Appendix D

New Well Site Evaluation

- **Lawrence & Associates Engineers and Geologists.** Evaluation of Three Potential Well Locations in Mt. Shasta, Siskiyou County, California. February 15, 2019

LAWRENCE & ASSOCIATES
ENGINEERS & GEOLOGISTS

018005.00

February 15, 2019

Mr. Paul Reuter
PACE Engineering
1730 South Street
Redding, CA 96001

Dear Paul:

SUBJECT: EVALUATION OF THREE POTENTIAL WELL LOCATIONS IN MT. SHASTA, SISKIYOU COUNTY, CALIFORNIA

INTRODUCTION

The letter presents the results of an evaluation of three potential municipal water-supply well locations in the town of Mt. Shasta (**Figure 1**). Our work was conducted for PACE Engineering (PACE), on behalf of the Mt. Shasta City (City). PACE requested that Lawrence & Associates (L&A) evaluate the hydrogeologic setting of three potential well locations identified by the City and PACE (**Figure 2**):

Location #1 – APN 057-781-220, off Spring Hill Drive, north of Spring Hill
Location #2 – APN 057-791-060, off North Mt. Shasta Blvd., immediately west of Big Springs.
Location #3 – APN 057-111-090, on Chestnut St., between East Field and East Ivy Streets.

SUMMARY

A well at the Spring Hill Drive Site likely would produce water from both clastic materials ("Upper Aquifer") and fractured andesite ("Lower Aquifer"). Yield could be in excess of 300 gallons per minute (gpm), up to as much as 500 gpm, and likely would need to be at least 300 feet deep. The static water level likely would be greater than 100 feet bgs. In consideration of groundwater quality protection, it would be beneficial to screen a well completed here solely in the "Lower Aquifer", because of the high permeability of the overlying clastic materials. Based on the historical groundwater elevations, to lessen potential impacts to Big Springs a new well could be located in the northern part of the Spring Hill parcel.

A well at the Mt. Shasta Blvd. Site, west of Big Springs, likely would produce water from only from the fractured andesite aquifer ("Lower Aquifer"). Yield could be in excess of 300 gpm, as illustrated by the high-producing DEX wells at the bottling plant site to the east, but there is insufficient data on

wells west of Big Springs that are completed in the "Lower Aquifer" to state this with certainty. The static water level likely would be near the ground surface, and a completed well at the Mt. Shasta Blvd. Site likely would not need to be of significant depth, although there is insufficient data to predict accurately the total depth of a future well. In consideration of groundwater quality protection, it is likely that the shallower portions of the aquifer would need to be sealed off, thereby reducing the yield. It is possible that a well at the Mt. Shasta Blvd. Site would be hydraulically connected to Big Springs. Groundwater quality likely would be good.

A well at the Chestnut Street Site likely would produce water from clastic materials consisting predominantly of sand and gravel. Yield could be as much as 200 gpm, or more. The static water level likely would be shallow (a nearby well is artesian), and a completed well at the Chestnut Street Site likely would not need to be of significant depth, probably less than 200 feet.

GENERAL HYDROGEOLOGIC SETTING

The vicinity of the proposed well locations has been evaluated in several studies, mainly in relation to the water-bottling plant located to the southwest of Spring Hill. The following discussion of the hydrogeologic setting of the area has been taken from those studies, along with other publicly available documents (a reference list is included at the end of this report).

The City is located on the flanks of Mt. Shasta, a stratovolcano of the Cascade Ranges Geomorphic Province. There has been volcanic activity in the Mt. Shasta area for at least 590,000 years, but the ancestral cone was destroyed in a major collapse and landslide approximately 300,000 years ago. The floor of Shasta Valley, and the low hills in the southern part of the Shasta Valley, represent deposits from that landslide. The current cone of Mt. Shasta has developed over the last 250,000 years. Eruptions within the last 10,000 years produced lava flows and domes on and around the flanks of Mount Shasta; pyroclastic flows from summit and flank vents extend as far as 12 miles from the summit.

The general stratigraphy underlying the proposed well locations, especially Locations #1 and #2, consist of an upper unit of clastic material and a lower unit of various types of volcanic deposits. The clastic material is composed of a wide variety of materials, from clay to cobbles, although larger sized materials (sand, gravel, and cobbles) predominate. The clasts themselves are mostly composed of materials derived from volcanic deposits. The volcanic rocks underlying the upper unit consist generally of andesite, basalt, and dacite, along with pyroclastic materials such as tuff and ash, and cinder deposits.

Spring Hill represents one of the plug domes erupted on the flanks of the mountain. As shown in the borings for the water-bottling plant, the core of Spring Hill is composed of reddish-brown andesite, with varying degrees of fracturing. Overlying the andesite, is a mixture of silty sand and gravel.

Away from the Spring Hill area, the upper clastic deposits thicken and are interbedded with differing types of volcanic deposits (cinders, ash, and pyroclastics).

