Luhdorff & Scalmanini
Consulting Engineers

Technical Memorandum

DATE: July 3, 2019

PROJECT: 19-1-047

TO: Shawnda Grady, ESQ
Ellison, Schneider, Harris & Donlan

FROM: Eddy Teasdale, P.G., CHG.
Mehrdad Bastani

SUBJECT: **Ground Water (Hydrologic) Technical Memorandum Report to Support San Bernardino Conditional Use Permit Related to Adequate Service Certification Water and Sewer (Form W2) - PVL Lime Plant APN: 0485-031-12**

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1 INTRODUCTION

This Technical Memorandum (TM) describes the process used to determine groundwater availability and evaluate potential impacts of operating a new planned industrial well on existing groundwater users in the area. Provided herein are the key findings, conclusions, and preliminary recommendations regarding water availability for the proposed PVL processing plant in Trona, California (Project).

Implementation of the Project will utilize water from a recently installed on-site production well. For drinking water, the Project proposed to utilize an estimated 1.3 gallons per minute (gpm). To meet operational requirements related to domestic and processing usage, the new planned well will need to produce a maximum of 30 gpm (49 AF/year).

2 GEOLOGY AND HYDROGEOLOGY

Searles Valley is a north-trending structural valley that is bound by the Argus Range on the west and north and by the Slate Range on the north and east. The Garlock Fault is generally recognized as the southern limit of the groundwater basin, however topographically, the surface water drainage area of the valley continues south of the Garlock fault. The area of the Searles Valley drainage basin is estimated to be about 693 square miles.

There are three primary hydrogeologic units within the Searles Valley, alluvial deposits, saline deposits and bedrock complex. The alluvial deposits are loosely to moderately lithified clay, silt, sand, gravel and boulders. Near the basin margins, the alluvial deposits consist of sand, gravel and boulders. Toward the center, the coarse-grained facies grades into finer grained silts and clay beds.

The saline deposits are a sequence of interbedded mud and soluble evaporites that grade laterally to the surrounding alluvial deposits. When saturated, saline deposits yield large quantities of brine to wells. The Bedrock complex underlies the alluvial deposits and is composed of granitic, metamorphic, sedimentary and volcanic rock. Two wells have been drilled into the southwestern portion of the valley and have yielded some water from the bedrock complex. Additional evidence of water within the bedrock complex is a series of springs located in the Argus Range. Some areas within the bedrock complex are heavily fractured thus allowing for underflow from Indian Wells Valley to Searles Valley.

Natural recharge to the basin is presumably from three sources, percolation of runoff, subsurface inflow in unconsolidated sediments and direct infiltration from rain. Analyses of groundwater from the basin indicate that dissolved solids range from 5,000 milligrams per liter (mg/L) on the edge of the late to more than 350,000 mg/L in the center. Groundwater from wells in the vicinity of Searless Lake is inferior for essentially all beneficial users. Due to this poor water quality, all domestic water in Searless Valley is piped in from wells in Indian Well Valley.

3 GROUNDWATER CONDITIONS

3.1 Well Inventory

An inventory of existing industrial and monitoring wells within 1 mile of the PVL project was conducted by LSCE. Locations of these existing wells are presented on **Figure 1**.

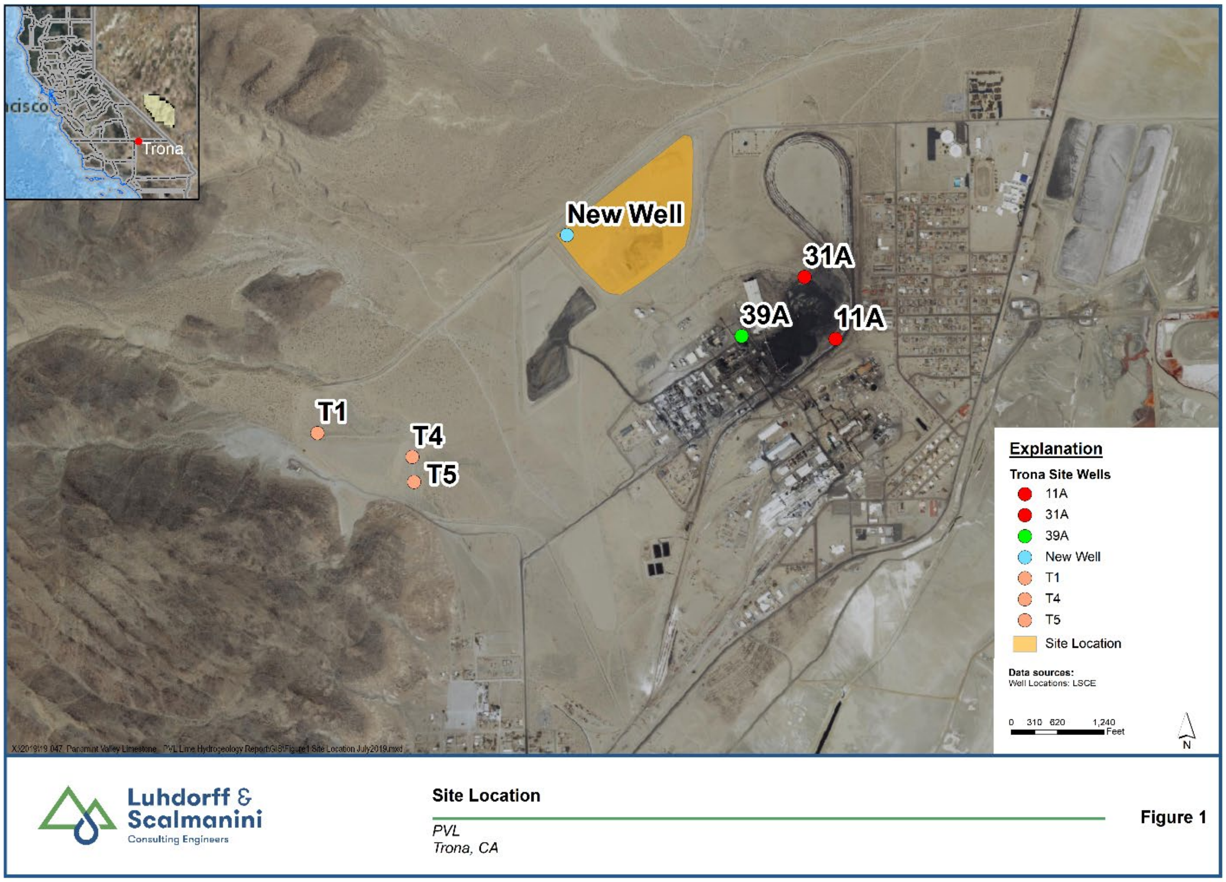

Figure 1: New Production Well and Nearby Industrial (39A, 31A and 11A) and Monitoring Wells(T1-T3)

