fine to
	" "		" coarse sand streaks
889	" "	918	" Fine to coarse sand
	" "		" with clay streaks
918	" "	938	" Red and gray clay, some
	" "		" shale with fine to coarse
	" "		" sand streaks
	" "		"

of conductor pipe cemented in place (only)
AND THEN CASED AT A LATER DATE.

Date of report 8/2/72

Don Pittman

Type and Rig No. used Hyd. Rotary #9, Lloyd ~~Yes~~ Driller Wells

Superintendent

rm RM114

101-B

ROSCOE MOSS COMPANY

4360 WORTH STREET
LOS ANGELES, CAL.

ell No. 8 Drilled for DiGiorgio Corporation
ame (Borrego Springs Water Company)
ddress P. O. Box "B"
Borrego Springs, Calif. 92004
ocation Continuation of log done for same well
mpleted 8/2/72 showing additional work done
d casing installed.
arted Work September 10, 1972
ompleted Work September 21, 1972
otal Depth Drilled 938
otal Depth Completed 850
rilled By Hydraulic, Reverse Rotary Hydraulic Rotary

	DIAMETER	FROM	TO
PILOT BORE	12-1/4 in.	0 ft.	938 ft.
	in.	ft.	ft.
CONDUCTOR BORE	29 in.	0 ft.	50 ft.
	in.	ft.	ft.
COMPLETED WELL BORE	22 in.	50 ft.	324 ft.
	17-1/2 in.	324 ft.	870 ft.
	in.	ft.	ft.

CASING AND SCREEN SCHEDULE

Conductor Casing

aterial Mild Steel copper bearing plate
ameter (~~OD~~) (ID) 24 in. Wall Thickness 1/4 in.
stalled From 0 ft. To 50 ft.
emented From 2 ft. To 50 ft.

Well Casing

DIAMETER (~~ID~~) (OD)	WALL	MATERIAL	FROM	TO
2-3/4	1/4	Mild steel	0	72
2-3/4	1/4	copper-bearing	240	260
8-5/8	1/4	plate	830	850

Screen

pe Standard Machine Louver
terial Mild steel copper-bearing plate

DIAM. D) (OD)	WALL	NO. PERF. PER ROW	ROWS PER FOOT	SIZE	FROM	TO
2-3/4	1/4	8	4.5	.070	72	240

Formation: Mention size of water gravel — ft. to ft.

(FOR AQUIFER FORMATION SEE PRECEDING WELL LOG) WELL WAS ORIGINAL DRILLED AND NOT CASED & THEN AT A LATER DATE RE-OPENED AND CASED AS LISTED.

Development Record

Was Well Swabbed? Yes
Method Line swab
No. of Hours
Total Material Removed

otal Depth Drilled 938

otal Depth Completed 850

rilled By Hydraulic, Reverse Rotary Hydraulic Rotary

	DIAMETER	FROM	TO
PILOT BORE	12-1/4 in.	0 ft.	938 ft.
	in.	ft.	ft.
CONDUCTOR BORE	29 in.	0 ft.	50 ft.
	in.	ft.	ft.
COMPLETED WELL BORE	22 in.	50 ft.	324 ft.
	17-1/2 in.	324 ft.	870 ft.
	in.	ft.	ft.

CASING AND SCREEN SCHEDULE

Conductor Casing

aterial Mild Steel copper bearing plate

iameter (~~OD~~) (ID) 24 in. Wall Thickness 1/4 in.

stalled From 0 ft. To 50 ft.

emented From 2 ft. To 50 ft.

Well Casing

DIAMETER ~~(ID)~~ (OD)	WALL	MATERIAL	FROM	TO
2-3/4	1/4	Mild steel	0	72
2-3/4	1/4	copper-bearing	240	260
8-5/8	1/4	plate	830	850

Screen

ype Standard Machine Louver

aterial Mild steel copper-bearing plate

DIAM. (D) (OD)	WALL	NO. PERF. PER ROW	ROWS PER FOOT	SIZE	FROM	TO
2-3/4	1/4	8	4.5	.070	72	240
2-3/4	1/4	8	4.5	.070	260	312
8-5/8	1/4	6	6	.070	312	830

ter level when first started Test 151 ft.

aw down from standing level 27 ft.

. of gallons per minute pumped when Test first started 253

. of gallons per minute pumped when Test completed 1100

aw down at completion of Test -80- ft.

urs Testing Well 30.

. of tons gravel installed 70 Tons

vel size: From in. To in. (Screen Size)

Crystal Silica 6-8 pit run

Development Record

Was Well Swabbed? Yes

Method Line swab

No. of Hours

Total Material Removed

Gravel Added

Rig No. 37 Developer Ronald A. Foster

Give any additional data which may be of future value

Date of report September 26, 1972

Donald G. Pittman

Driller

Type and Rig No. used Hydraulic Rotary #9, Lloyd Well

Superintender

ROSCOE MOSS COMPANY

4360 WORTH STREET
LOS ANGELES, CAL.

101-10

Well No. 10 Drilled for DiGiorgio Corporation
Name (Borrego Springs Water Company)
Address P. O. Box "B"
Borrego Springs, Calif. 92004
Location N. W. Corner of Section 22, Twp. 11-S, Rg. 6-E, Borrego Springs, Calif. (San Diego County)

Started Work August 16, 1972
Completed Work September 9, 1972
Total Depth Drilled 816
Total Depth Completed 392
Drilled By Hydraulic, Reverse Rotary Hydraulic Rotary

	DIAMETER	FROM	TO
PILOT BORE	12-1/4 in.	0 ft.	816 ft.
	in.	ft.	ft.
CONDUCTOR BORE	29 in.	0 ft.	50 ft.
	in.	ft.	ft.
COMPLETED WELL BORE	22 in.	50 ft.	429 ft.
	in.	ft.	ft.
	in.	ft.	ft.

CASING AND SCREEN SCHEDULE

Conductor Casing

Material Mild Steel Copper-Bearing Plate
Diameter (OD) (ID) 24 in. Wall Thickness 1/4 in.
Installed From 0 ft. To 50 ft.
Cemented From 1 ft. To 50 ft.

Well Casing

DIAMETER (ID) (OD)	WALL	MATERIAL	FROM	TO
12-3/4	1/4	Mild steel	0	162
12-3/4	1/4	copper-bearing plate	372	392

Screen

Type Standard Machine Louver
Material Mild steel copper-bearing plate

DIAM. (ID) (OD)	WALL	NO. PERF. PER ROW	ROWS PER FOOT	SIZE	FROM	TO
12-3/4	1/4	9	4.5	.070	162	372

Water level when first started Test 130 ft.
Draw down from standing level 11 ft.
No. of gallons per minute pumped when Test first started 233
No. of gallons per minute pumped when Test completed 1110
Draw down at completion of Test 65 ft.
Hours Testing Well 24
No. of tons gravel installed 45
Gravel size: From in. To in. (Screen Size)

Formation: Mention size of water gravel —

From (ft.)	To (ft.)	Formation
0	40	Fine to coarse sand
40	77	Fine to coarse sand with some gravd
77	110	Fine to coarse sand with brown sand, clay streak
110	137	Fine to coarse sand
137	170	Fine to coarse sand with brown sandy clay streak
170	179	Cemented sand with some gravel
179	227	Fine to coarse sand with gravel
227	308	Cemented sand
308	385	Fine to coarse cemented sand with some gravel
385	391	Sandy red clay
391	399	Very fine sand
399	416	Fine to coarse sand with silt streaks
416	443	Fine to coarse with silt streaks
443	471	Fine to coarse sand and sandy clay with pink cla streaks
471	483	Very fine to medium sanc
483	517	Fine to very coarse sanc
517	588	Fine to coarse sand with sandy clay streaks
588	757	Fine to coarse sand, sor silt
757	816	Grey and blue clay with pink clay streaks.