Groundwater occurs in all of the deposits in this area. Informally, groundwater occurring in the upper clastic materials in the Spring Hill area has been designated as the "Upper Aquifer" and groundwater in the lower, fractured andesitic rocks as the "Lower Aquifer". These designations do not necessarily apply at a distance from Spring Hill, because the stratigraphy changes.

In general, both the clastic deposits and the fractured volcanics are of relatively high permeability (or hydraulic conductivity) in certain areas. Of the wells that have been drilled on the east side of Spring Hill (labeled as DEX- and OB- on **Figure 2**), the aquifer transmissivity have been calculated to range from approximately 70,000 to over 400,000 gallons per day/foot. This translates to high specific capacities: Well DEX-6 (tested at 490 gpm) has a specific capacity of 434 gallons per minute/foot of drawdown, and DEX-7, 14.2 gpm/foot (both wells produce from the "Lower Aquifer").

The high hydraulic conductivity of this aquifer also is illustrated by Big Springs, which discharges at approximately 10,000 gpm from the same fractured andesite aquifer, at the base of the south slope of Spring Hill.

The direction of the groundwater hydraulic gradient is generally away from the higher elevations of Mt. Shasta, as that is the recharge area for the aquifers underlying the Mt. Shasta area. The groundwater gradient is altered, however, by geologic features such as the Spring Hill plug dome. In the area of Spring Hill, the gradient steepens as the groundwater moves towards the plug dome, then flattens as it enters a zone of permeable fractures in the andesite of Spring Hill, and moves towards the discharge point of Big Springs. **Figure 3** shows a copy of the groundwater-elevation contour map prepared for a previous study of the area.

SPRING HILL DRIVE SITE (LOCATION #1)

The Spring Hill Drive Site is located to the northwest of Spring Hill. **Figures 4** and **6** show cross sections through the Spring Hill Site. The nearest deeper wells of record show the following characteristics and stratigraphy (all depths are in feet below ground surface) :

Well 573056, ~500 feet northwest, 8-inch cased, tested at 290 gpm for 30 hours:

0 – 4'	Loam
4 – 96'	Cemented sand & gravel with large boulders
96 – 145'	Andesite gravel & sand
145 – 160'	Coarse andesite gravel (screened interval)
160 – 203'	Sand mixed with boulders
203 – 300'	Coarse andesite, white pumice, & some brown rock (screened interval)

Well 115464, ~2,000 feet east, 8-inch borehole, tested at 50 gpm:

0 – 10'	Andesite gravel
10 – 58'	Red brown clay & gravel
58 – 390'	Reddish Spring Hill rock (no screen, open borehole below 65 feet)

Well 115476, ~1,500 feet south-southeast, 6-inch cased, tested at 20 gpm for one hour:

0 – 60'	Soil, clay, & boulders
60 – 74'	Boulders
74 – 140'	Cemented sand and gravel
140 - 180'	Sand & gravel, first water
180 – 190'	Hard layer (tuff)
190 – 230'	Sand & gravel ¾″, more water
230 – 246'	Sand & gravel (screened interval 240 – 246')

Based on these wells, a well at the Spring Hill Site likely would produce water from both the clastic unit ("Upper Aquifer") and the fractured andesite ("Lower Aquifer"). Yield could be in excess of 300 gpm, up to as much as 500 gpm, as illustrated by DEX-6 at the bottling plant site. A completed well at the Spring Hill Site likely would need to be at least 300 feet deep. The static water level likely would be greater than 100 feet bgs. In consideration of groundwater quality protection, it would be beneficial to screen a completed well solely in the "Lower Aquifer", because of the high permeability of the overlying clastic materials.

A well at the Spring Hill Site may or may not be hydraulically upgradient of Big Springs. As shown on **Figure 3**, a well located closer to Spring Hill Road would be less likely to be directly upgradient of Big Springs. A well located farther south on the Spring Hill Road parcel may be directly upgradient of Big Springs. Based on the historical groundwater elevations, to lessen potential impacts to Big Springs a new well could be located in the northern part of the Spring Hill parcel.

The groundwater quality at the Spring Hill Site would be expected to be good. **Table 1** summarizes the results of laboratory analysis of a sample from Well 573056 (500' north), collected in May 2010 and June 2015:

Table 1. Summary of Water-Quality Well 573056 (2010 & 2015)

Parameter	Result
General Parameters	
pH (units)	6.91
EC (umhos/cm)	99
Turbidity (NTU)	4.5
Calcium (mg/L)	10
Magnesium (mg/L)	2.62
Sodium (mg/L)	6.89
Hardness (mg/L)	34
Alkalinity as $CaCO_3$ (mg/L)	48
Bicarbonate (mg/L)	58
Carbonate (mg/L)	0
Chloride (mg/L)	3
Fluoride (mg/L)	<0.1
Nitrate as NO_3 (mg/L)	2.13
Sulfate (mg/L)	<5
Total Dissolved Solids (mg/L)	110
MBAS (mg/L)	<0.02
Color (units)	<5
Odor (units)	<1
Metals	
Aluminum (µg/L)	142
Arsenic (µg/L)	<10
Barium (µg/L)	<100
Cadmium (µg/L)	<1
Chromium (µg/L)	<10
Copper (µg/L)	<50
Iron (µg/L)	<100
Lead (µg/L)	<5
Manganese (µg/L)	<30
Mercury (µg/L)	<1
Selenium (µg/L)	<5
Silver (µg/L)	<10
Zinc (µg/L)	<50
Organic compounds by Method 524.2 (µg/L)	All Nondetected