3.2 Groundwater Level Mapping

Groundwater level mapping was conducted using groundwater level data from nearby wells. The most recent data is from monitoring wells located on the Trona-Argus Sanitary Landfill which is located approximately ½ mile west of the Project. **Figure 2** illustrates the general groundwater flow direction and gradient from the landfill site. As illustrated on **Figure 2**, groundwater flow is generally to the northeast across the area. Based on the most recent data collected in 2016, the horizontal gradient in the area ranges from 0.08 ft per foot (ft/ft) to 0.12 ft/ft.

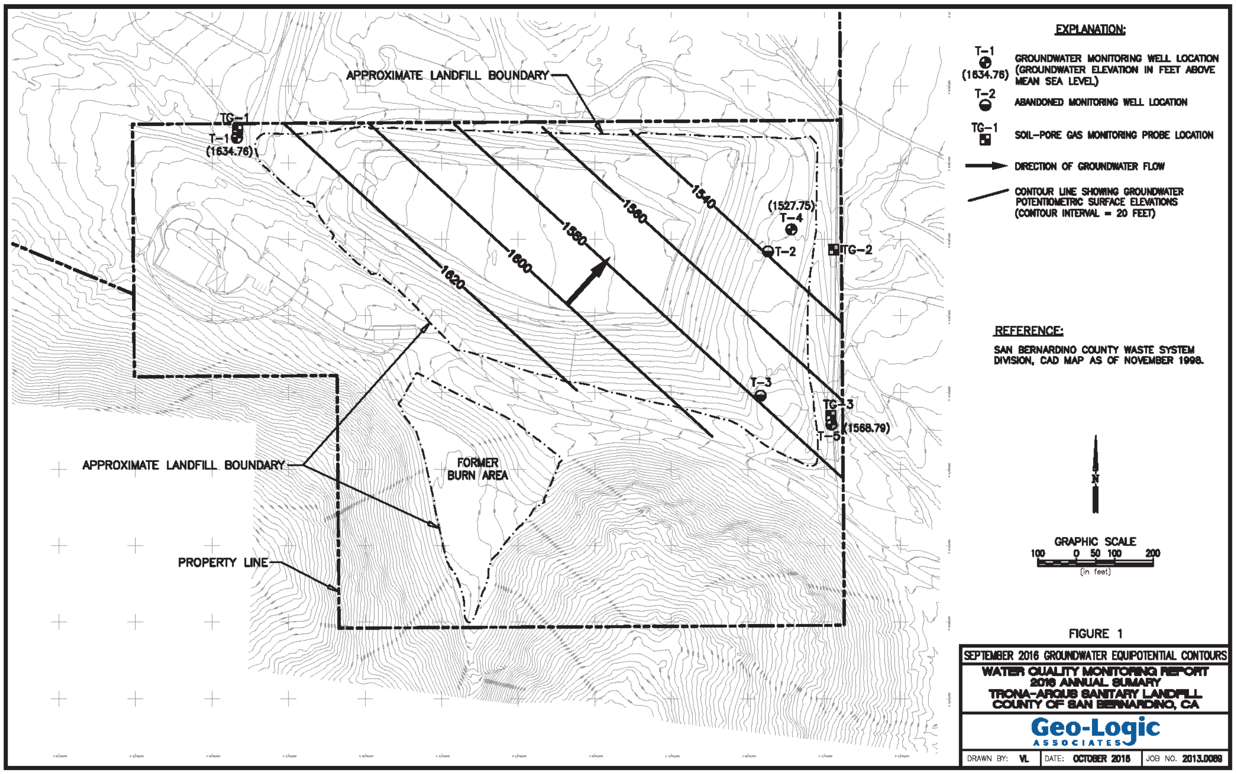

Figure 2: Equipotential contours and direction of the groundwater flow (Geo-Logic Associates, 2016)

3.3 Historical Water Level Changes

Limited historical water level data were available for the area. A hydrograph from T-1, a nearby monitoring well on the Trona-Argus Landfill is presented on **Figure 3**. Well locations are shown on **Figure 1**. The hydrograph indicates an increase in groundwater levels (groundwater was rising) starting in 1992 through approximately 1994, when depth to groundwater ranged from 262 feet below ground surface (BGS) to 268 feet BGS. From 1994 until 2009 depth to groundwater increased from approximately 262 feet BGS to 267 feet BGS. Since about 2010, groundwater levels have been relatively stable in this part of the basin.