Development Record

Was Well Swabbed? Yes
Method Bailer and wet swab.
No. of Hours 14
Total Material Removed 5 feet
Gravel Added 14 feet
Rig No. 53 Developer Wallace Wilson

Give any additional data which may be of future value

Date of report September 22, 1972
Donald G. Pittman
Driller

Type and Rig No. used Hydraulic Rotary #9, Lloyd W

DUPLICATE
Driller's Copy

1D1 1c

Well 12

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in

No. 157263

Notice of Intent No. ______
Local Permit No. or Date W30037

State Well No. ______
Other Well No. ______

(1) OWNER: Name Digiorgio Development Corp.
Address P.O. Box A
City Borrego Springs, CA Zip 92004

(2) LOCATION OF WELL (See instructions):
County San Diego Owner's Well Number ______
Well address if different from above ______
Township 11S Range 6E Section ______
Distance from cities, roads, railroads, fences, etc. ______

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic [ ]
Irrigation [X]
Industrial [ ]
Test Well [ ]
Stock [ ]
Municipal [ ]
Other [ ]

(5) EQUIPMENT:
Rotary [X] Reverse [ ]
Cable [ ] Air [ ]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:
Yes [X] No [ ] Size 4/8 well rock
Diameter of bore 0 to 50 is 36", 50 to 768 is 24"
Packed from 0 to 580 ft.

(7) CASING INSTALLED:
Steel [X] Plastic [ ] Concrete [ ]

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	50	26"		conductor		
50	580	14 3/4	5/16	248	568	20 rows 40 cuts of 3/32 x 2¼"

(12) WELL LOG: Total depth 768 ft. Depth of completed well ______

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	12	White sand
12	13	Gravel & sand
13	20	Sand
20	28	Sand with clay
28	54	Clay w/ little sand
54	60	Sand & clay with small cobbles
60	94	Sand with little cobbles
94	96	Sand & brown clay
96	143	Gray clay & sand
143	150	Gray & brown clay with light cobbles
150	154	Cobbles & sand with some clay
154	176	Sand & cobbles
176	185	Cobbles & sand
185	205	Sand & cobbles
205	208	Cobbles and loose sand
208	234	Sand & cobbles
234	235	Boulder
235	294	Hard cobbles
294	340	Cobbles with clay & sand
340	380	Sand & clay with cobbles
380	384	Sand & clay
384	387	Cobbles & sand with clay
387	550	Sand & clay with cobbles
550	554	Cobbles
554	560	Sand & cobbles with clay
560	596	Sand with clay
596	645	Brown clay
645	652	Clay with sand
652	665	Clay
665	725	Clay with sand
725	768	Clay

(9) WELL SEAL:
Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 50 ft.
Were strata sealed against pollution? Yes [ ] No [X] Interval ______ ft.
Method of sealing sanitary seal, conductor casing cement grout

Work started July 11 1984 Completed July 31 1984

(10) WATER LEVELS:
Depth of first water, if known ______ ft.
Standing level after well completion 82' 6" ft.

(11) WELL TESTS: Aug. 18 & 19
Was well test made? Yes [X] No [ ] If yes, by whom? contractor
Type of test Pump [X] Bailer [ ] Air lift [ ]
Depth to water at start of test ______ ft. At end of test ______ ft.
Discharge 2,000+ gal/min after 24 hours from 113 ft. Water temperature ______
Chemical analysis made? Yes [ ] No [X] If yes, by whom? ______
Was electric log made? Yes [X] No [ ] If yes, attach copy to this report

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED [signature] (Well Driller)

NAME AMERICAN DRILLING, INC.
(Person, firm, or corporation) (Typed or printed)
Address P.O. Box 278
City Aguanga, CA Zip 92302
License No. 324684 Date of this report Aug. 20, 1984

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

101

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in

No. 338383

Notice of Intent No. ______
Local Permit No. or Date ______

State Well No. ______
Other Well No. ______

(1) OWNER: Name Borrego Springs Dev. Corp.
Address P.O. Box 9
City Borrego Springs, Ca. ZIP 92004

(2) LOCATION OF WELL (See instructions):
County San Diego Owner's Well Number W-16
Well address if different from above ______
Township 11S Range 6E Section 16
Distance from cities, roads, railroads, fences, etc. ______

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic [ ]
Irrigation [ ]
Industrial [ ]
Test Well [X]
Municipal [ ]
Other [ ]
(Describe)

(5) EQUIPMENT:
Rotary [X] Reverse [ ]
Cable [ ] Air [ ]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:
Yes [X] No [ ] Size 5/16 x 4/16
Diameter of bore 26"
Packed from 50 to 550 ft.

(7) CASING INSTALLED:
Steel [X] Plastic [ ] Concrete [ ]

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	550	16"	.250	160	540	.060

(9) WELL SEAL:
Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 50 ft.
Were strata sealed against pollution? Yes [ ] No [X] Interval ______ ft.
Method of sealing Cement Grout

(10) WATER LEVELS:
Depth of first water, if known ______ ft.
Standing level after well completion 172' ft.

(11) WELL TESTS:
Was well test made? Yes [X] No [ ] If yes, by whom? C.V. Pump
Type of test Pump [X] Bailer [ ] Air lift [ ]
Depth to water at start of test 172' ft. At end of test 230 ft.
Discharge 2500 gal/min after 72 hours Water temperature ______
Chemical analysis made? Yes [ ] No [ ] If yes, by whom? ______
Was electric log made Yes [X] No [ ] If yes, attach copy to this report

(12) WELL LOG: Total depth 705 ft. Completed depth 550 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	65	Coarse med to fine sand
		and gravel mixed
65	420	Coarse med to fine sand
		and gravel w/small rocks
420	490	Fine med to coarse sand
490	520	Fine med to coarse sand
		w/a couple thin streaks
		brown clay
520	640	Fine med to coarse sand
640	705	Fine med to coarse sand
		w/boulders (very tight)

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

Work started 5/8 1989 Completed 7-20 1989

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Signed [signature] (Well Driller)
NAME Coachella Valley Pump & Supply, Inc.
(Person, firm, or corporation) (Typed or printed)
Address P.O. Drawer 999
City Indio, Ca. ZIP 92202
License No. 161541 Date of this report ______

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

104-95

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Retain this copy

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do Not Fill In

№ 61425

State Well No.

Other Well No.

(1) OWNER:
Name Borrego Springs Water District
Address P. O. Box B - Borrego Springs, Ca. 92004

(2) LOCATION OF WELL:
County San Diego Owner's number, if any Well No. 4
Township, Range, and Section
Distance from cities, roads, railroads, etc. Borrego Springs Road Borrego Springs, Ca.