NORTH MT. SHASTA BLVD. SITE (LOCATION #2)

The North Mt. Shasta Blvd. Site is located to the southwest of Spring Hill and less than 500 feet west of Big Springs. **Figures 5** and **6** show cross sections through this Site. The nearest deeper well of record shows the following characteristics and stratigraphy (all depths are in feet below ground surface):

Well 101708, ~1,000 feet northwest, 6-inch cased, tested at 60 gpm for 4.5 hours:

0 – 23'	Very sandy with boulders
23 – 57'	Sandy clay & boulders
57 – 68'	Volcanic rock with sandy clay & boulders
68 – 80'	Very sandy with volcanic rock (screened interval)
80 – 100'	Volcanic rock (screened interval)

DEX-1, ~1,500 feet east, 4-inch cased, tested at 30+ gpm for 8 hours:

0 – 33'	Brown to yellowish brown tuff with boulders & cobbles
33 – 88'	Reddish brown andesite, large fractures (screened interval 40 – 82')

Based on these wells, a well at the Mt. Shasta Blvd. Site likely would produce water from only from the fractured andesite aquifer ("Lower Aquifer"). Yield could be in excess of 300 gpm, as illustrated by the high-producing DEX wells at the bottling plant site, but there is insufficient data on wells west of Big Springs that are completed in the "Lower Aquifer" to state this with certainty.

The static water level likely would be near the ground surface, considering the water level in Well 1010708 to the east (it appears to be coincident with the elevation of Big Springs). Thus, a completed well at the Mt. Shasta Blvd. Site likely would not need to be of significant depth, although there is insufficient data to predict accurately the total depth of a future well. In consideration of groundwater quality protection, it is likely that the shallower portions of the aquifer would need to be sealed off, thereby reducing the yield.

Based on the water level in Well 1010708 and the elevation of Big Springs, it is possible that the Mt. Shasta Blvd. Site would be hydraulically connected to Big Springs. If this is the case, the groundwater quality would be expected to be good and of similar to that of Big Springs.

CHESTNUT STREET SITE (LOCATION #3)

The Chestnut Street Site is located approximately ¾ miles south-southeast of Spring Hill, off South Mt. Shasta Blvd. **Figure 6** shows a cross sections through the Spring Hill Site down to the Chestnut Street Site. The nearest deeper well of record is from the hospital, approximately 700 feet to the west of the Chestnut Street Site. It shows the following characteristics and stratigraphy (all depths are in feet below ground surface) :

Well 555762, ~700 feet west, 6-inch cased, tested at 200+ gpm for 12.5 hours:

0 – 8'	Red clay
8 – 28'	Andesite & boulders with sand
28 – 96'	Silty brown clay & andesite gravel
96 – 118'	Red & gray andesite gravel
118 – 140'	Andesite gravel & sand with gray color (120 – 190', screened interval)
140 – 190'	Andesite gravel, boulders with brown clay (120 – 190', screened interval)
190 – 208'	Heaving sand

Well 555762 was artesian upon drilling (the static water level is above the top of the casing); the initial water level is not indicated on the log. No hard-rock volcanics were noted – all production is from clastic materials.

Well 202003, approximately 1,500 feet west of Well 101708, showed a similar stratigraphy as Well 101708, with predominantly sand and gravel to a depth of 105 feet. First water in that well was above 65 feet bgs and it reportedly produced approximately 200 gpm.

Based on these wells, a well at the Chestnut Street Site likely would produce water from clastic materials consisting predominantly of sand and gravel. Yield could be as much as 200 gpm, or more (it is possible that the formation would have a higher yield with a larger borehole and casing than in the above wells).

The static water level likely would be shallow, considering the water level in Well 555762 (the Chestnut Street site is slightly higher in elevation than Well 555762, and may not be artesian). Thus, a completed well at the Chestnut Street Site likely would not need to be of significant depth, probably less than 200 feet.

REFERENCE LIST

California Department of Water Resources, Driller's Logs for Township 40 North, Range 4 West.

Geosyntec Consultants, March 2014, *"Report: Hydrogeologic* Review *and Well Testing" Report prepared for Coca Cola Mt. Shasta Bottling Facility*.

Lawrence Livermore National Laboratory, February 2017, *GAMA: Groundwater Ambient Monitoring & Assessment Program, Special Study – Tracers of Recent Recharge to Predict Drought Impacts on Groundwater: Mount Shasta Study Area*.

SECOR, March 1998, *Confidential Hydrogeologic Evaluation Report, Spring Hill Property, Siskiyou County, California*.

Richard C. Slade & Associates LLC, October 2016, *Hydrogeologic Evaluation for Proposed Crystal Geyser Water Bottling Facility Project, Mount Shasta City, Siskiyou County, California*.