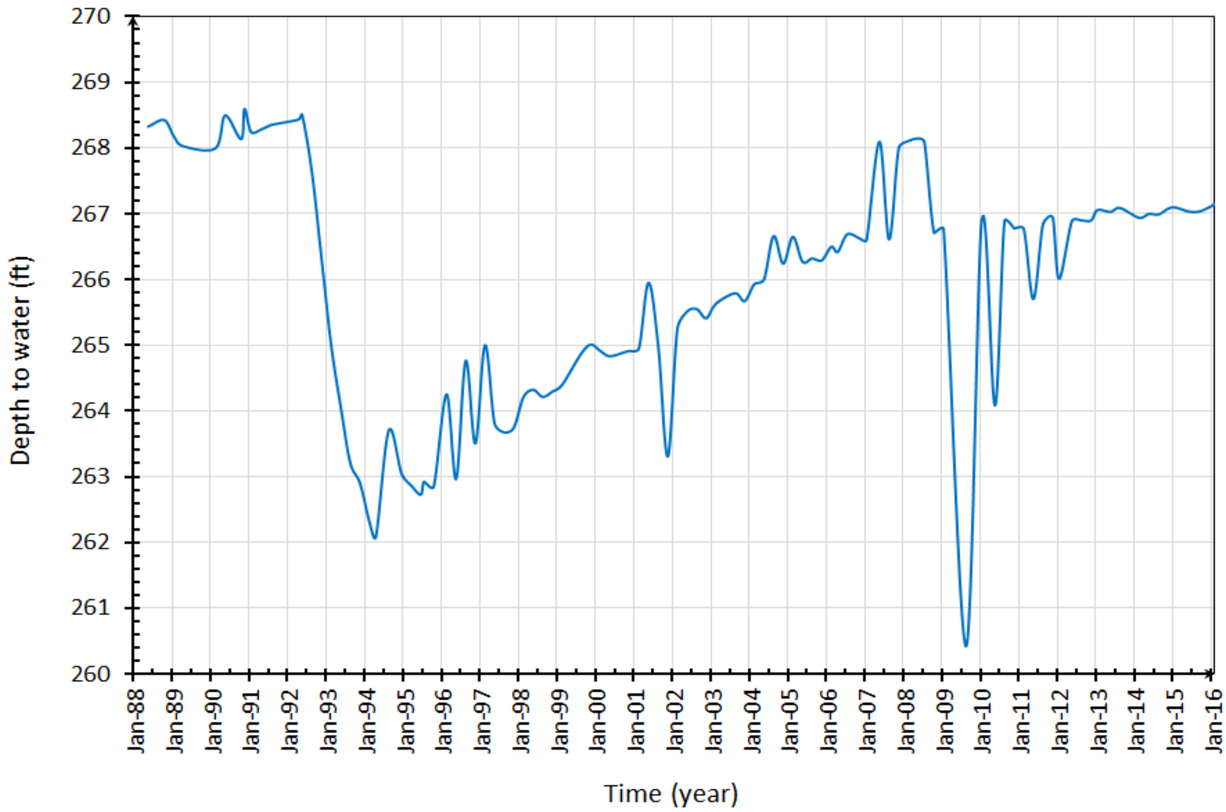

Figure 3: The hydrograph of depth to water at well T1

4 GROUNDWATER AVAILABILITY

Two well-established and accepted methodologies were combined to evaluate groundwater availability for the Project. The first methodology evaluated the availability based on calculating the amount of groundwater flowing beneath the Project site. This groundwater would be available for extraction by one or more wells for use on the overlying lands. This evaluation was done by using Darcy's Law, which described flow through porous media. The second methodology quantified the groundwater resource by comparing the total amount of annual project usage to estimates of groundwater storage prepared by the California Department of Water Resources.

4.1 Availability based on Flowing Groundwater beneath the Project

Approximate groundwater discharge flowing through the PVL area was calculated from the 2016 seasonal groundwater elevation contours. These estimates were made utilizing Darcy's Law:

$$Q = KiA$$

Where Q is discharge (ft^3/day or AF/year), K is hydraulic conductivity (ft/day), i is the hydraulic horizontal gradient (ft/ft), and A (ft^2) is the cross-sectional area.

Hydraulic Conductivity, K: Values for transmissivity, T, were derived by drawdown type curve matching from a single-well test conducted on May 2019 on the new production well. The new well was installed by a licensed California well driller, following local and state regulations. The well completion report (WCR2019-008283) was submitted to DWR on June 13, 2019. The aquifer transmissivity was determined from the pumping test with a constant-rate extraction of 15 gpm with periods of very short recovery for total operation period of 2 days and 6 hours (**Figure 4**).

Using the Neuman type curve matching, the estimated transmissivity (T) would be 300 ft^2/day, and the storativity (S) is 0.003. To calculate hydraulic conductivity, K, LSCE used the equation:

$$T = Kb$$

Where b is the aquifer thickness. The derivation of aquifer thickness is described in detail below. For this analysis, an aquifer thickness of 33 feet was used to calculate K. This results in a K of 9 ft/day.