(3) TYPE OF WORK (check):
New Well [X] Deepening [ ] Reconditioning [ ] Destroying [ ]
If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic [X] Industrial [ ] Municipal [ ]
Irrigation [ ] Test Well [ ] Other [ ]

(5) EQUIPMENT:
Rotary [ ]
Cable [X]
Other [ ]

(6) CASING INSTALLED:
STEEL: OTHER:
SINGLE [ ] DOUBLE [X]

If gravel packed

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.
0	50	20ID	5/16			
0	802	14ID	10 ga.			

Size of shoe or well ring 14"x14"x1-1/4" Heat treated
Describe joint Welded

(7) PERFORATIONS OR SCREEN:
Type of perforation or name of screen Moss Hydraulics

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
470	500	6	12	5/32 x 2-1/4"
532	570	6	12	5/32 x 2-1/4"
586	786	6	12	5/32 x 2-1/4"

(8) CONSTRUCTION:
Was a surface sanitary seal provided? Yes [X] No [ ] To what depth 50 ft.
Were any strata sealed against pollution? Yes [ ] No [X] If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing Cement Grout

(9) WATER LEVELS:
Depth at which water was first found, if known 150 ft.
Standing level before perforating, if known 139 ft.
Standing level after perforating and developing 139 ft.

(10) WELL TESTS:
Was pump test made? Yes [X] No [ ] If yes, by whom? R. M. Co.
Yield 1155 gal./min. with 90 ft. drawdown after 127 hrs.
Temperature of water Was a chemical analysis made? Yes [ ] No [X]
Was electric log made of well? Yes [ ] No [X] If yes, attach copy

(11) WELL LOG:
Total depth 802 ft. Depth of completed well 802 ft.
Formation: Describe by color, character, size of material, and structure

From ft.	To ft.	Formation
0	25	Sand
25	40	Sandy clay
40	125	Sandy clay some gr
125	210	Sand, Clay, gravel to 1/4"
210	225	Hard sandy clay, fi gravel
225	235	Hard packed sand
235	250	Hard clay
250	254	Clay & gravel to 1/
254	274	Hard clay
274	278	Sand
278	282	Loose gravel up to 2-1/2"
282	286	Sand, some gravel
286	346	Sandy
346	350	Hard clay
350	354	Sandy
354	358	Sand&gravel to 3"
358	394	Sand
394	418	Sandy
418	426	Sand, &some gravel 3"
426	430	Sand
430	438	Hard sand
438	458	Sandy
458	466	Hard sand
466	470	Sand, some gravel to 1-1/2"
470	494	Sand, small gravel to 1/4"
494	502	Sand, fine gravel
502	514	Hard sand
514	526	Sand, fine gravel
526	530	Clay
530	534	Sand&gravel to 1-1/
534	538	Sand&small gravel to 1/4"

Work started 4-4 19 79, Completed 5-23 19 79

LOG CONTINUES PAGE 2

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Roscoe Moss Company
(Person, firm, or corporation) (Typed or printed)

Address 4360 Worth Street, Los Angeles, Ca. 9003

[SIGNED] Joe Garcia (Well Driller)

License No. 624 (C-57) Dated Nov. 28, 1979, 19

SKETCH LOCATION OF WELL ON REVERSE SIDE

Borrego Springs Water District
Well No. 4 Well Log:

Page 2. . . . .

Ft.	Ft. to	Ft.
538	546	San & fine gravel
546	554	Sand & small gravel to 1/4"
554	574	Sand & gravel to 3"
574	582	Sandy clay
582	606	Sand& small gravel to 1/4"
606	610	Hard sandy clay
610	618	Sand & gravel to 1-1/2"
618	630	Sand & small gravel to 1/8"
630	634	Sand
634	666	Sand & small gravel to 1/8"
666	674	Sand & fine gravel
674	686	Sand & gravel to 1/8"
686	746	Sand & gravel to 1/2"
746	762	Sand & small gravel to 1/8"
762	778	Sand, clay, small gravel to 1/8"(gray)
778	786	Sand, & small gravel to 3/8"
786	802	Sand, clay, &gravel to 3".

Form RM 114

ROSCOE MOSS COMPANY

4360 WORTH STREET
LOS ANGELES, CAL.

JUN 6 - 1979

Well No. Well No. 4 Job No. A-511
Owner Borego Springs Water District
Address P. O. Box B, Borrego Springs, Ca. 92004
Location T ___ R ___ Sec. ___ ¼ ¼ ¼
Borego Springs Road

Started Work 4-4-79
Completed Work 5-23-79
Total Depth Drilled 802'
Depth Water First Encountered 150'

MATERIALS

Conductor Casing

Material Mil Steel
Diameter (OD) (ID) 20" in. Wall Thickness 5/16 in.
Installed From 0 ft. To 50' ft.
Cemented From 45 ft. To 50' ft.

Well Casing

DIAMETER (OD)(ID)	WALL OR GAUGE	MATERIAL	FROM	TO
14" ID	10	Kai Wel	0	802'

Starter Used 18 ft. of 2 ply 8 wall or gauge
Size Shoe 14x14x1¼" Heat treated shoe

PERFORATIONS

Type of Perforator Used Moss Hydraulics

FROM	TO	WIDTH	LENGTH	Rows per FOOT	Perf.
470	500	5/32	2¼	12	6 per row
532	570	5/32	2¼	12	6 per row
586	786	5/32	2¼	12	6 per row

Formation: Mention size of water gravel —

From (ft.)	To (ft.)	Formation
0	25	Sand.
25	40	Sandy clay.
40	125	Sandy clay, some gravel.
125	210	Sand, clay, gravel to ¼".
210	225	Hard sandy clay, fine gra
225	235	Hard packed sand.
235	250	Hard clay.
250	254	Clay & gravel to 1/8".
254	274	Hard clay.
274	278	Sand.
278	282	Loose gravel up to 2½".
282	286	Sand, some gravel.
286	346	Sandy.
346	350	Hard clay.
350	354	Sandy.
354	358	Sand & gravel to 3".
358	394	Sand.
394	418	Sandy.
418	426	Sand, &some gravel to 3".
426	430	Sand.
430	438	Hard sand.
438	458	Sandy.
458	466	Hard sand.
466	470	Sand, some gravel to 1½".
470	494	Sand, small gravel to ¼".
494	502	Sand, fine gravel.
502	514	Hard sand.
514	526	Sand, fine gravel.
526	530	Clay.
530	534	Sand & gravel to 1½".
534	538	Sand & small gravel to ¼"
538	546	Sand & fine gravel.
546	554	Sand& small gravel to ¼".
554	574	Sand & gravel to 3".
574	582	Sandy clay.
582	606	Sand & small gravel to ¼"
606	610	Hard sandy clay.
610	618	Sand & gravel to 1½".

See back of paper for rest of formation.

If Well Is Reduced, Indicate:
Amount of Lap at Reduction ___ ft.
Amount of Lap at Reduction ___ ft.
Amount of lap at Reduction ___ ft.
Method of Sealing at Reduction ___

Give any additional data which may be of future value ___

Formation: Mention size of water gravel.

618	ft.-to	630 ft.	Sand & small gravel to 1/8".
630	"	634 "	Sand.
634	"	666 "	Sand and small gravel to 1/8"
666	"	674 "	Sand and fine gravel.
674	"	686 "	Sand and gravel to 1/8".
686	"	746 "	Sand and gravel to ½".
746	"	762 "	Sand and small gravel to 1/8".
762	"	778 "	Sand, clay, small gravel 1/8" (gray).
778	"	786 "	Sand, and small gravel to 3/8".
786	"	802 "	Sand, clay, and gravel to 3".