USGS, 2016, *"Mt. Shasta Geology and History"*, online article, https://volcanoes.usgs.gov/volcanoes/mount_shasta/mount_shasta_geo_hist_5.html

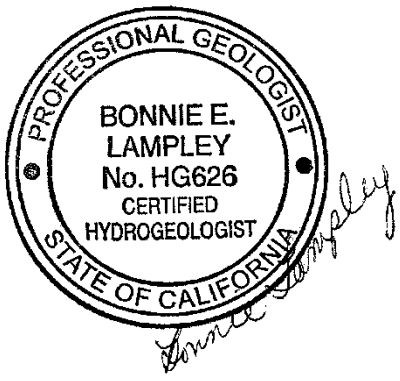
Wagner, D.L. and Saucedo, G.J.,1987, *"Geologic Map of the Weed Quadrangle"* California Division of Mines and Geology, Regional Geologic Mapping Program Series Map RGM-004A.,Sheet 1 of 4.

Please feel free to contact me at blampley@lwrnc.com or 530-275-4800 if you have questions regarding this report.

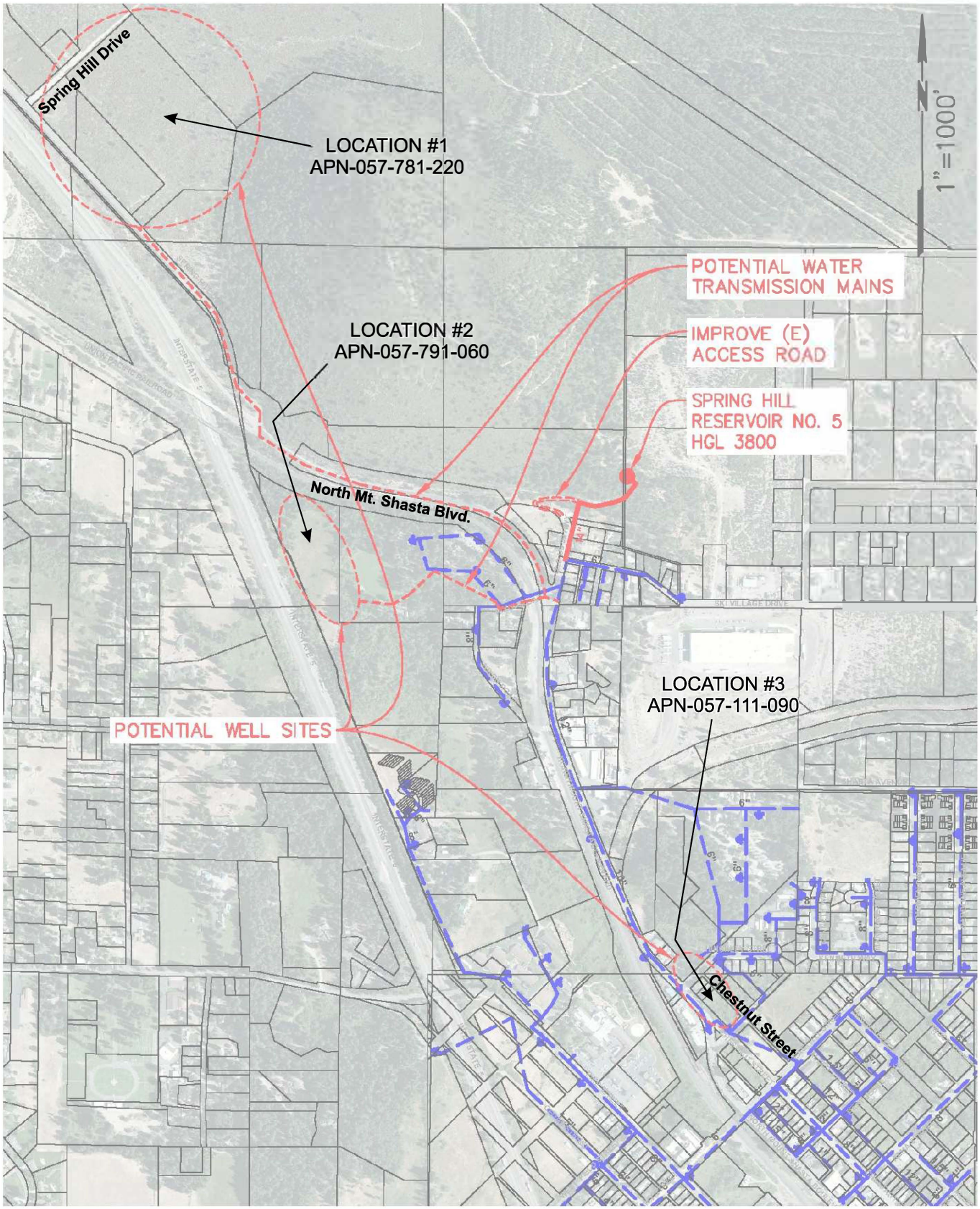
Sincerely,

Bonnie E. Lampley

Bonnie Lampley
Principal Hydrogeologist, CHG 626



enc. **Figure 1.** Location Map
Figure 2. Site Map
Figure 3. Groundwater Elevation Contour Map
Figure 4. Section A-A'
Figure 5. Section B-B'
Figure 6. Section C-C'