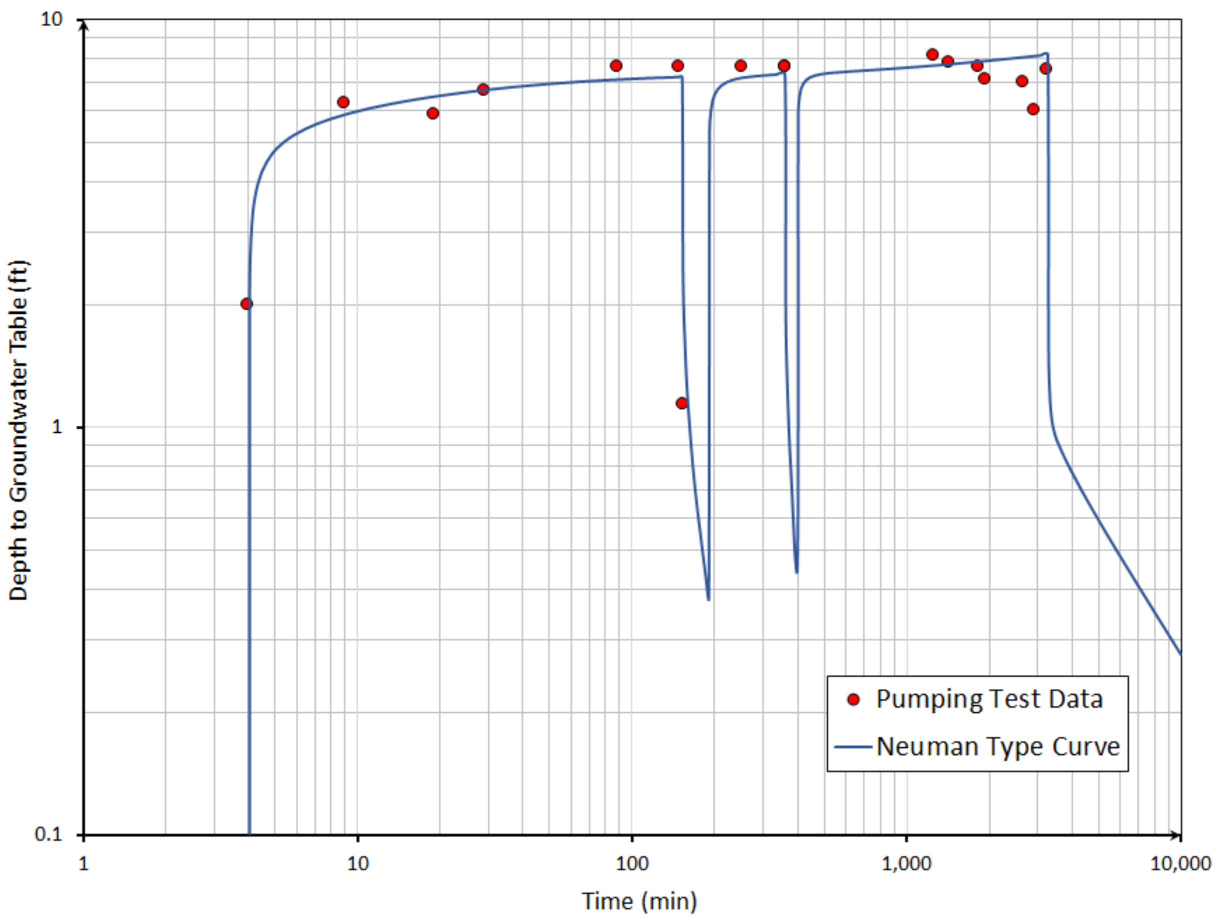

Figure 4: Estimation of Aquifer Properties by Matching Neuman Type Curve Solution to Time-Drawdown Data Collected from Constant-Rate Pumping Test

Hydraulic Gradient, i: Range of hydraulic gradient (i) value was 0.08 to 0.12 (ft/ft) from Geo-Logic Associate (2016).

Cross-Section Area, A: The cross-sectional area of the aquifer (A) was determined based on utilizing the saturated thickness across the width of the aquifer that would be available to the proposed well.

Aquifer Width: The aquifer width utilized for this calculation is 2,500 ft.

Aquifer Thickness: The test well was drilled to a depth of 343 ft based on the drillers log and the bottom of the well is still within the alluvial aquifer (**Figure 5**). With a depth to water of 310 ft bgs, this results in a saturated aquifer thickness of 33 ft.

Quantity of Groundwater Flow, Q: The calculated values of Q ranged from 1 AF/day to 2 AF/day. The anticipated groundwater demand for site development and future operations is 0.13 AF/day (49 AF/year). On this basis, sufficient groundwater is available to supply the PVL project.

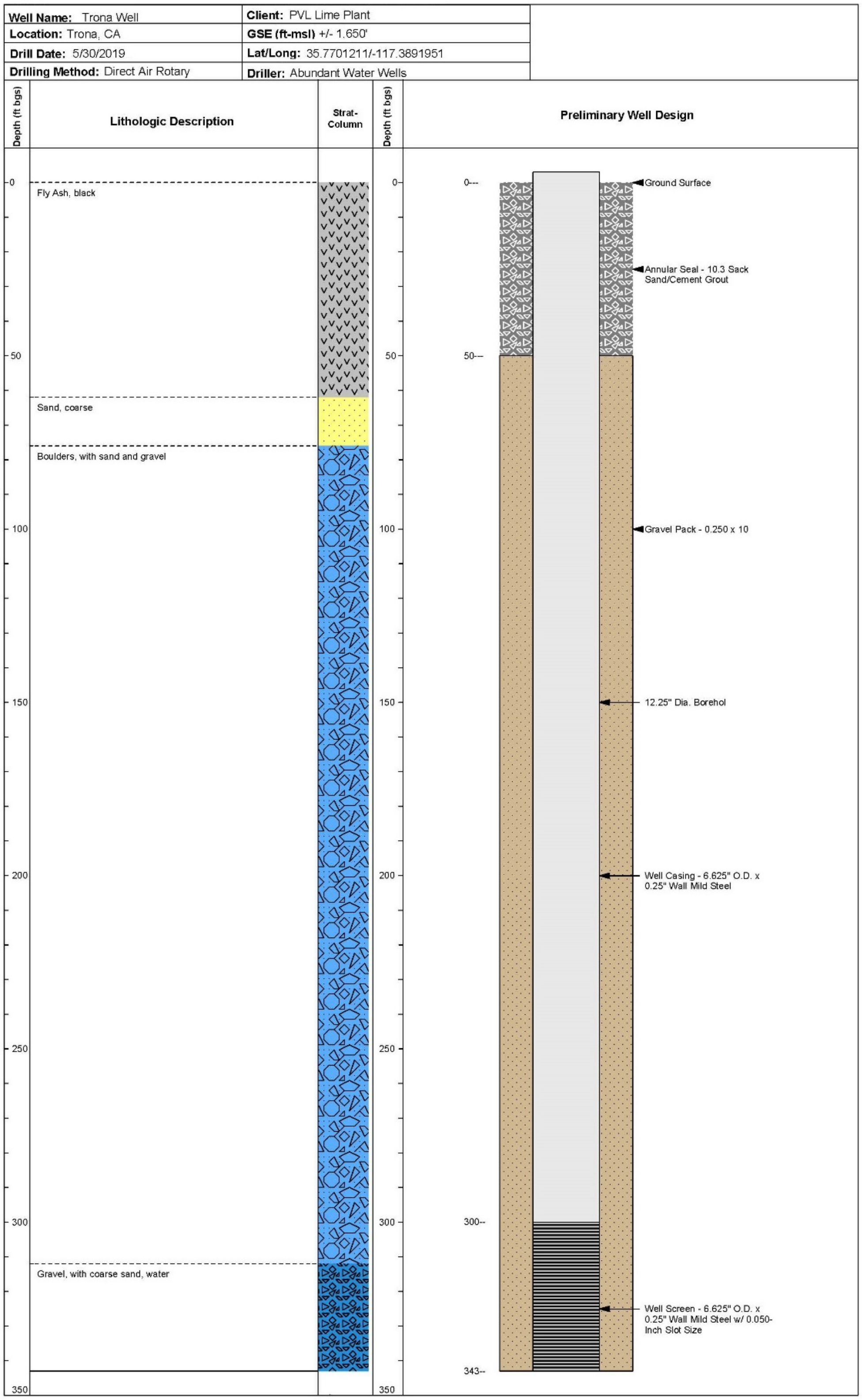

Figure 5: Well Log Driller for the New Well (June 2019)

4.2 Availability based on Groundwater Balance

DWR estimated that the groundwater storage capacity of the Valley is approximately 2,140,000 AF (DWR, 2004). The annual project use is 49 AF which is less than 0.003 percent of the regional groundwater storage capacity.