1D4-11

TRIPLICATE
Owner's Copy
Page 1 of 1
Owner's Well No. 11
Date Work Began 3/30/95, Ended
Local Permit Agency Co. of San Diego, Environmental Health
Permit No. W62937 Permit Date 3/30/95

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 460084

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) XXX VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION (Describe material, grain size, color, etc.)
0'	30'	Fine to coarse sand gravel
30'	60'	Brown Clay
60'	90'	Brown, Silty, Clay, Strike, sand gravel
90'	120'	Brown, silty clay
120'	190'	Brown, Silty clay, strike fine med sand.
190'	220'	Brown, Clay
220'	280'	Brown, clay strike, fine med sand gravel, lime.
280'	400'	Fine med coarse sand
400	430'	Fine to coarse sand gravel strike brown clay
430'	570'	Fine to coarse sand
570'	740'	Fine to coarse sand
740'	770'	Fine med coarse sand thin strike e brown clay
770'	800'	Fine, med sand tight cement sand

TOTAL DEPTH OF BORING 800' (Feet)
TOTAL DEPTH OF COMPLETED WELL 770' (Feet)

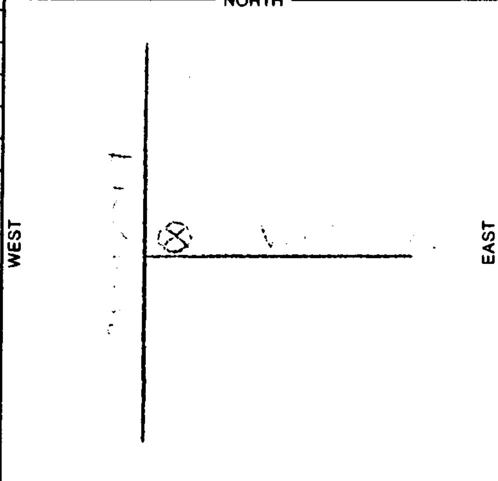
WELL OWNER

Name Borrego Springs Water Company
Mailing Address P.O. Box 369
CITY Vista STATE CA ZIP 92805

WELL LOCATION

Address 2201 Diegumo
City Borrego Springs CA 92004
County San Diego
APN Book ___ Page ___ Parcel 141-030-36
Township 10S Range R6E Section 32
Latitude ___ DEG. MIN. SEC. NORTH Longitude ___ DEG. MIN. SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

XX NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
___ Domestic
___ Public
___ Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
XX OTHER (Specify) Community

DRILLING METHOD Rotary FLUID Bentonite

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 162' (Ft.) & DATE MEASURED 5/16/95
ESTIMATED YIELD* 185' (GPM) & TEST TYPE 2000
TEST LENGTH 7 1/2 (Hrs.) TOTAL DRAWDOWN 23 (Ft.)
* *May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0'	450'	22"	XX					14"	.250	
450'	760'	22"		XX				14"	.250	.060
760'	770'	22"	XX					14"	.250	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0'	50'	XXX			
50'	150'			XXX	3/8"
150'	770'				8 x 12

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Ari-Cal Pump & Supply, Inc.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

PO Drawer 090 Indio, CA 92202
ADDRESS CITY STATE ZIP

Signed [signature] 7-11-95 490061
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

TRIPLICATE
Owner's Copy

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in

No. 230419

Notice of Intent No. 197556
Local Permit No. or Date

State Well No.
Other Well No. WELL 18

(1) OWNER: Name Di Giorgio Development Corp
Address 3230 5th Ave Suite A
City San Diego Zip 92103

(2) LOCATION OF WELL (See instructions):
County San Diego Owner's Well Number
Well address if different from above Henderson Canyon & Borrego SpRd.
Township 10 S Range 6 E Section 18
Distance from cities, roads, railroads, fences, etc.

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic ☐
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☒
Other ☐

(5) EQUIPMENT:
Rotary ☒ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) GRAVEL PACK:
Yes ☒ No ☐ Size #4 x #7
Diameter of bore 12"
Packed from 41 yds. to ft.

(7) CASING INSTALLED:
Steel ☒ Plastic ☐ Concrete ☐

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	50	24	.250	240	300	3/32" x
0	570	12	3/4" x .250	310	385	2½" x
				395	405	22 row

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 50 ft.
Were strata sealed against pollution? Yes ☐ No ☒ Interval ft.
Method of sealing cement grout

(10) WATER LEVELS:
Depth of first water, if known ft.
Standing level after well completion 226 ft.

(11) WELL TESTS:
Was well test made? Yes ☒ No ☐ If yes, by whom? R. Anderson
Type of test Pump ☒ Bailer ☐ Air lift ☐
Depth to water at start of test ft. At end of test ft
Discharge 1200 gal/min after hours Water temperature
Chemical analysis made? Yes ☐ No ☒ If yes, by whom?
Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

(12) WELL LOG: Total depth 699 ft. Depth of completed well 570 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	34	Fine-med. sand w/few rocks @ 31'
34	42	Loose medium sand
42	44	Cemented sand
44	66	Loose sand & gravel, occasional rock
66	105	Tighter sand & gravel
105	243	Looser sand & gravel, occasional rocks, semi consolidated sand & gravel
243	273	Semi-consolidated sand
273	280	Consolidated sand
280	308	Semi consolidated sand and gravel
308	314	Consolidated sand
314	330	Semi consolidated sand & gravel
330	341	Consolidated sand & gravel
341	375	Semi consolidated sand & gravel
375	380	Consolidated sand & gravel
380	410	Semi consolidated sand & gravel
410	455	Very silty sand & gravel
455	477	Slightly cleaner sand & gravel
477	507	Silty sand & gravel
507	560	Slightly cleaner sand & gravel
560	565	Silty sand & some gravel
565	570	Very silty sand & gravel
570	585	Silty sand & gravel
585	590	Very silty sand
590	699	Silty sand & gravel w/ occasional boulders that drill very rough.

PERFORATION CONTINUED
425-440' 460-475' 490-560'

Work started 19 82 Completed 5/17 19 82

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED (Well Driller)
NAME REX ANDERSON CORPORATION (Person, firm, or corporation) (Typed or printed)
Address P.O. BOX 384
City Julian Zip 92036
License No. A 305739 Date of this report March 1982

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

Page 1 of 1

Owner's Well No. 2

No. 765054

Date Work Began 5/15/00 Ended 6/1/00

Local Permit Agency San Diego Co. Dept. Enviromental Health

Permit No. W30559 Permit Date 4/26/00

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD Rotary FLUID Bentonite

DEPTH FROM SURFACE Ft. to Ft.		DESCRIPTION (Describe material, grain size, color, etc.)
0	37	Medium sand with streaks of fine sand
37	67	Coarse medium to fine sand
67	97	Coarse fine to medium sand
97	708	Coarse medium sand with thin streaks of fine sand

TOTAL DEPTH OF BORING 708 (Feet)

TOTAL DEPTH OF COMPLETED WELL 700 (Feet)

WELL OWNER

Name Cameron Brothers

Mailing Address 7756 BalboaAve

San Diego, CA 92111

CITY STATE ZIP

WELL LOCATION

Address Borrego Springs Country Club

City Borrego Springs

County San Diego

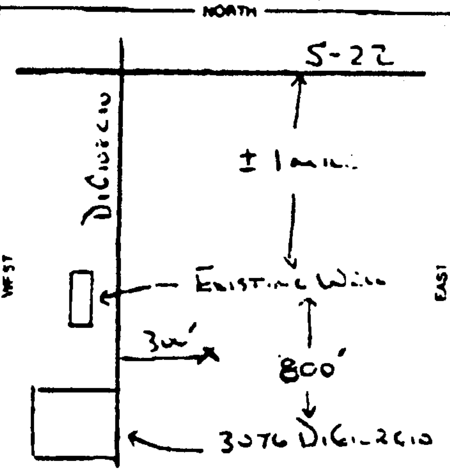
APN Book 199 Page 080 Parcel 14

Township ___ Range ___ Section ___

Latitude ___ NORTH Longitude ___ WEST

DEG. MIN. SEC.