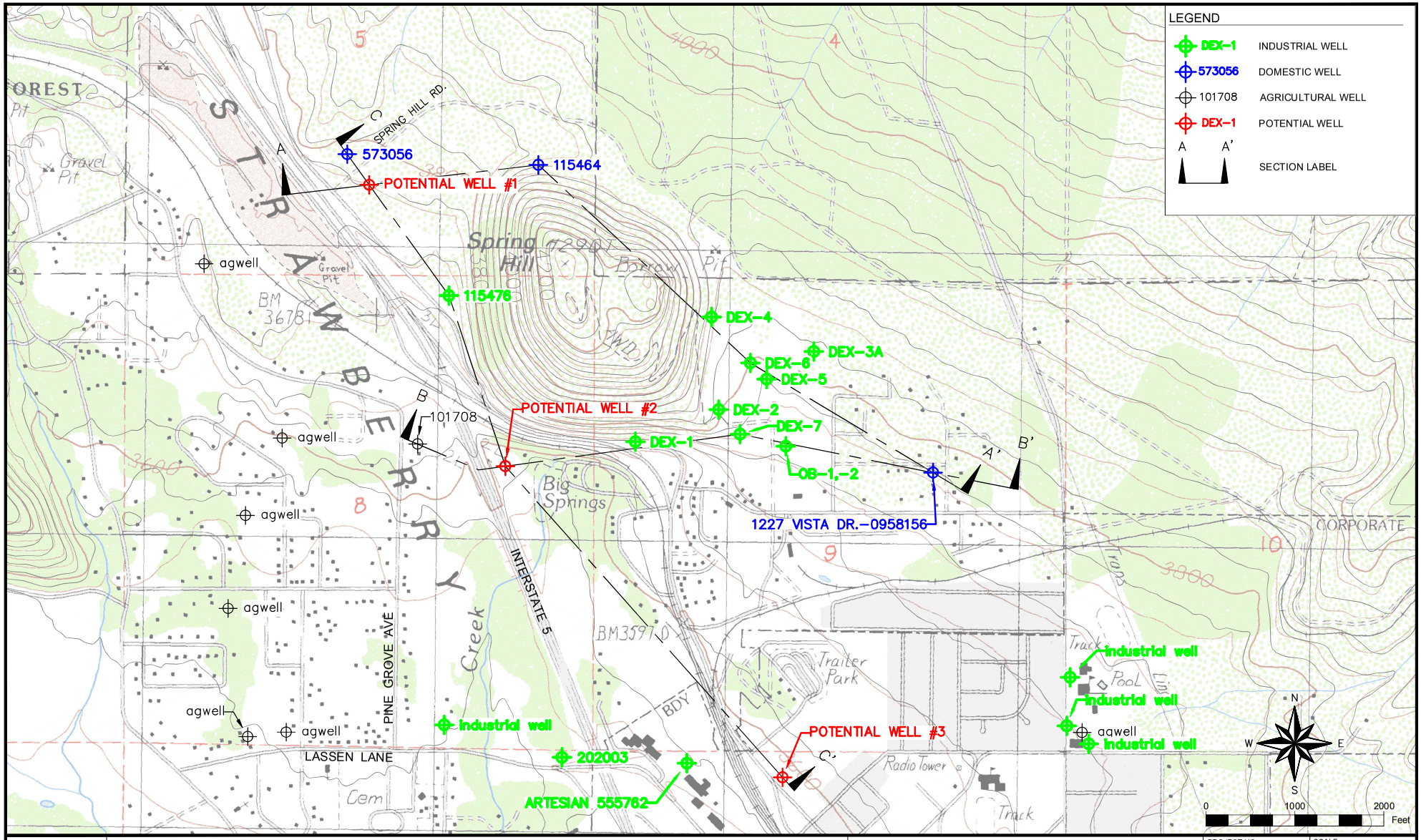


Base Map From Pace Engineering

LAWRENCE & ASSOCIATES
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LOCATION MAP
NORTH MT. SHASTA

PROJECT NAME:	PROJECT NO:	DATE:
WELL LOC. EVAL.	018005.00	FEB. 8, 2019
CLIENT:	DRAWN BY:	FIGURE 1
PACE	B. LAMPLEY	
SCALE:	CHECKED BY:	
1" = 1,000'	B. GARTNER	