5 IMPACTS OF PROPOSED PUMPING

To assess the extent and degree of groundwater drawdown in response to Project extraction at 30 gpm, a drawdown analysis was conducted. The impact analysis is based on continuous pumping rate of 30 gpm on a 24-hour per day schedule for a 20-year period.

5.1 Analytical Approach

In order to estimate the amount of drawdown expected during long-term pumping, LSCE used an analytical model which incorporates the Neuman (1974) aquifer equation to determine the drawdown radially from a pumping well once the transmissivity (T) and storativity (S) values of the aquifer material have been determined. For reference, the transmissivity (T) is the rate at which water is transmitted through a unit width of the aquifer for its full thickness at a unit hydraulic gradient, usually in feet squared per day. Storativity (S) is the ratio of the volume of water a rock or soil will yield to the volume of rock or soil, a dimensionless number. Q is the pumping rate in either AF/year or gpm (note: 1 AF equals 325,851 gallons).

The Neuman equation was developed based on the following assumptions (Fetter, 2001):

1. The aquifer is unconfined and homogeneous.
2. All flow is radial and horizontal toward the well.
3. The pumping well and observation wells are fully penetrating the aquifer.
4. The pumping well is 100% efficient.
5. All geologic formations are horizontal with infinite horizontal extent.
6. The potentiometric surface of the aquifer is horizontal and steady before starting to pump.
7. The vadose zone has no influence on the drawdown.
8. Initially pumped water comes from the instantaneous release of elastic storage water.
9. Eventually water comes from the storage due to gravity.
10. The drawdown is negligible compared with the saturated aquifer thickness.
11. The specific yield is at least 10 times greater than the elastic storativity.
12. Anisotropic hydraulic conductivity is an option.

The Neuman's solution is:

$$h_0 - h = \frac{Q}{4\pi T} W(u_A, u_B, \Gamma)$$

With:

$$u_A = \frac{r^2 S}{4Tt} \quad (Type\ curve\ for\ early\ drawdown\ data)$$

$$u_B = \frac{r^2 S_y}{4Tt} \quad (Type\ curve\ for\ later\ drawdown\ data)$$

$$\Gamma = \frac{r^2 K_v}{b^2 K_r}$$

Where, $W(u_A, u_B, \Gamma)$ is the well function (tabulated in the literature), $h_0 - h$ is the drawdown [L], Q is the pumping rate of the well [L^3 /T], T is the transmissivity [L^2 /T], r is the radial distance from the pumping well [L], S is the storativity (dimensionless), S_y is the specific yield (dimensionless), t is the time [T], K_r is the horizontal hydraulic conductivity [L/T], K_v is the vertical hydraulic conductivity [L/T], and b is the initial saturated thickness of the aquifer [L].

Parameters used for the Neuman calculation are listed in **Table 1** and change of drawdown due to the operation of the new well in the area is shown in **Figures 6 and 7**.

Table 1: Neuman Parameters

Parameter	Units	Value	Reference
Q	[ft3/d]	5775	Panamint Valley Limestone, INC. (Q = 30 gpm = 5775 cfd)
T	[ft2/d]	300	Estimated from constant-rate pumping test
S_y	[ ]	0.15	Indian Wells Valley Groundwater Basin (DWR, 2004-IWVGB)
b	[ft]	33	Calculated using Test Well's driller log
Kv/Kr	[ ]	0.1	Todd (1980)
n	[ ]	0.25	Geo-Logic Associate (2016)
S	[ ]	0.003	$S = \rho g(\alpha + n\beta)b$, where ρ = density of water = 1000 kg/m^3 g = gravitational acceleration = 9.8 m/s^2 α = aquifer compressibility = 3e-8 m^2/N n = porosity = 0.25 β = water compressibility = 4.4e-10 m^2/N b = aquifer thickness = 311 ft = 95 m

As a result of the continuous extraction of water through the new well operation, a cone of depression occurs around the well with the highest amount of groundwater drawdown at the new well's location and less impact far from the well. **Figure 6** illustrates the amount of drawdown at different distances from the new well. For instance, at the distance of 2,000 ft, groundwater table is simulated to be lowered by 3.5 ft

LSCE

after 20 years of nonstop pumping of the new well. This drop of the water table occurs only in response to this well's operation while the current condition of the water table is the superposition (contribution) of all drawdowns due to all other pumping wells active in the area.

The lowering of the water table at a specific distance from the well also changes by time. **Figure 7** demonstrates this change for three different distances. For instance, at 2,000 ft away from the new well, the groundwater table starts to drop with a very low rate at the first year of pumping the new well and the drawdown after 20 years at the same location is less than 3.5 ft. The shape of the curves in **Figure 7** follows the Neuman (1974) calculations which encounters the effects of elastic storage at early times and specific yield at later time in the unconfined aquifer.