LOCATION SKETCH



Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
X Domestic ___ Public
X Irrigation ___ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 200 (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 260' (Ft.) & DATE MEASURED 6/1/00

ESTIMATED YIELD * 50 (GPM) & TEST TYPE 3000 GPM / Turbine

TEST LENGTH 24 (Hrs.) TOTAL DRAWDOWN 50 (Ft.)

* *May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE: BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	400	26"	X				Steel	16"	.250	
400	700	26"		X			Steel	16"	.250	.060

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	100	X			
100	700			X	8 x 16

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Palm Springs Pump Company

(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

PO Box 94 Thermal CA 92274

ADDRESS CITY STATE ZIP

Signed [signature] 8/12/00 749713

WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

County Mail Station —A-21

FIRST CARBON COPY
send to County Health Dept. Room 104

ASSESSORS PARCEL NUMBER: 200 130 01

COUNTY OF SAN DIEGO
DEPARTMENT OF HEALTH SERVICES
1700 PACIFIC HIGHWAY, SAN DIEGO, CA 92101

WATER WELL DRILLERS REPORT

(INSERT under ORIGINAL PAGE w/carbon of State Form)

Notice of Intent No. 154172
Local Permit No. or Date ______

State Well No. ______
Other Well No. ______

(1) OWNER: Name THOMAS WILCOX
Address ONE MONTGOMERY STREET
City SAN FRANCISCO Zip 94104

(2) LOCATION OF WELL (See instructions):
County SAN DIEGO Owner's Well Number ______
Well address if different from above BORREGO SPRINGS
Township 11S Range 6E Section 21
Distance from cities, roads, railroads, fences, etc. SEE ATTACHED

FOR HEALTH DEPARTMENT USE ONLY
Completed Well Construction:
Date 1? [illegible]
Date Inspected ______
Comments [illegible]
Water Sample Taken? ______
Sanitarian's Approval: [illegible]

(3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item (2))

(4) PROPOSED USE:
Domestic ☐
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other COMMERCIAL ☐

(5) Equipment:
Rotary ☒ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) Gravel Pack:
Yes ☒ No ☐ Size 5/16" x 1/16
Diameter of above 12"
Packed from 35 YDS. ______ ft.

(7) Casing Installed:
Steel ☒ Plastic ☐ Concrete ☐

(8) Perforations:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot Size
0	502	12¾	.250	242	502	3/32" x 2¼" x 22 ROW

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 50 ft.
Were strata sealed against pollution? Yes ☐ No ☒ Interval ______ ft.
Method of sealing CEMENT GROUT

(10) WATER LEVELS:
Depth of first water, if known ______ ft.
Standing level after well completion 245.9 ft.

(11) WELL TESTS:
Was well test made? Yes ☒ No ☐ If yes, by whom? R. ANDERSON
Type of test Pump ☐ Bailer ☐ Air lift ☒
Depth to water at start of test ______ ft. At end of test ______ ft.
Discharge 900+ gal/min after ______ hours Water temperature ______
Chemical analysis made? Yes ☐ No ☒ If yes, by whom? ______
Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

(12) WELL LOG: Total depth ____ ft. Depth of completed well 502 ft.

from ft. to ft.	Formation (Describe by color, character, size or material)
0 - 8	SAND + GRAVEL, QUITE LOOSE
8 - 14	TIGHTER SAND + GRAVEL
14 - 17	ROCKS (COLD FROM 155' TO 17')
17 - 33	SEMI-CONSOLIDATED SAND + GRAVEL
33 - 76	FAIRLY LOOSE SAND + GRAVEL W/ROCKS @ 38' + 42'
76 - 82	TIGHTER SAND + GRAVEL
82 - 89	LOOSE SAND + GRAVEL
89 - 91	CEMENTED SAND + GRAVEL
91 - 122	FAIRLY LOOSE SAND + GRAVEL W/OCCASIONAL CHATTER
122 - 123	CEMENTED SAND + GRAVEL
123 - 141	LOOSER SAND + GRAVEL
141 - 141'6"	CEMENTED (VERY HARD)
141'6" - 143	LOOSE SAND + GRAVEL
143 - 152	TIGHTER SAND + GRAVEL
152 - 212	CONSOLIDATED SAND + GRAVEL DRILLS SLOW W/SLIGHT ROUGHIES
212 - 223	SEMI-CONSOLIDATED SAND + GRAV
223 - 224	CEMENTED SAND
224 - 231	CONSOLIDATED SAND + GRAVEL
231 - 251	SEMI-CONSOLIDATED SAND AND SMALL GRAVELS - SLIGHTLY LOOSER DRILLING.
251 - 283	CONSOLIDATED SAND + SMALL GRAVEL - TIGHTER + ROUGHER DRL
283 - 287	ROUGH + SLOW DRLG. CEMENTED SAND.
287 - 315	SEMI-CONSOLIDATED SAND + SMALL GRAVELS. DRILLS LOOSER PAST 29
315 - 325	SEMI-CONSOLIDATED SAND + LIGHT GRAVEL
325 - 385	CONSOLIDATED (CEMENTED?) SANDS W/OCCASIONAL ROUGH SPOTS. VERY ROUGH FROM 363-365
385 - 435	CONSOLIDATED SAND + LIGHT GRAVEL
435 - 437	CONSOLIDATED SAND + SMALL GRAVEL
437 - 447	SEMI-CONSOLIDATED SAND
447 - 487	CONSOLIDATED SAND W/CLAY OVE

Work started 8/26/81 19 ______ Completed 11/19 1981

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
SIGNED [signature] (Well Driller)
NAME REX ANDERSON CORPORATION (Person, firm, or corporation) (Typed or printed)
Address P.O. BOX 384
City JULIAN Zip 92036
License No. A 305734 Date of this report 12-28-81