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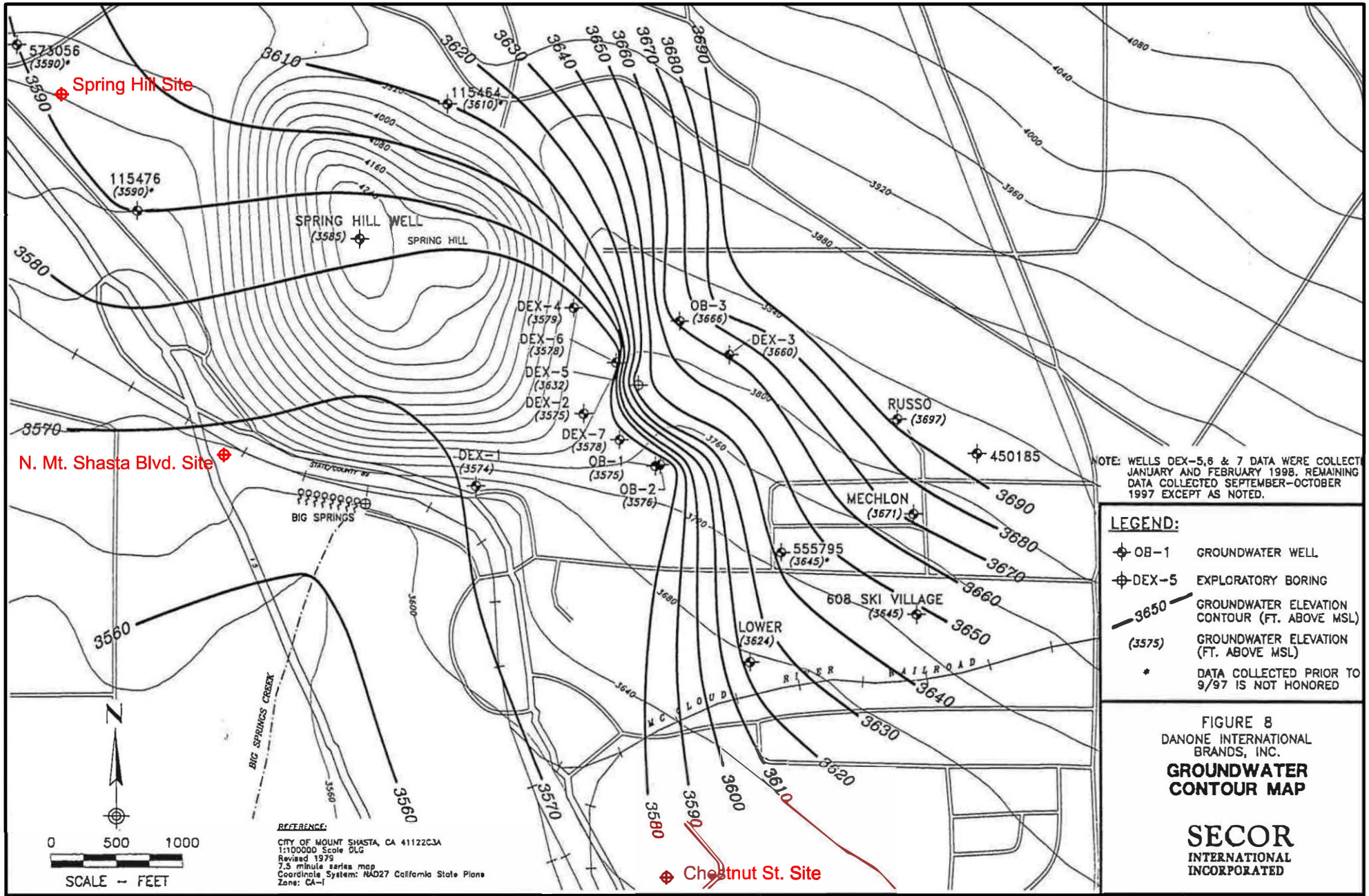
SITE MAP

WELL LOCATION EVALUATION

PACE ENGINEERING

PROJECT NO: 018005.00	SCALE: 1" = 1,000'
DRAWN BY: J. BEERS	DATE: 2/15/2019
CHECKED BY: B. LAMPLEY	FIGURE 2

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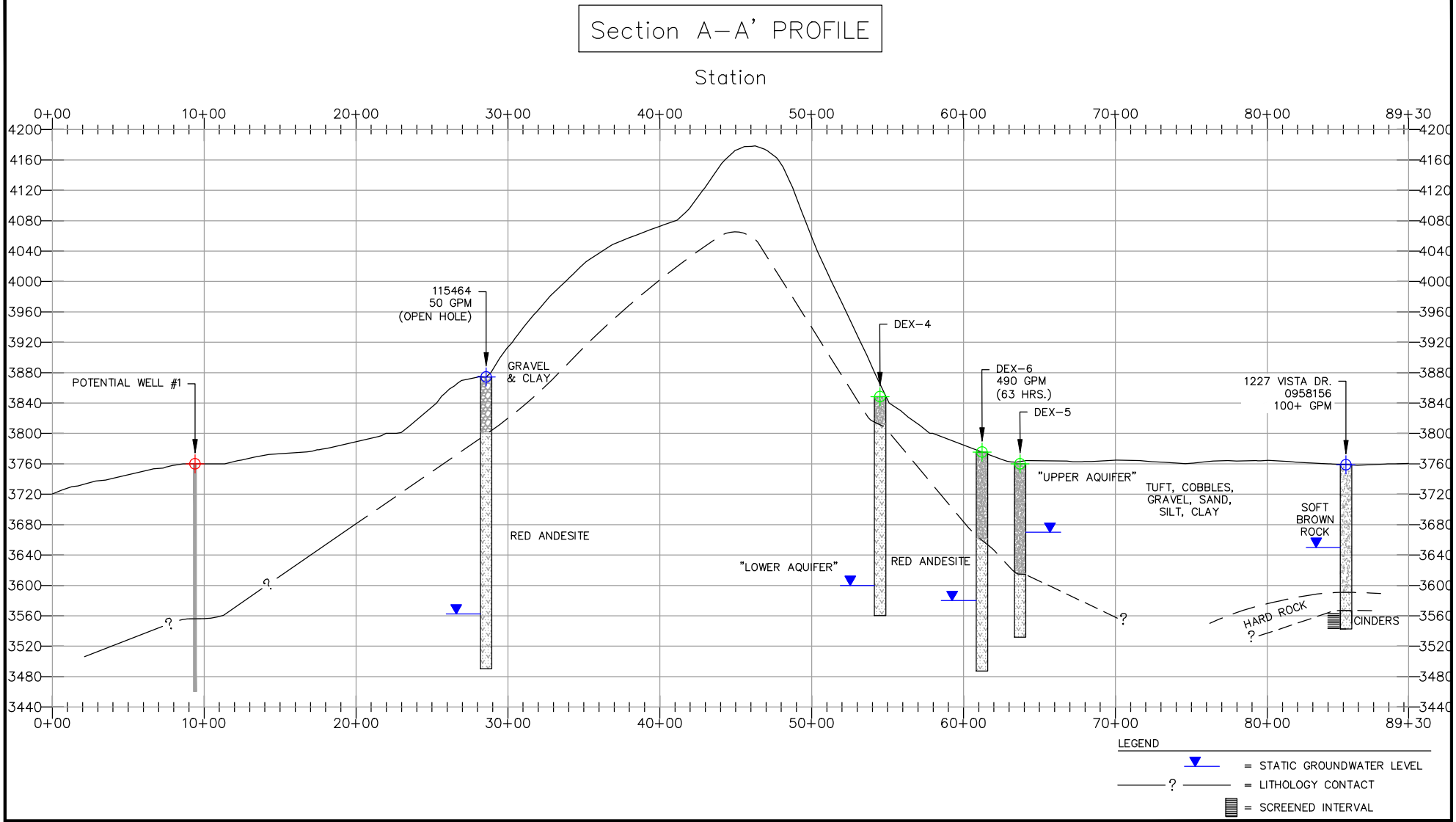


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GROUNDWATER ELEVATION CONTOUR MAP
SPRING HILL AREA
From: SECOR, 1998

PROJECT NAME: WELL LOC. EVAL.	PROJECT NO: 018005.00	DATE: FEB. 8, 2019
CLIENT: PACE	DRAWN BY: B. LAMPLEY	FIGURE 3
SCALE: 1 INCH = 1,000 FEET	CHECKED BY: B. GARTNER	

Section A–A' PROFILE



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SECTION A–A'

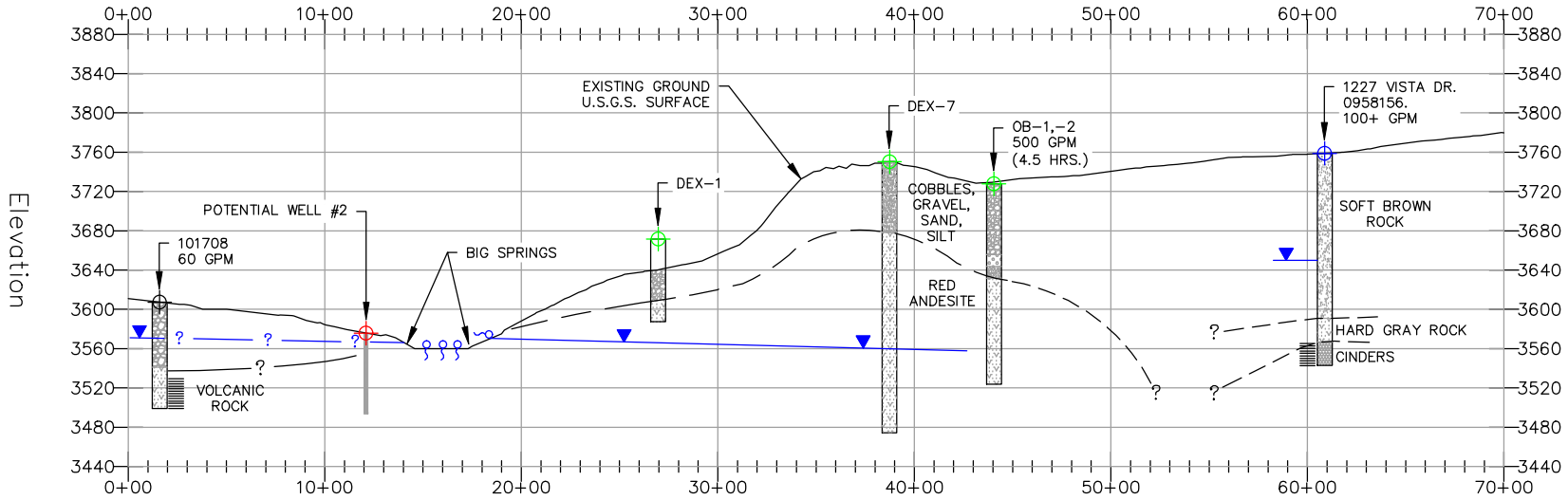
WELL LOCATION EVALUATION

PACE ENGINEERING

PROJECT NO: 018005.00	SCALE: 1" = 600' H; 1" = 120' V
DRAWN BY: J. BEERS	DATE: 2/15/2019
CHECKED BY: B. LAMPLEY	FIGURE 4

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Section B–B' PROFILE



LEGEND

= STATIC GROUNDWATER LEVEL

= LITHOLOGY CONTACT

= SCREENED INTERVAL

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SECTION B–B'

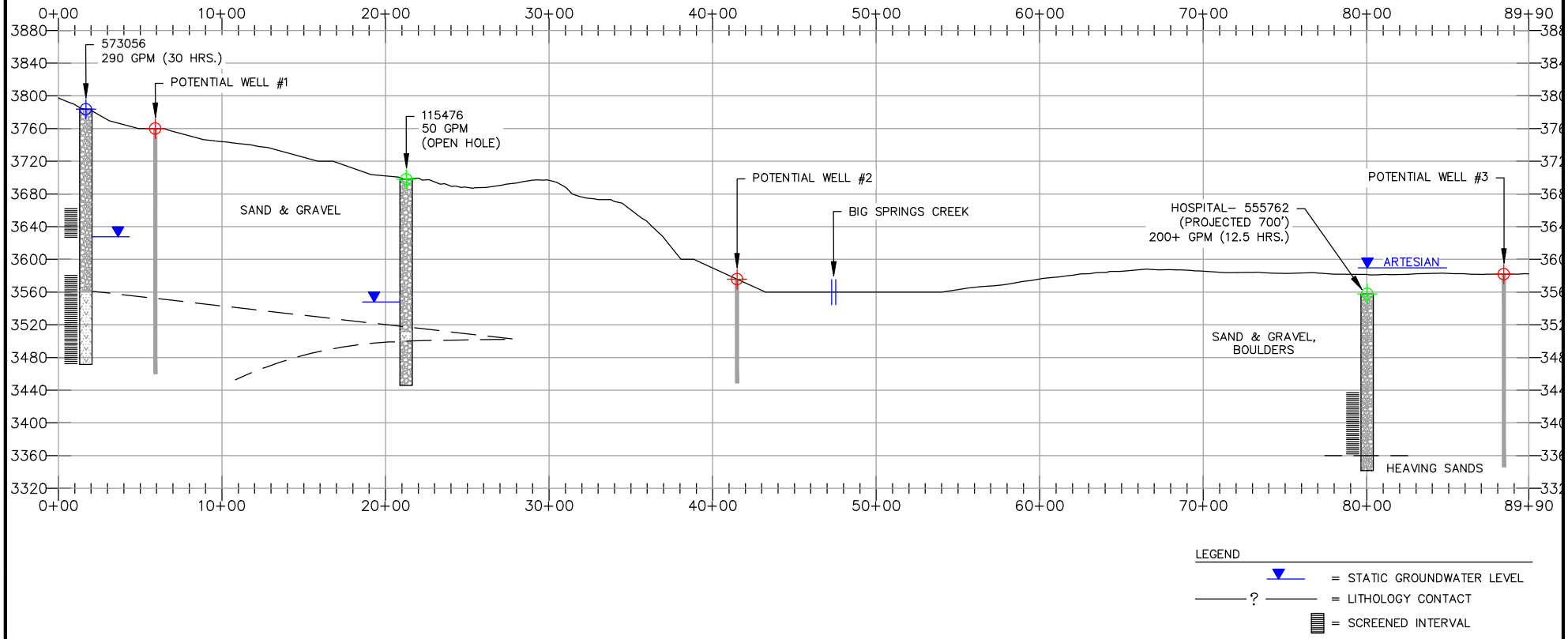
WELL LOCATION EVALUATION

PACE ENGINEERING

PROJECT NO: 018005.00	SCALE: 1" = 600' H; 1" = 120' V
DRAWN BY: J. BEERS	DATE: 2/15/2019
CHECKED BY: B. LAMPLEY	FIGURE 5

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Section C–C' PROFILE



LEGEND

= STATIC GROUNDWATER LEVEL

= LITHOLOGY CONTACT

= SCREENED INTERVAL

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SECTION C–C'

WELL LOCATION EVALUATION

PACE ENGINEERING

PROJECT NO: 018005.00	SCALE: 1" = 600' H; 1" = 120' V
DRAWN BY: J. BEERS	DATE: 2/15/2019
CHECKED BY: B. LAMPLEY	FIGURE 6

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