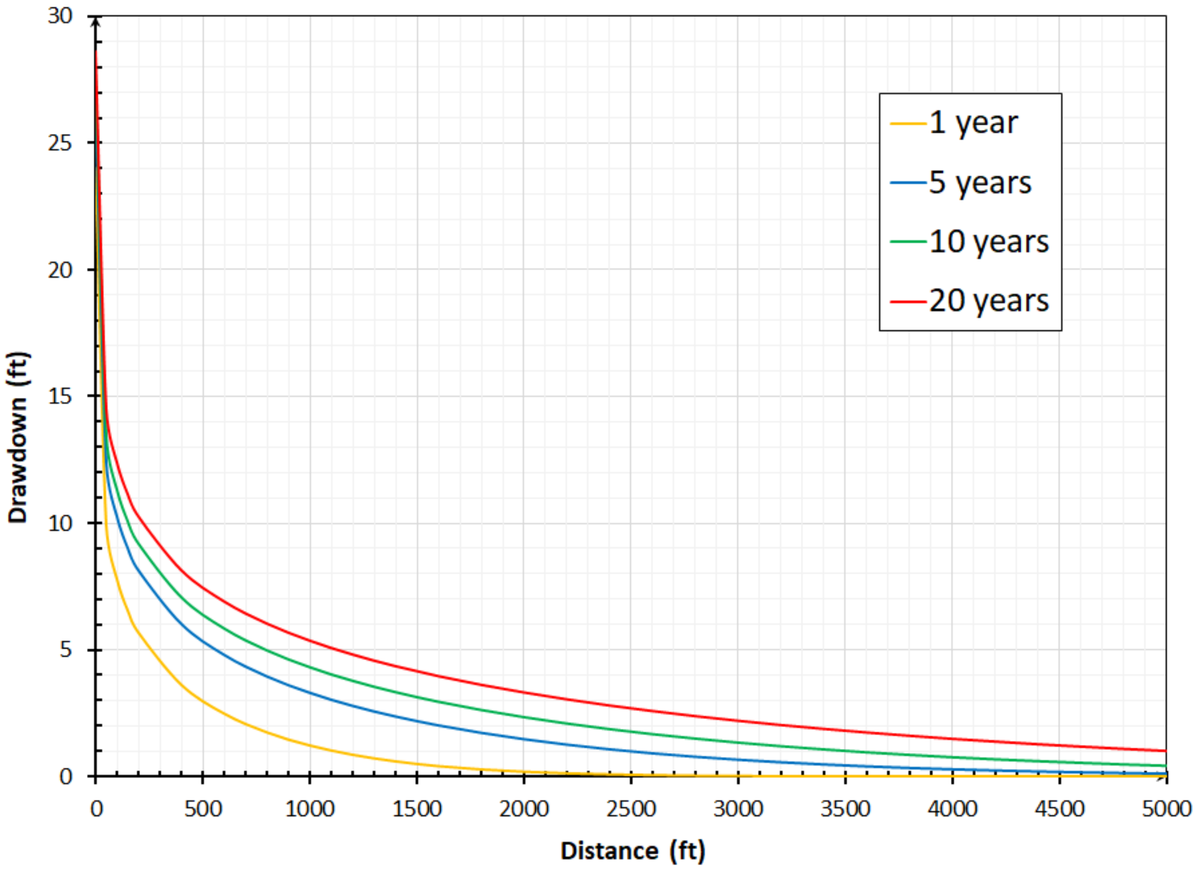

Figure 6: Change of drawdown due to the new well operation after different years of pumping

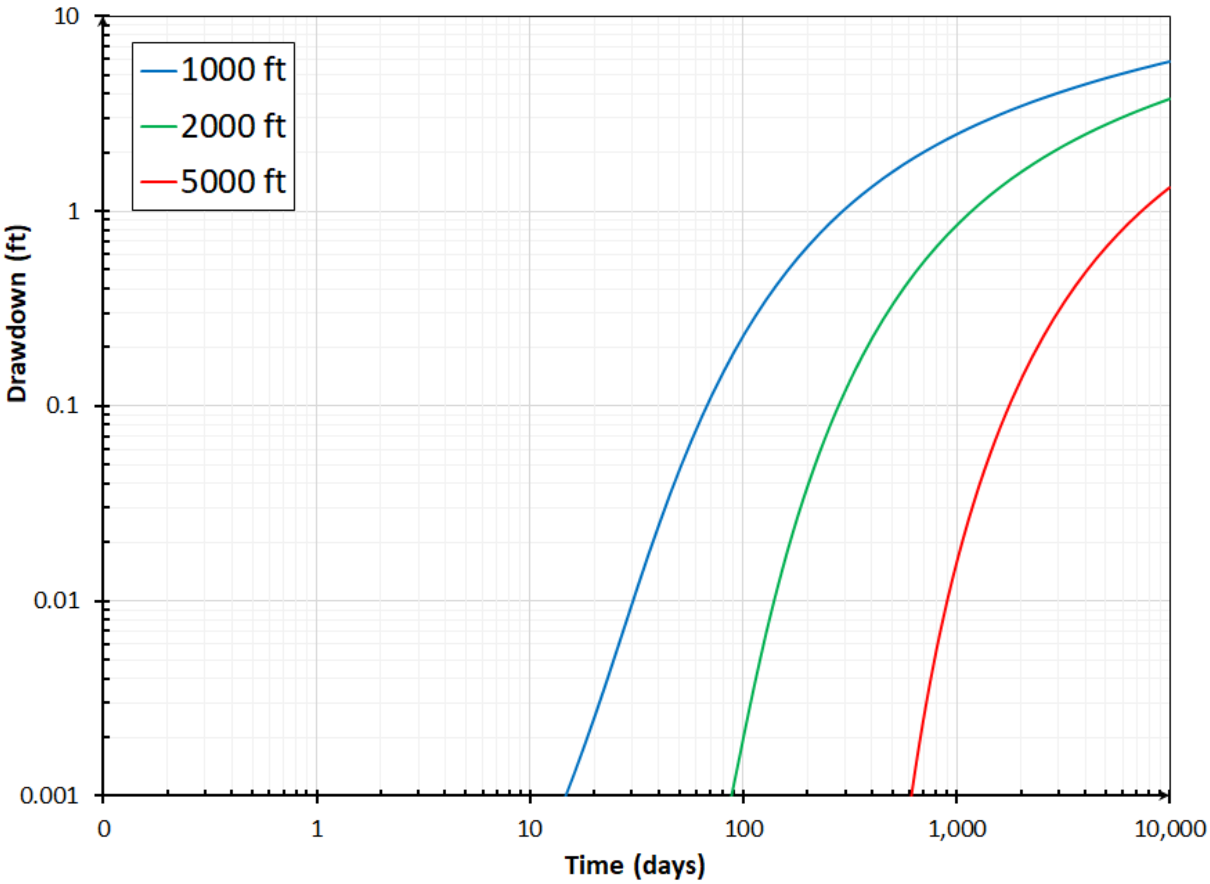

Figure 7: Change of drawdown at different distances due to the operation of the new pumping well

5.2 Area of Potential Impact

The results of this analysis indicate the drawdown of water table at the radius of approximately one mile from the well, after 20 years of continuous pumping at 30 gpm, is almost 12 inches. This is shown graphically on **Figure 8**.