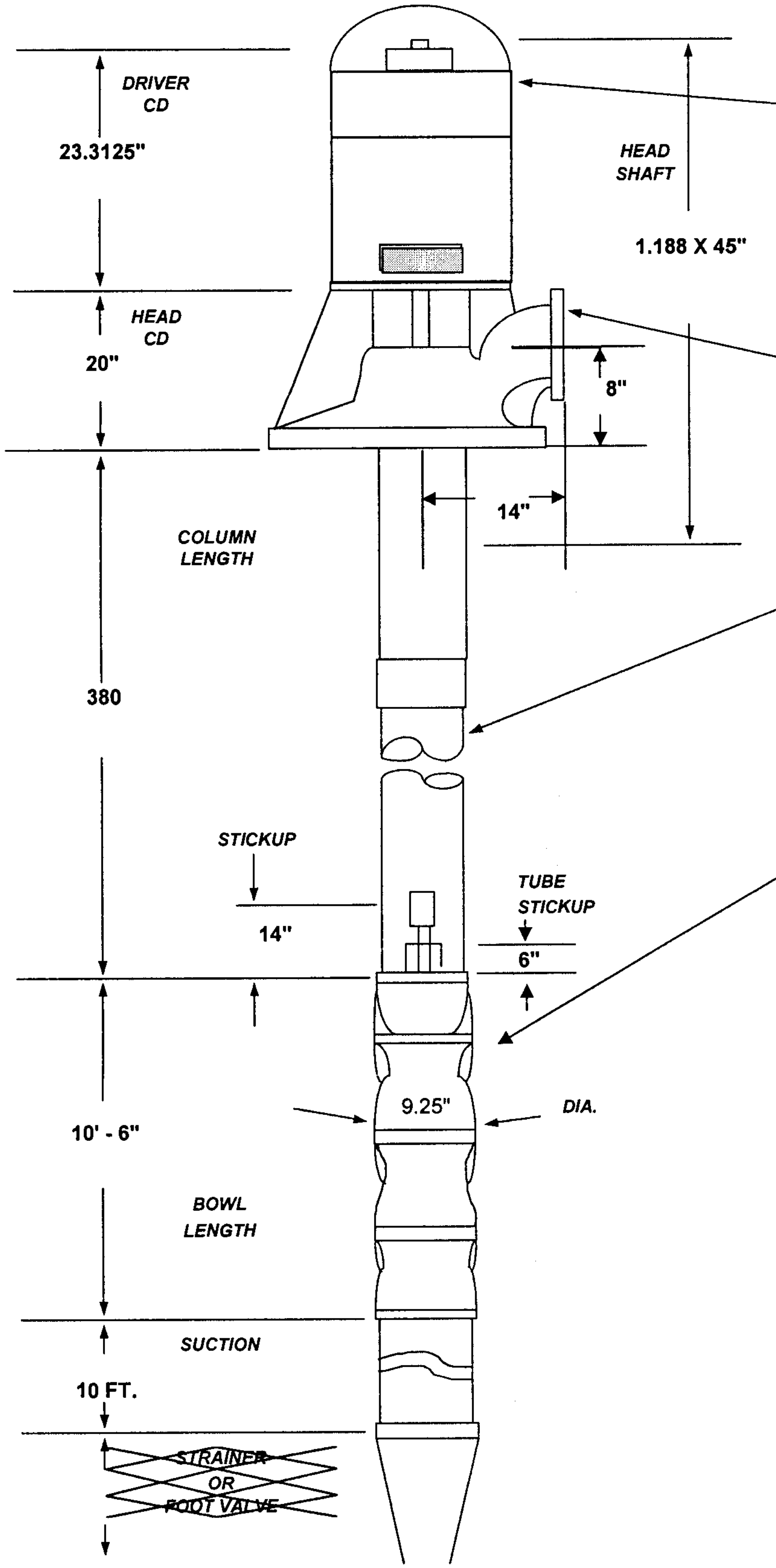
CONFIDENTIAL — NOT FOR PUBLIC USE — WATER CODE SEC. 13752

HVPS, Inc.

CUSTOMER : BORREGO WATER DISTRICT
WELL #: WILCOX WELL
W.O. # 14514
DATE : 10/27/00

DESIGN CONDITIONS

GPM: 350 FTDH: 570 BHP: 61.2



MOTOR NAMEPLATE INFO.

MFG. AMARILLO VOLTS
MODEL 80A FRAME RPM 1775
ENCL BD 16.5 SHAFT DI 1.188
ID/SER #

SIZE AND TYPE HEAD

INLET 6 OUTLET 6 BASE 14" 150# FLG.
MOTOR B 16.5 MAKE GOULDS MODEL 6 X 16.5 L
TOP COLUM NIPPLE SIZE: 6" LENGTH: 12"

COLUMN ASSY. AND TYPE

TOP COLUMN: 6" OIL TUBE: 2" SHAFT: 1.188"
TPI: 14 TPI: 12
BOTTOM COLUMN: 6" OIL TUBE: 2" SHAFT: 1.188
TPI: 14 TPI: 12

BOWL ASSY. INFO.

DIA.: 9.5" #STAGES 13 IMP DIA: 6.8125"
BOWL #: IMP #
MAKE: OULDS MODEL: 9RCLC
SER #: FR430294

SUCTION INFO. (LIST ADAPTIONS)

6" X 10FT. LONG T.O.E. SUCTION NIPPLE

OTHER ADAPTIONS:

WELL DIAMETER AND DEPTH

12" DIA. , 482' DEEP

104-2

ORIGINAL
File with DWR

Notice of Intent No. ______
Local Permit No. or Date ______

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in

No. 126538

State Well No. ______
Other Well No. ______

(1) OWNER: Name Borrego Springs Water Co.
Address Box B
City Borrego Springs, Calif. Zip 92004

(2) LOCATION OF WELL (See instructions):
County San Diego Owner's Well Number No. 2 (New)
Well address if different from above ______
Township T11S Range R6E Section Sec. 7
Distance from cities, roads, railroads, fences, etc. Approx. 2 1/2 mi south west of Christmas Circle on Country Club Rd., Borrego Springs, Calif.

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic [ ]
Irrigation [ ]
Industrial [ ]
Test Well [ ]
Stock [ ]
Municipal [X]
Other [ ]

(5) EQUIPMENT:
Rotary [X] Reverse [ ]
Cable [ ] Air [ ]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:
Yes [X] No [ ] Size #4 x #7
Diameter of bore 24"
Packed from 0 to 380 ft.

(7) CASING INSTALLED:
Steel [X] Plastic [ ] Concrete [ ]

From ft.	To ft.	Dia. in.	Gage or Wall
0	50	26	.322
2	380	14	.250

(8) PERFORATIONS:
Type of perforation or size of screen ______

From ft.	To ft.	Slot size
240	325	3/32
355	370	

(9) WELL SEAL:
Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 50 ft.
Were strata sealed against pollution? Yes [ ] No [X] Interval ______ ft.
Method of sealing Cement Grout

(10) WATER LEVELS:
Depth of first water, if known — ft.
Standing level after well completion 254 ft.

(11) WELL TESTS:
Was well test made? Yes [X] No [ ] If yes, by whom? Rex Anderson
Type of test Pump [X] Bailer [ ] Air lift [ ]
Depth to water at start of test 254 ft. At end of test 254 ft.
Discharge 350 gal/min after 24 hours Water temperature —
Chemical analysis made? Yes [X] No [ ] If yes, by whom? Borrego Springs Water Co.
Was electric log made? Yes [X] No [ ] If yes, attach copy to this report

(12) WELL LOG: Total depth 468 ft. Depth of completed well 380 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	66	Sand
66	73	Fine gravel w/ very little sand
73	86	Sand w/ small gravel
86	141	Sand w/ small gravel & rock
141	154	Sand & Gravel
154	159	Boulders & sand
159	188	Sand & gravel
188	191	Sand & gravel w/ some clay
191	255	Sand & gravel w/ some clay, semi-consolidated
255	270	Boulders & clay
270	290	Sand & gravel in clay
290	294	Boulders & clay
294	320	Sand & clay
320	322	Rocks & clay
322	328	Sand w/ clay, slow drilling
328	337	Sand, clay & gravel
337	338	Sand w/ little clay
338	347	Clay
347	359	Sand, clay & gravel
359	367	Sand & gravel w/ some clay
367	372	Clay & sand, slow drilling
372	418	Sand & clay w/ rock, slow drilling
418	426	Gravel & Rock in clay
426	460	Clay w/ sand & small gravel
460	468	Clay

Work started 3/14 1978 Completed 4/26 1978

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED Rex E. Anderson
(Well Driller)

NAME Rex Anderson Corp.
(Person, firm, or corporation) (Typed or printed)
Address 10303 Channel Rd.
City Lakeside, Calif. Zip 92040
License No. A305739 Date of this report 4/26/78

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

MAIN OFFICE:
3132 West 17th Street
Santa Ana, California 92703
Phone: 714-554-4142

BRANCH OFFICES:
13855 Central Avenue
Chino, California 91710
Phone: 714-627-1521

980 Nevada Street
Redlands, California 92373
Phone: 714-793-2913

53-381 Hiway 111
P.O. Box 886
Coachella, California 92236
Phone: 619-398 8867

McCalla Bros.

Well Drilling & Pump Sales

January 20, 1987

L.R. Burzell
Palm Canyon Estates
1002 Bennie Brea Place
Vista, CA 92084

SUBJECT: 12" Well-Palm Canyon Estates
Borrego Springs *Well 5 BSWC.*

Dear Lin,

Confirming our conversation of 1-15-86, outlined below are details concerning construction of the subject well.

As you are aware the construction of the well proceeded without any unusual problems. The "E" Log was not unusual and the bore samples were as expected.

Outlined here are dates of work as completed:

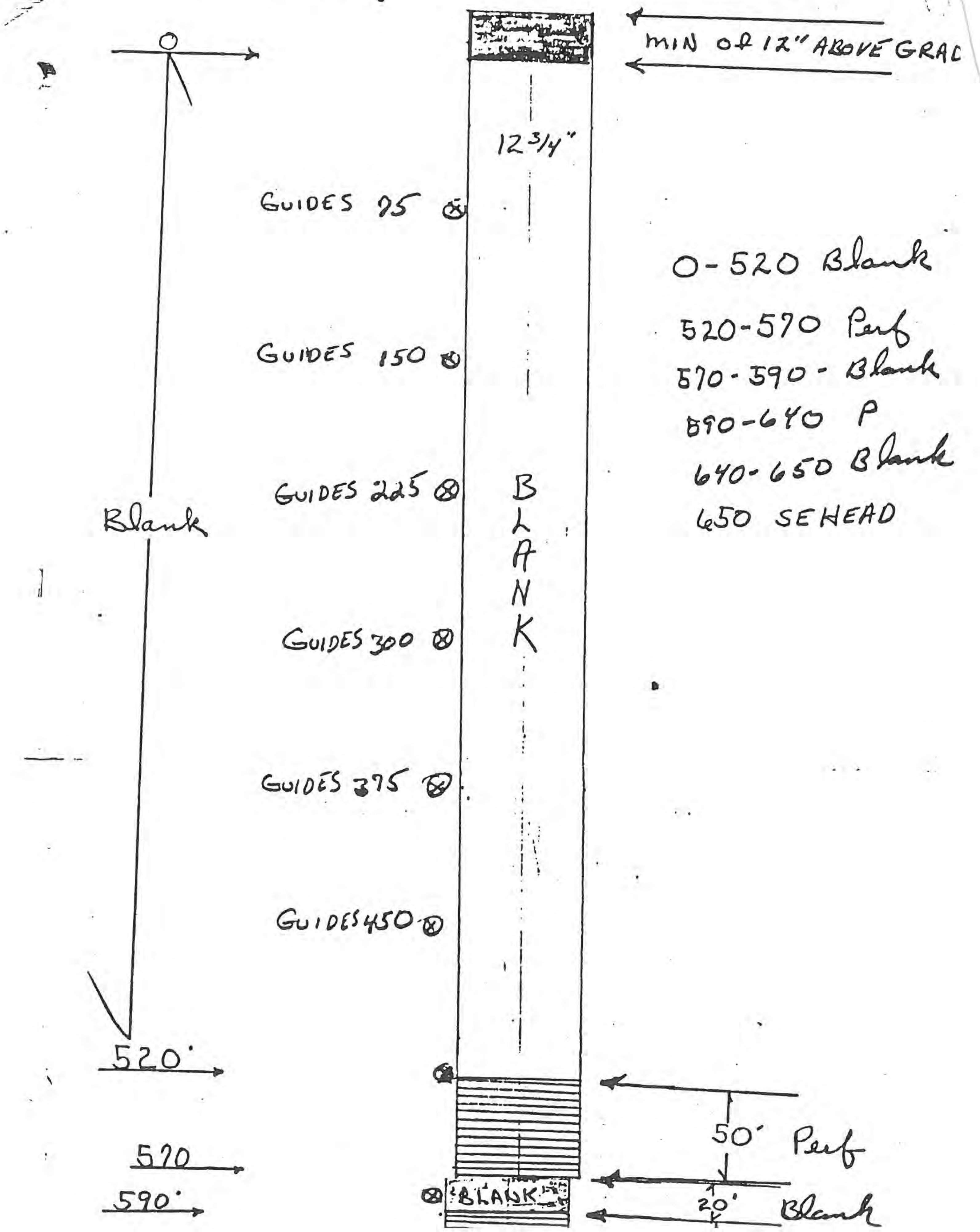
9-10-86	Move In - Set Up
9-16-86	Began Pilot Bore
9-19-86	Ran "E" Log
9-22-86	Began Constructing Conductor Set 50' of 25" Pipe Cemented In Place
9-23-86	Began Reaming 24" Hole
10-04-86	Completed Reaming 24" Bore to 659'
10-04-86	Set Well Casing & Gravel Pack
10-06-86	Air Lift Well To Remove Drill Fluids (7 Hrs)
10-07-86	Air Lift Well To Remove Drill Fluids (11 Hrs)
10-20-86	Install Test Pump
10-22-86	Test Pump Well (6 1/2 Hrs)
10-23-86	Test Pump Well (7 1/2 Hrs)
10-27-86	Install 80' Extension to 330' Setting
10-28-86	Test Pump Well (6 Hrs)
10-29-86	Test Pump Well (7 Hrs)
10-30-86	Test Pump Well (4 Hrs)