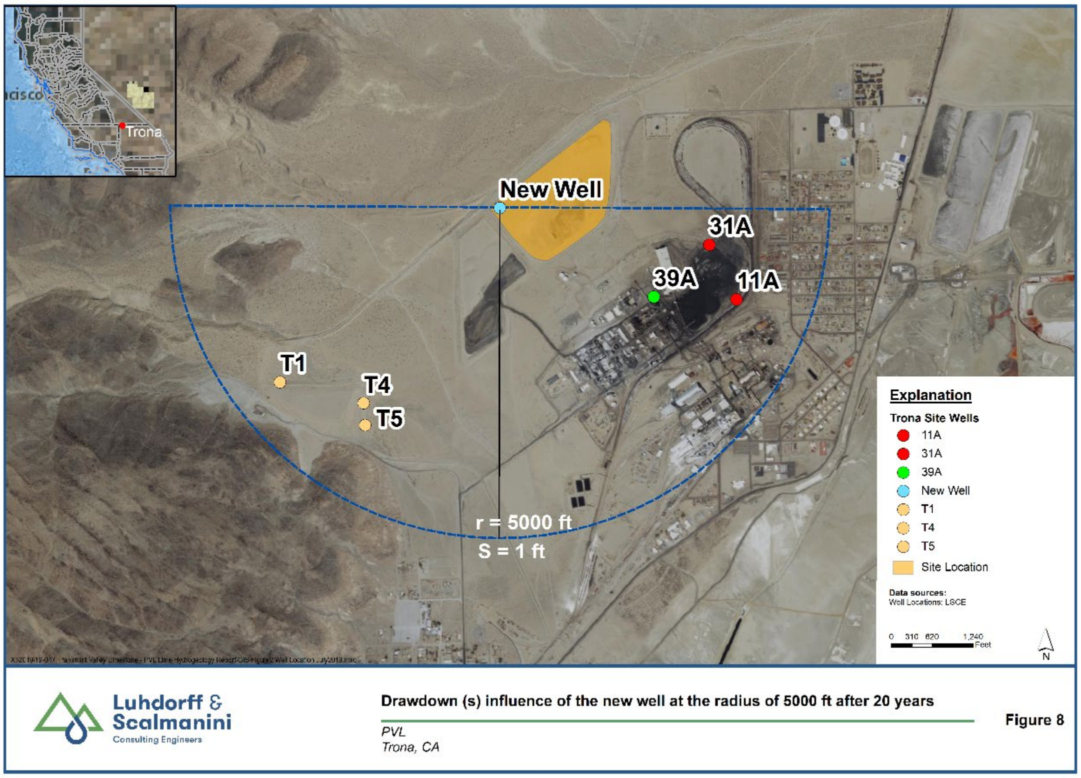

Figure 8: Simulated Drawdown after 20 years

6 GROUNDWATER QUALITY

During the constant rate aquifer testing, a groundwater sample was collected from the discharge line and submitted to Clinical Laboratory of San Bernardino for water quality analysis. Laboratory results are included as **Figures 9 and 10** below. As discussed above in Section 2 and summarized in water quality data from the recent sampling event, water quality in this area is not suitable for drinking water unless the water is treated prior to use. Currently PVL is evaluating treatment options for both the domestic and process supply. Once an appropriate treatment system has been selected, all groundwater supplied for domestic purposes (estimated to be less than 2 gpm) will be treated to meet drinking water standards. Process water will also require additional treatment, although not to the same degree as the domestic supply.

Clinical Laboratory of San Bernardino, Inc.

Celebrating 50 Years of Analytical Service 1967-2017

Barker, Shawn	Project: Routine	Work Order: 19F0302
82532 Second Street	Sub Project: APN # 048503112	Received: 06/04/19 17:10
Trona CA, 93562	Project Manager: Water Quality Supervisor	Reported: 06/17/19

Well **19F0302-01 (Water)** **Sample Date:** 06/04/19 11:10 **Sampler:** Greg Ross

Analyte	Method	Result	Rep. Limit	MCL	Units	Prepared	Analyzed	Batch	Qualifier
General Physical Analyses									
Apparent Color	SM 2120BM	**5.0**	3.0	15	Color Units	06/04/19	06/04/19	1923096	
Odor Threshold	EPA 140.1-M	**1**	1	3	TON	06/04/19	06/04/19	1923096	
Turbidity	EPA 180.1	**0.8**	0.1	5	NTU	06/04/19	06/04/19	1923096	
General Chemical Analyses									
Alkalinity, Total (as CaCO3)	SM 2320 B	**450**	5.0		mg/L	06/10/19	06/10/19	1923062	
Bicarbonate (HCO3)	SM 2320 B	**120**	5.0		mg/L	06/10/19	06/10/19	1923062	
Carbonate (CO3)	SM 2320B	**210**	5.0		mg/L	06/10/19	06/10/19	1923062	
Chloride (Cl)	EPA 300.0	**510**	2.0	500	mg/L	06/07/19	06/07/19	1923121	
Cyanide (CN)	SM4500CNF	ND	100	150	ug/L	06/10/19	06/10/19	1924021	
Specific Conductance (E.C.)	SM 2510B	**2700**	2.0	1600	umhos/cm	06/10/19	06/10/19	1923062	
Fluoride (F)	EPA 300.0	**3.3**	0.10	2	mg/L	06/05/19	06/05/19	1923075	
Hydroxide (OH)	SM 2320B	ND	5.0		mg/L	06/10/19	06/10/19	1923062	
MBAS (LAS Mole. Wt 340.0)	SM 5540C	ND	0.10	0.5	mg/L	06/05/19	06/05/19	1923068	
Nitrate as N (NO3-N)	EPA 300.0	ND	0.40	10	mg/L	06/05/19	06/05/19	1923075	
Nitrate + Nitrite (as N)	EPA 300.0	ND	0.40	10	mg/L	06/05/19	06/05/19	1923075	
Nitrite as N (NO2-N)	EPA 300.0	ND	0.40	1	mg/L	06/05/19	06/05/19	1923075	
Perchlorate (ClO4)	EPA 314.0	ND	3.0	6	ug/L	06/14/19	06/14/19	1924156	
pH (Lab)	SM 4500HB	**10.1**			pH Units	06/05/19	06/05/19	1923062	
Sulfate (SO4)	EPA 300.0	**230**	0.50	500	mg/L	06/05/19	06/05/19	1923075	
Total Filterable Residue/TDS	SM 2540C	**1500**	5.0	1000	mg/L	06/06/19	06/07/19	1923127	
Metals									
Aluminum (Al)	EPA 200.7	ND	50	200	ug/L	06/07/19	06/07/19	1923161	
Antimony (Sb)	EPA 200.8	ND	6.0	6	ug/L	06/10/19	06/10/19	1924005	
Arsenic (As)	EPA 200.8	**2400**	4.0	10	ug/L	06/11/19	06/11/19	1924031	
Barium (Ba)	EPA 200.7	ND	100	1000	ug/L	06/07/19	06/07/19	1923161	
Beryllium (Be)	EPA 200.8	ND	1.0	4	ug/L	06/10/19	06/10/19	1924005	
Boron (B)	EPA 200.7	**11000**	1000		ug/L	06/07/19	06/07/19	1923161	
Cadmium (Cd)	EPA 200.8	ND	1.0	5	ug/L	06/10/19	06/10/19	1924005	
Calcium (Ca)	EPA 200.7	ND	1.0		mg/L	06/06/19	06/06/19	1923119	
Chromium (+6)	EPA 218.6	ND	1.0		ug/L	06/04/19	06/07/19	1923054	
Chromium (Total Cr)	EPA 200.8	ND	10	50	ug/L	06/10/19	06/10/19	1924005	
Copper (Cu)	EPA 200.7	ND	50	1000	ug/L	06/07/19	06/07/19	1923161	
Iron (Fe)	EPA 200.7	ND	100	300	ug/L	06/07/19	06/07/19	1923161	
Lead (Pb)	EPA 200.8	ND	5.0		ug/L	06/10/19	06/10/19	1924005	
Magnesium (Mg)	EPA 200.7	ND	1.0		mg/L	06/06/19	06/06/19	1923119	
Manganese (Mn)	EPA 200.7	ND	20	50	ug/L	06/07/19	06/07/19	1923161	
Mercury (Hg)	EPA 200.8	**7.0**	1.0	2	ug/L	06/12/19	06/12/19	1924082	
Nickel (Ni)	EPA 200.8	ND	10	100	ug/L	06/10/19	06/10/19	1924005	
Potassium (K)	EPA 200.7	**11**	1.0		mg/L	06/06/19	06/06/19	1923119	

Figure 9: Groundwater Quality Data (Prior To Treatment)

Clinical Laboratory of San Bernardino, Inc.
Celebrating 50 Years of Analytical Service 1967-2017

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82532 Second Street	Sub Project: APN # 048503112	Received: 06/04/19 17:10
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Well **19F0302-01 (Water)** **Sample Date:** 06/04/19 11:10 **Sampler:** Greg Ross

Analyte	Method	Result	Rep. Limit	MCL	Units	Prepared	Analyzed	Batch	Qualifier
Metals									
Selenium (Se)	EPA 200.8	ND	5.0	50	ug/L	06/10/19	06/10/19	1924005	
Silver (Ag)	EPA 200.8	ND	10	100	ug/L	06/10/19	06/10/19	1924005	
Sodium (Na)	EPA 200.7	**630**	10		mg/L	06/06/19	06/06/19	1923119	
Thallium (Tl)	EPA 200.8	ND	1.0	2	ug/L	06/10/19	06/10/19	1924005	
Vanadium (V)	EPA 200.8	**140**	3.0		ug/L	06/14/19	06/14/19	1924158	
Zinc (Zn)	EPA 200.7	ND	50	5000	ug/L	06/07/19	06/07/19	1923161	
Anion / Cation Balance									
Hardness, Total (as CaCO3)	Calculated	0.0			mg/L	06/06/19	06/06/19	[CALC]	
Total Anions	Calculated	**28.3**			meq/L	06/06/19	06/10/19	[CALC]	
Total Cations	Calculated	**27.7**			meq/L	06/06/19	06/06/19	[CALC]	
% difference	Calculated	**2.2**				06/06/19	06/10/19	[CALC]	

pH (Lab) was analyzed ASAP but received and analyzed past the 15 minute hold time.

ND Analyte NOT DETECTED at or above the reporting limit

Figure 10: Groundwater Quality Data (Prior To Treatment)

7 CONCLUSIONS

Groundwater availability was calculated on the basis of Darcy's Law using available parameters from existing wells. The result of the groundwater analysis is that sufficient groundwater supplies exist and are quantified as being at least 7,000 AF/year (inflow) flowing beneath the Project Site, or stated differently, the Project site is located on lands overlying the groundwater supplies for which at least 365 AF/year (inflow) of groundwater exists. The proposed project will only utilize approximately 49 AF/year, or less than 15% of the total amount of groundwater flowing in this area. These calculations confirm that Project pumping of 49 AF/year from the local aquifer could be maintained by groundwater inflow.

Operating this well will have minimal impacts on nearby industrial wells. The predicted drawdown after 20 years of continuous pumping (assuming no recharge) is less than 12 inches at a radius of 5,000 feet. As a comparison, groundwater levels fluctuate seasonally more than 1 ft in this area.

Our evaluation of other professional engineering and hydrogeological analyses, coupled with LSCE's analysis of this Project site using accepted methodologies, results in calculations and conclusions that represent a conservative quantification of groundwater supplies available to the proposed Project, and more generally, the local vicinity.

8 LIMITATIONS

The conclusions presented in this report are professional opinions based solely upon the presented data. They are intended exclusively for the purpose outlined herein and the site location and Project indicated. This report is for the sole use and benefit of the Client. The scope of services performed in execution of this investigation may not be appropriate to satisfy the needs of other users, and any use or reuse of this document or the findings, conclusions, or recommendations presented herein is at the sole risk of said user.

Given that the scope of services for this investigation was limited, it is possible that currently unrecognized subsurface conditions may be present at the site. Should site use or conditions change, the information and conclusions in this report may no longer apply. Opinions relating to environmental, geologic, and geotechnical conditions are based on limited data and actual conditions may vary from those encountered at the times and locations where data were obtained. The effects of boundary mountains (barriers) at north-west side of the area are neglected in this study. No express or implied representation or warranty is included or intended in this report except that the work was performed within the limits prescribed by the Client with the customary thoroughness and competence of professionals working in the same area on similar projects.

9 REFERENCES

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