10S/6E 33Q

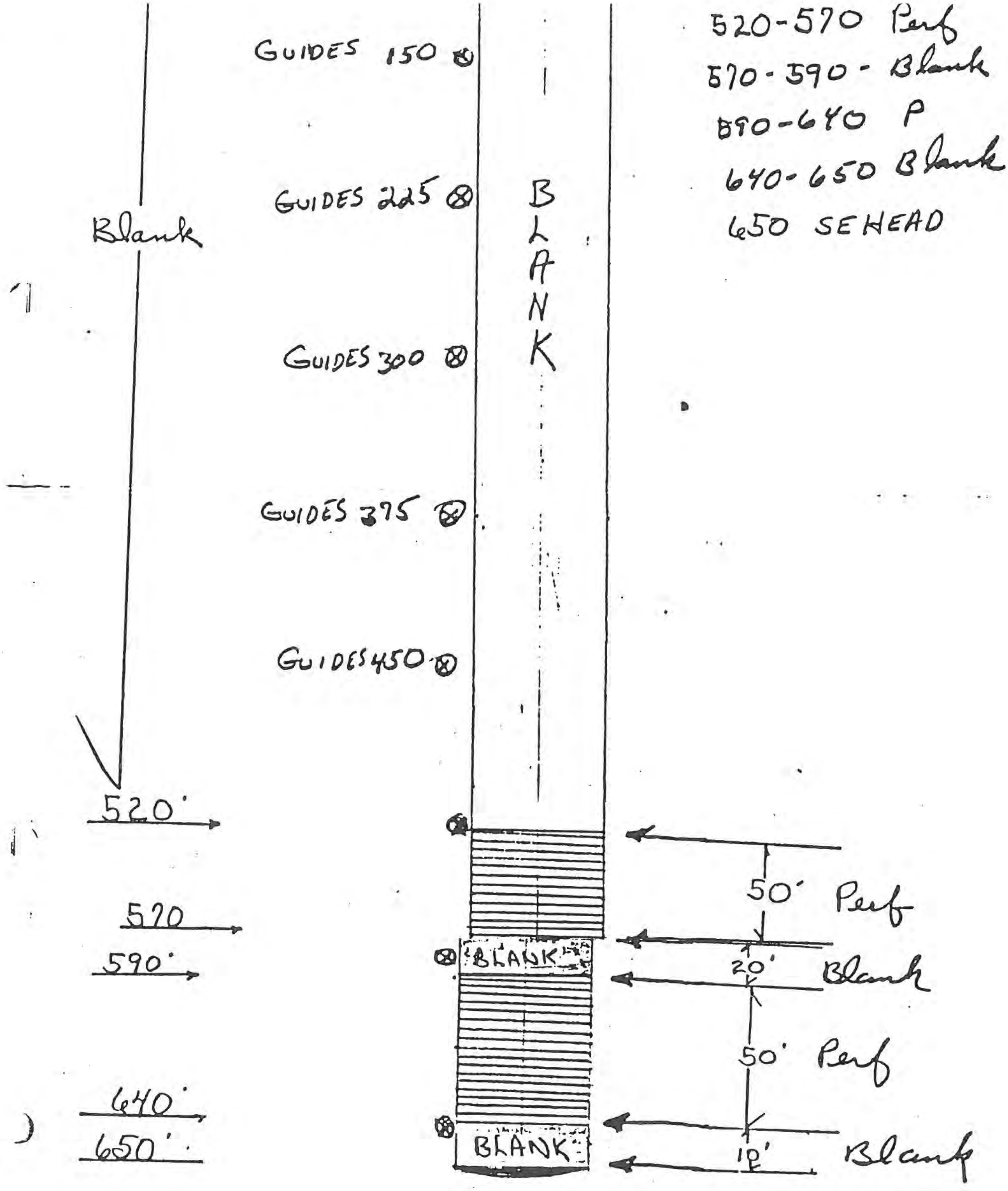
Palm Canyon Estates CC-1327

Depth	Material		
1.8	Sand		
6.0	Sand		
26	Sand		
46	Sand		
66	Sand		
86	Sand		
106	Sand		
126		Clay	
146	Sand	Clay	Rock
166	Sand		Rock
186		Gravel	Rock
206	Sand	Clay	Gravel
226	Sand		Gravel
246		Clay	
266		Clay	Gravel
286	Sand		Gravel
306	Sand		
326	Sand	Clay	
346		Clay	
366		Clay	
386		Clay	
406	Sand	Clay	
426	Sand	Clay	
446	Sand	Clay	
466	Sand	Clay	
486	Sand	Clay	
506		Clay	
520			Gravel
526			Gravel
546			Gravel
566		Clay	Gravel
586		Clay	Gravel
606			Gravel
610			Gravel
626			Gravel
646		Clay	Gravel
666		Clay	Gravel
686		Clay	Gravel
Bottom			

Palm Canyon Estates # CC 1321



520-570 Perf
570-590 - Blank
590-640 P
640-650 Blank
650 SEHEAD



BSWCo Well 10

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in

No. 278130

ID4 Well 10

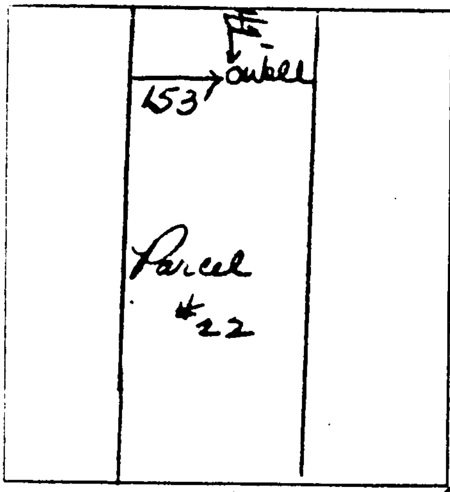
Local Permit No. or Date

State Well No.

Other Well No.

(1) OWNER: Name ~~Pete Petersen~~
Address ~~2436 Five Diamonds Rd.~~
City ~~Borrego Springs, Ca. 92004~~ ZIP

(2) LOCATION OF WELL (See instructions):
County San Deigo Owner's Well Number
Well address if different from above
Township ~~11/S~~ Range ~~6E~~ Section ~~18~~
Distance from cities, roads, railroads, fences, etc.



WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic ☐
Irrigation ☐
Industrial ☐
Test Well ☐
Municipal ☐
Other ☒
(Describe)

(5) EQUIPMENT:
Rotary ☒ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) GRAVEL PACK:
Yes ☒ No ☐ Size 12/16 4/16
Diameter of bore 12 1/4
Packed from 160 to 630 ft.

(7) CASING INSTALLED:
Steel ☒ Plastic ☐ Concrete ☐

(8) PERFORATIONS:
Type of perforation or size of screen Mill cut

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	630	8	.188	420	630	

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 160 ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval ft.
Method of sealing B entonite slurry

(10) WATER LEVELS:
Depth of first water, if known 385 ft.
Standing level after well completion 385 ft.

(11) WELL TESTS:
Was well test made? Yes ☐ No ☒ If yes, by whom?
Type of test Pump ☐ Bailer ☐ Air lift ☐
Depth to water at start of test ft. At end of test ft.
Discharge gal/min after hours Water temperature
Chemical analysis made? Yes ☐ No ☒ If yes, by whom?
Was electric log made Yes ☐ No ☒ If yes, attach copy to this report

(12) WELL LOG: Total depth 630 ft. Completed depth 630 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	50	Coarse med to fine sand & grave
50	120	Med. fine to coarse sand & gravel
120	245	medfine to coarse sand & gravel with small rocks & cobbles
245	440	Boulders
440	470	Fine to coarse sand with thin streaks of brown clay w/lime
470	630	Fine to coarse sand

Work started 5/24/89 19 Completed 6/21/89 19

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Signed [signature] (Well Driller)
NAME Coachella Valley Pump & Supply, Inc. (Person, firm, or corporation) (Typed or printed)
Address P.O. Drawer QQQ
City Indio, Ca. 92202 ZIP
License No. 161541 Date of this report 7/14/89

DWR 188 (REV. 12-88) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM