# PRELIMINARY HYDROGEOLOGIC ASSESSMENT
# OCOTILLO WELLS SOLAR PROJECT
# MAJOR PRE-APPLICATION
# CASE NUMBER 3992 11-003 (MPA)

**6953 SPLIT MOUNTAIN ROAD**
**BORREGO SPRINGS, CALIFORNIA**

**March 19, 2013**

**Prepared For:**

**J. Whalen Associates, Inc.**
**1660 Hotel Circle North, Suite 725**
**San Diego, CA 92108-2820**

**Prepared By:**

**Wiedlin & Associates, Inc.**
*Applications in Groundwater Science*

**P.O. Box 910462**
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# EXECUTIVE SUMMARY

A preliminary evaluation of site hydrogeologic conditions to meet long term operational water demand rates at the proposed Ocotillo Wells Solar Project has been prepared.

The site is overlain by alluvial fan deposits and older sedimentary rock deposits. Groundwater inflow to the site originates from moister, more mountainous terrain to the west. Groundwater inflow to the site, based on measured water table gradients, well driller description of subsurface sediments, and literature values of sediment permeability with respect to water, is estimated to be in the range of 0.9 acre-feet per day to 90 acre-feet per day. Though operational requirements for the site will require episodic well pumping, average daily groundwater demand over the course of a year is estimated at 0.005 to 0.008 acre-feet per day. Hence estimated groundwater inflow to the site is expected to be substantially greater than long term operational demand.

Based on similar estimates of groundwater flow parameters, groundwater drawdown estimates over time induced by pumping to meet long term operational water demand have been prepared. These estimates indicate that after five years of pumping, groundwater drawdown at a distance less than 100 feet from the pumping well is anticipated be less than 0.5 feet. Hence use of groundwater to support the long term operation of the facility is not expected to significantly affect the availability of groundwater to neighboring properties.

Temporary water demand for grading and brushing has been estimated by RBF Consultants to be approximately 40 acre-feet over a construction period that will likely be a minimum of nine weeks, perhaps longer. This temporary demand will be met by trucking in water provided by the Borrego Water District.

Long term operational water demand is low and groundwater drawdown induced by well pumping to meet this demand have been evaluated and is expected to be minor. With on-site storage, the existing well may be sufficient to meet this demand. However, the well is in poor condition and would probably eventually need to be replaced. Long term operational water use will require low salinity water. On-site, self contained water treatment to reduce dissolved solids is anticipated.

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## INTRODUCTION

The Ocotillo Wells Solar Farm Project proposes installation of a photovoltaic (PC) or concentrated photovoltaic (CPV) solar farm for the long-term generation of clean, renewable energy from solar power. The Project requires approval from the County of San Diego for a Major Use Permit (MUP) to allow construction, operation, and maintenance of such facilities.

The Project site is located southeast of the community of Ocotillo Wells, California, within northeastern San Diego County (Figure 1). The Project would affect two privately-owned parcels totaling approximately 440 acres (the site), located 0.4 mile east of Split Mountain Road and three miles south of State Highway 78 (SR 78). The affected County Assessor Parcel Numbers (APNs) are 253-390-57 and 253-390-58, that are approximately 280 acres and 160 acres, respectively.

A preliminary hydrogeologic assessment has been conducted for the site. The objective of this work is to assess the likelihood that sufficient groundwater resources are available to support long term operations at the facility which are principally solar panel rinsing for dust removal.

Work conducted as part of the assessment included a site visit, groundwater sample collection and general water quality analysis, a video log of the on-site water well, calculation of groundwater inflow to the site, and groundwater drawdown calculations in response to long term average pumping rates to meet site operational water demands.

## ANTICIPATED WATER DEMAND

RBF Consultants (RBF) have prepared water demand estimates for temporary construction activities and long term facility operations (RBF, 2012). According to RBF, construction water is principally required for grading, estimated at 11.1 million gallons, brushing and clearing, estimated at 1.35 million gallons, and soil binding, estimated at 0.41 million gallons. In total, 12.86 million gallons, or approximately 40 acre-feet of water are estimated to be required for construction.

The time required to complete brushing and clearing, grading, and soil binding has not been confirmed. However, based on earlier discussions with the project coordinator, J. Whalen & Associates, a minimum nine week construction period for these activities is tentatively anticipated.

Though there may be adequate groundwater resources to meet this demand on-site, additional production wells would be required to meet the temporary construction flow demand. Considering the limited time this flow demand would be needed, it is economically more feasible to purchase water from the Borrego Water District and truck it to the site.

RBF estimates that long term operational water demand between 2 and 3 acre-feet per year depending upon the type of solar technology is selected for the site (RBF, 2012). Long term operational water demand is derived from ongoing soil binding dust control work and quarterly solar panel rinsing. Each solar panel rinsing episode is anticipated to take approximately 5 weeks. It is not expected that the project will require additional on-site workers on a regular, full time basis. Potable and sanitary water demand for on-site workers is expected to be less than 0.1 acre-feet per year. Hence potable and sanitary water demands for the site are minimal. No landscape irrigation is anticipated for the site.

Based on these long term water demand estimates and on-site water storage of 20,000 gallons, daily water demand for solar panel rinsing and workers is approximately 12,000 gpd. A water demand for the site of 8 gpm is expected to meet this demand assuming 5 day work weeks, on-site water storage, and groundwater production operating 75 percent of the time. This is equivalent to a continuous average pumping rate of 6 gpm for the 5 week maintenance period. Over the course of a year, three acre-feet of annual groundwater production averages approximately 1.9 gallons per minute (gpm).

## HYDROGEOLOGIC CONDITIONS

The following presents regional and on-site hydrogeologic information. Regional information includes a generalized description of stratigraphy to support the identification of aquifers. State and federal data bases were reviewed to obtain groundwater levels from wells in the general vicinity of the site. On-site information includes existing well construction and pump information used to develop a preliminary estimate of well yield. These data, combined with on-site groundwater level information, were used to prepare a groundwater elevation map, groundwater level hydrographs, and conceptual hydrogeologic cross sections (Figures 4 -6). From this work, a discussion of groundwater occurrence, including a preliminary estimate of groundwater inflow into the site has been developed. Chemical and biological groundwater quality information, based on a grab sample from the existing well is presented.

### REGIONAL INFORMATION

The site is located in lower Borrego Valley between the Fish Creek Mountains and the Ocotillo Mountains (Figure 2). The site is located on a moderately large alluvial fan created by flash flood deposits from the Fish Creek Wash (Figure 2 and Figure 3). A United States Geological Survey reconnaissance geologic map of the area characterizes the alluvial fan deposits as Quaternary in age (recent to 1.8 million years old, and describes them as “Unconsolidated, poorly bedded gravel, sand, and silt underlying the relatively steep fans bordering the mountain fronts. Equivalent in age to the desert alluvium, but moderately to poorly water yielding. Water levels are commonly deep.” (USGS, 1953).

Pliocene to Miocene age (approximately 2.6 to 24 million years ago) marine and nonmarine sedimentary deposits are exposed in the Fish Creek Mountains and Ocotillo Badlands (Dorsey, 2005). These deposits vary widely in texture and water permeability, but in general can be expected to yield less water than the alluvial deposits as the older, deeper rocks will be denser and tend to have more fine-grained sediments. The exposures of Pliocene-Miocene sedimentary rocks in the Fish Creek Mountains and the Ocotillo Badlands show that significant structural deformation occurs in these outcrops. Accordingly, though it is highly likely that Miocene sedimentary deposits underlie the alluvial fan deposits at the site, the complexity of geologic conditions dictate that the specific nature of these deposits is currently limited to what can be inferred from the on-site driller’s log. Underlying the Pliocene and Miocene sedimentary rocks are Cretaceous (approximately 65 to

146 million years old) granitic rocks. These rocks likely have not been well explored with respect to groundwater, but are generally considered to yield low quantities of groundwater.

The Agua Caliente Fault Zone passes between the site and the Fish Creek Mountains (Figure 3). The direction and magnitude of fault offset have not been investigated for this project, nor have the hydraulic effects of the fault on groundwater flow.

A review of California Department of Water Resources and USGS online data bases provided water level records for two water wells in the vicinity of the site (Figure 4). These wells are approximately 1.3 miles to the northwest and 2.0 miles to the northeast of the on-site water well. The water level measurement period of record for these wells are 1951 to 1994 and 1953 to 2008 respectively. Groundwater levels have remained stable for the well (State Well No. 12S08E 22E-001) (Figure 5) closest to the site at an elevation of approximately 0 feet msl and a depth of approximately 110 feet below ground surface. Groundwater levels at the well located slightly further away (State Well No. 12S09E 23D-001) suggest that this well was actively pumped in the 1950s and 1960s and that pumping in the vicinity of Well 23D-001 continued into the late 1990's (Figure 5). Based on the available data, groundwater levels since then have remained stable at an elevation approximately 150 feet lower than the initial measurements from the 1950s. The most recent water level measurement at Well 23D-001, taken in 2008, indicate that the depth to water is approximately 211 feet and the groundwater elevation is approximately -226 feet msl.

Based on this information as well as groundwater elevation information from the on-site well, the regional direction of groundwater flow circa the mid-1980's was toward the northeast with a hydraulic gradient of 0.015. The groundwater flow direction is generally consistent with the direction of the topographic gradient.

## ON-SITE HYDROGEOLOGIC CONDITIONS

Information regarding the on-site well, including the drilling contractor's log, a down hole video of the well, and a preliminary assessment of well yield are presented. A discussion of groundwater occurrence including alluvial fan aquifer thickness and groundwater inflow rates to the site are presented. Lastly, chemical water quality and microbial activity information are presented.

### Driller's Log

The driller's log for the on-site water well indicates that the well was drilled to a total depth of 303 feet (Appendix A). Based on the driller's description of the drill cuttings, it is likely that the alluvial fan deposits extend from ground surface to a depth of 112 feet. Below that depth the rocks are reported by the driller to have greater density and more frequent occurrences of silt and clay. Below 112 feet it is likely that the Pliocene-Miocene sedimentary rocks were encountered.

Groundwater depth was reported to be 93.6 feet by the driller shortly after the well was completed in March, 1987. W&A measured the depth to groundwater on June 2, 2011 at 92 feet. This suggests that groundwater levels at the site were not influenced by groundwater pumping at or near Well 23D-001. It also suggests that pumping in the vicinity of the site has not been extensive.

Water level data also indicates that only the lower 20 feet of the alluvial fan deposits are below the water table. Hence, the yield of the well and groundwater quality may decrease if longer term pumping substantially drops the water table.

The driller's log indicates the well is completed to a depth of 303 feet with 5-inch diameter PVC casing. The casing was perforated at three depth intervals, 102 to 112 feet, 248 to 270 feet, and 298 to 303 feet. The log also indicates that a 20-foot sanitary seal was constructed. A video log of the well provide further detail on well construction and well condition beyond the information provided in the driller's log.

## Video Log

The video log survey was conducted on May 31, 2011 by Groundwater Data, Inc. The video log indicates that the casing has 30 feet of vertical manual cut perforations to allow water in the well over the two shallowest depth intervals reported in the driller's log. The deepest perforated intervals in the well were not observed by the video log as the bottom of the well has filled in with debris. The limited perforated intervals combined with the crude manual cuts results in a limited amount of open area for water to flow into the well. Accordingly, it is not unreasonable to expect that the water level in the well to drop quite a bit compared to the water level in the aquifer under pumping conditions. In other words the well is likely to be hydraulically inefficient.

The video log shows clear water suggesting a good flow of water is moving through the well. This implies the aquifer has some permeability which suggests the potential for a reasonable yield. The video log also shows a moderate amount of microbial biomass in the water and growing in the well slots. This suggests that some bio-fouling has occurred in the well. The microbial growth further reduces the amount of open area for water to flow into the well.

## Estimated Yield of Existing Well

Well yield was to be assessed on a preliminary basis when the well was purged during groundwater sample collection. However, access problems precluded the reliable entry and exit of a pump setting rig that was to be used to install a water level access tube. Consequently the pump was removed from the well to permit access for the video log survey, but was not re-installed for well purging purposes. Consequently the groundwater sample was collected from a bailer as a grab sample.

However, the following information regarding well yield is available. The driller's log reports a well yield of 150 gpm by airlifting. However, the duration of the airlift test nor the amount of drawdown induced by the test were reported. Additionally, the submersible pump installed in the well, Goulds Model No. 18E15412, equipped with a single phase 1.5 horsepower motor, was set at a depth of 168 feet. Assuming a pumping level of 140 feet and a back pressure of 0 psi or 60 psi, this pump would likely produce approximately 15 to 27 gpm.

## Groundwater Occurrence

Based on the groundwater elevation map and the inferred stratigraphy derived from the drilling contractor's log, a conceptual hydrogeologic cross section oriented in the direction of groundwater flow has been prepared (Figure 6). This cross section depicts the rise of the water table elevation beyond the southwestern corner of the site. If the contact between the alluvial fan deposits and the underlying sedimentary rock are relatively level compared to the water table's hydraulic gradient, the alluvial fan aquifer thickness may be approximately 20 feet thicker near the southern boundary of the site. Because land surface elevation is also rising, the depth to the water table at the southern boundary is expected to be on the order of 50 feet below land surface.

This hydrogeologic scenario suggests that alluvial fan aquifer may be limited in it's northerly extent as the hydraulic gradient eventually drops the water table below the alluvial fan - sedimentary rock contact down gradient from the existing water well. Immediately south of the property, the Agua Caliente Fault Zone is present. It is not known how the fault zone may be controlling the elevation of the contact between the alluvial fan and the sedimentary rock. Nor is it known whether the fault zone acts as a barrier or a conduit to groundwater flow.

An estimate of groundwater inflow to the site, based on a cross sectional application of Darcy's law is presented. Darcy's law is an empirical relationship that relates the resistance to water flow and the change in hydraulic head within the aquifer, to the rate of groundwater flow. Darcy's law, applied in a cross sectional format that is perpendicular to flow, also includes the thickness of the aquifer and the width of the area of interest (Equation 1).

$$Q = K*i*b*W \qquad \text{(Equation 1)}$$

Where Q = groundwater flow in cubic feet per day

K = the permeability of the sediment with respect to water in feet per day (a.k.a. hydraulic conductivity)

$i$ = the horizontal groundwater gradient in vertical feet of water table elevation change per horizontal distance of flow in feet (dimensionless)

b = the aquifer thickness in feet

W = the width of the cross sectional area in feet as measured along Cross Section Line B-B-B' (Figures 3 and 4)

The following values were assigned to the variables. For hydraulic conductivity (K), Freeze and Cherry (1979) provide a range of values for various sediments. A hydraulic conductivity of 0.01 centimeter per second (28 feet per day) is a mid-range value for silty sand and lower to mid-range value for clean sand. The upper range of hydraulic conductivity for clean sand and mid-lower range for gravel is 1 centimeter per second (2,830 feet per day).

A hydraulic gradient (*i*) of 0.015 was measured based on water level measurements taken on-site and at two off-site locations by others (Figure 4).

Aquifer thickness (b) is assumed to be no greater than that measured at the on-site well, 20 feet, though it may be significantly greater upgradient.

The width of the cross sectional area is taken to be the distance across the site, perpendicular to the direction of groundwater flow; approximately 4,800 feet; as depicted by cross section line B-B' that is shown on Figure 4..

Applying these values to Equation 1, and using the lower end value for hydraulic conductivity (K) yields:

$$Q = (28 \text{ ft/d}) * 0.015 * (20 \text{ ft}) * (4{,}800 \text{ ft})$$

$$Q = 40{,}320 \text{ ft}^3\text{/d, or}$$

$$Q = 0.9 \text{ acre-feet/d}$$

Using the upper end value for hydraulic conductivity (K) yields a daily groundwater inflow rate to the site of 90 acre-feet per day. Both inflow rates would be several times higher if accounting for a likely greater aquifer thickness at the up gradient end of the site.

## Water Quality

The groundwater grab samples collected on June 2, 2011 was analyzed for a suite of anions, cations, and general minerals by EnviroMatrix Analytical Laboratories (Table 1). The ionic balance between cations and anions is within 2 percent, suggesting that no major constituents were missed in the analysis and that the overall analysis is reliable. Total Dissolved Solids (TDS), is a measure of water salinity. The TDS concentration in the grab sample collected from the on-site well, is 883 milligrams per liter (mg/l). Water with TDS concentrations greater than 1,000 mg/l is considered brackish. City of San Diego water in 2010 typically had a concentration of 560 to 600 mg/l. Groundwater quality may be relevant in assessing the suitability of the water for the periodic rinsing of the solar panels to remove dirt. Specific water quality requirements have not been specified.

Water hardness is a function of the concentration of calcium and magnesium and is measured as mg/l of calcium carbonate ($CaCO_3$). The on-site groundwater sample has a hardness of 172.1 mg/l $CaCO_3$. Relative to the standard hardness table provided below, this concentration is considered to be hard. For reference, the City of San Diego reported an average hardness of approximately 240 to 260 mg/l $CaCO_3$.

| **Range of Hardness Concentrations** | |
|---|---|
| 0-60 | Soft |
| 61-120 | Moderately Hard |
| 121-180 | Hard |
| > 180 | Very Hard |

## Bio-Activity Reaction Tests

Biologic activity reaction tests (BART) were conducted using the groundwater grab samples collected from the on-site well. BART tests were performed to assess the level of microbial activity and the related risk of well corrosion, well plugging, and health risk. The assessment is based on the bio-activity of for four different classes of bacteria; iron related bacteria (IRB), slime forming bacteria (SLYM), sulfate reducing bacteria (SRB), and heterotrophic aerobic bacteria (HAB). BART testers are designed to be conducted in non-laboratory environments by water well workers and professionals. As such they provide a less specific analysis of microbial conditions than professional lab tests, but are done at substantially less cost and designed in large part for water well assessment.

Based on the type of growth observed in the clear glass testers, and how quickly the bacteria growth occurs, an estimate of the bacteria count, the aggressivity of the bacteria, and an assessment of corrosion, well/aquifer plugging, and health risk can be developed by utilizing the BART manufacturer's software (BART-SOFT v.6). Aggressivity is the state in which an organism is active in its environment and able to compete with other strains for space, nutrients, water and gases.

The IRB test identifies and characterizes a group of bacteria which are able to accumulate iron, and often manganese, as well as use it as an energy or food source through oxidation (rusting) or reduction. These accumulated iron compounds generally collect within the slime around the cells and gradually harden (crystallize) over time. In quantifying a risk for well fouling, this class of bacteria usually has the greatest influence on the well/aquifer plugging risk calculation (Droycon Bioconcepts, 2010). The IRB population estimate for the on-site groundwater sample is approximately 8,820 probable active colonies per milliliter (pac/ml) and has a high aggressivity rating.

The SLYM test identifies bacteria which do produce slimes but do not necessarily accumulate iron within these slimes. SLYM test results are factored into the well/aquifer plugging risk calculation (Droycon Bioconcepts, 2010). The SLYM population estimate for the on-site groundwater sample is approximately 632,000 pac/ml and has a high aggressivity rating.

The HAB test identifies and characterizes those microbes which obtain their energy from breaking down of organic material such as total organic carbon dissolved in groundwater. HAB test results are factored into the well/aquifer plugging risk calculation at a weight similar to the SLYM test results (Droycon Bioconcepts, 2010). The HAB population estimate for the on-site groundwater sample is approximately 454,000 pac/ml and has a high aggressivity rating.

The SRB test identifies sulfate reducing bacteria that are anaerobic in nature. These bacteria are not considered a risk to well fouling but are the dominant factor in assessing corrosion risk. The other three types of tests also factor in to the corrosion risk calculation but at lower weightings. The SRB population estimate for the on-site groundwater sample is approximately 226 pac/ml and has a medium aggressivity rating.

Based on the type of growth observed in the clear glass testers, and how quickly the bacteria growth occurs, BART-SOFT, prepares a risk assessment for corrosion, well/aquifer plugging, and health.

There are five categories for risk from negligible (0 to 1), minor (2 to 3), medium (4 to 5), major (6 to 7) and extreme (8 to 9). In general, corrosion risk is considered minor with a value of 2.1. For the on-site well, the estimated well/aquifer plugging risk is considered major with a value of 6.3. Corrosion risk at the on-site well is assessed as medium with a value of 3.1, and health risk considered extreme at 8.1. The extreme health risk assessment rating at the on-site well merely indicates that a coliform bacteria test is appropriate. If positive, chemical and physical well cleaning would likely resolve the issue.

## OFF-SITE GROUNDWATER USE

The water well permit data base managed by the San Diego County Environmental Health Department indicates that there are 17 parcels in the general vicinity of the site that have well permits (Figure 7). Of these parcels, only one parcel directly borders the proposed site near the southwestern corner of the site (Figure 7). Though the County data base does not necessarily provide an exact location for the wells, if in fact the well was actually drilled, but aerial photo work in this case suggests that the well is located in the northwest quadrant of the off-site parcel, approximately 3,600 feet southwest of the existing well.

With the exception of one property approximately one mile northwest of the existing on-site well, groundwater use in the immediate vicinity of the site appears to be limited to residential or partially developed properties. The one exception being a site that appears to have approximately 3 to 4 acres of irrigated land (Figure 7).

## GROUNDWATER DRAWDOWN

Estimates of groundwater drawdown induced by on-site pumping to meet operational water demands were prepared. The estimates were derived using an analytical model of unconfined aquifer groundwater flow based on S.P. Neuman's 1972 publication, *Theory of Flow in Unconfined Aquifers Considering Delayed Response of the Water Table* as applied by the aquifer test and groundwater modeling software program, AquiferWin32, Version 4.04 by Environmental Simulations, Inc. AquiferWin32 digital output files for hydraulic head and drawdown calculations are provided in Appendix B.

The following site specific assumptions were developed for the drawdown calculations:

- Hydraulic gradient (0.015), hydraulic conductivity (28 feet per day), and aquifer thickness (20 feet) are consistent with the cross sectional groundwater inflow calculation presented earlier. Hence, it was assumed that groundwater production is limited to the upper 20 feet of saturated sediment in the existing on-site water well.

- A specific yield value of 0.05 (dimensionless) was used to represent the unconfined groundwater storage factor which accounts for the amount of water released from the sediments under gravity drainage. This value is the default County specific yield value for alluvial aquifers used in the absence of site specific data. Based on the texture of the sediments reported in the driller's log between a depth of 86 feet and 112 feet, a specific yield of 10 to 30 percent is likely. Hence, the default value for specific yield used in the model will likely over estimate groundwater drawdown.

- Specific storage, a measure of an aquifer's capacity to store and release water while the aquifer remains fully saturated was estimated at 0.0001 cubic meters of water released per cubic meter of aquifer for a 1 meter decline in hydraulic head, or groundwater level. The specific storage estimate is based on an intermediate value of aquifer compressibility for sand of $10^{-7}$ $meters^2$ per Newton (Freeze and Cherry, 1979). Hence, the storativity of the aquifer which is the product of aquifer thickness, 20 feet or 6 meters, and specific storage, is 0.0006 (dimensionless).

- An average annual pumping rate of 1.9 gpm was applied to the transient Neuman solution over a five year continuous pumping period, a.k.a. a long term simulation of groundwater drawdown. This pumping rate is equivalent to three acre-feet of pumping per year.

- Alternatively, a second drawdown calculation was developed using an average pumping rate of 6 gpm over a 5 week, 7 day per week pumping period was also applied to the transient Neuman solution, a.k.a. a short term simulation of groundwater drawdown. This calculation was intended to represent the drawdown induced at the end of single solar panel rinsing episode.

The following are general assumptions inherent in applying an analytical groundwater flow model:

- Groundwater flow is horizontal and occurs in an aquifer of infinite extent.

- Hydraulic conductivity is the same throughout the aquifer.

- The base of the aquifer is horizontal and fixed at a constant elevation.

- The analytical model calculates groundwater elevation across the model domain in response to pumping at the single on-site well. Drawdown is calculated by comparing the groundwater elevation at the end of the time period of interest to the pre-pumping groundwater elevation.

Practically speaking, these numerically ideal conditions are unusual to find in the real world. Site conditions are expected to not deviate so greatly from these assumptions to preclude the use of this approach as a screening assessment.

## LONG TERM DRAWDOWN SIMULATION RESULTS

After five years of continuous pumping at a rate of 1.9 gpm, groundwater drawdown at the closest off-site location to the on-site well is slightly less than 0.4 feet (Figure 8). At the boundary to the nearest adjoining properties with a record of well permits, drawdown after five years of pumping is less than 0.2 feet (Figure 8). Drawdown at the pumping well, not accounting for well inefficiency, is less than 1.1 feet after five years of pumping (Appendix B).

## SHORT TERM DRAWDOWN SIMULATION RESULTS

After five weeks of continuous pumping at a rate of 6 gpm, groundwater drawdown at the closest off-site location to the on-site well is slightly less than 0.6 feet (Figure 9). At the boundary to the nearest adjoining properties with a record of well permits, drawdown after five weeks of pumping is less than 0.1 feet (Figure 9). Drawdown at the pumping well, not accounting for well inefficiency, is approximately 3.4 feet (Appendix B). This approach reflects the short term more acute stress on the aquifer. However, in between the solar panel rinsing episodes, groundwater levels are expected to partially recover as little or no on-site groundwater pumping is planned during those interim periods.

## FINDINGS

The site overlies coarse to fine-grained alluvial fan deposits that at the existing well are likely to be 112 feet thick. The lower 20 feet of the alluvial deposits are saturated with groundwater. Beneath the alluvial deposits are older sedimentary deposits. These deposits are more dense, and often finer-grained than the alluvial fan deposits. The driller's log for the on-site well indicates that there are sand deposits within this stratigraphic interval that likely yield water. However, it is possible that the overlying alluvial fan deposits provide most of the water for the existing well. Additionally, it is possible that groundwater quality is superior within the alluvial fan deposits than the older sedimentary deposits.

With on-site storage, a well yield of 8 gpm is estimated to meet water demand for operations. Driller's information as well as the existing pumping equipment suggest that the existing well may have a yield that is sufficient to meet this estimate. However, preliminary bio-activity testing and video log information indicate that well's hydraulic efficiency is impaired. Hence, more drawdown within the well bore may occur because of marginal well design, marginal well construction, and biofouling induced well plugging. Additionally, well design and well construction limitations will present challenges to the effective rehabilitation of the well with respect to plugging.

Groundwater flow is toward the northeast (Figure 4). Based on the direction of groundwater flow and the hydraulic gradient, the water table may be approximately 20 feet higher in elevation along the southern boundary of the site. Therefore the alluvial fan aquifer in this area may have a saturated thickness that is significantly thicker compared to the existing well. Additionally, as one moves south on the property toward the head of the alluvial fan, it is likely that the sediments will be coarser in texture and therefore more permeable and capable of transmitting water at faster rates. Greater aquifer thickness and more permeable sediments is expected to provide improved well yield compared to the existing on-site well. Hence, new well construction would be best located at the upgradient or southwestern edge of the site.

Long term operational water demand for the site is expected to be 2 to 3 acre-feet per year or 0.005 to 0.008 acre-feet per day. A preliminary estimate of groundwater inflow into the site ranges between 0.9 and 90 acre-feet per day. Hence groundwater inflow is expected to be several orders of magnitude greater than groundwater production requirements.

Drawdown simulations representing acute short term demand and overall long term demand are consistent with the groundwater inflow versus site pumping demand. Drawdown induced by pumping to meet operational demands is expected to be on the order of 0.5 feet less than 100 feet from the well after five years of pumping (Figure 8). Hence use of groundwater to support the long term operation of the facility is not expected to significantly affect the availability of groundwater to neighboring properties.

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# TABLES

# TABLE 1
# GENERAL GROUNDWATER QUALITY ANALYSIS
# GRAB SAMPLE COLLECTED ON-SITE JUNE 2, 2011

| ANALYTE | RESULT |
|---|---|
| | *(milligrams per liter)* |
| Total Dissolved Solids | 883 |
| Specific Conductance (EC) | 1680 umhos/cm |
| pH | 7.92 |
| Boron | < 5.00 |
| Calcium | 46.7 |
| Magnesium | 13.5 |
| Potassium | < 10 |
| Sodium | 261 |
| Iron | 2.81 |
| Manganese | 0.108 |
| Bicarbonate Alkalinity | 86, as CaC03 |
| Carbonate Alkalinity | < 5, as CaC03 |
| Chloride | 240 |
| Sulfate as SO4 | 283 |
| Total Kjeldahl Nitrogen | 2.3 |
| Nitrite as N | < 0.007 |
| Nitrate as N | 0.08 |
| Dissolved Sulfide | < 0.05 |

# FIGURES

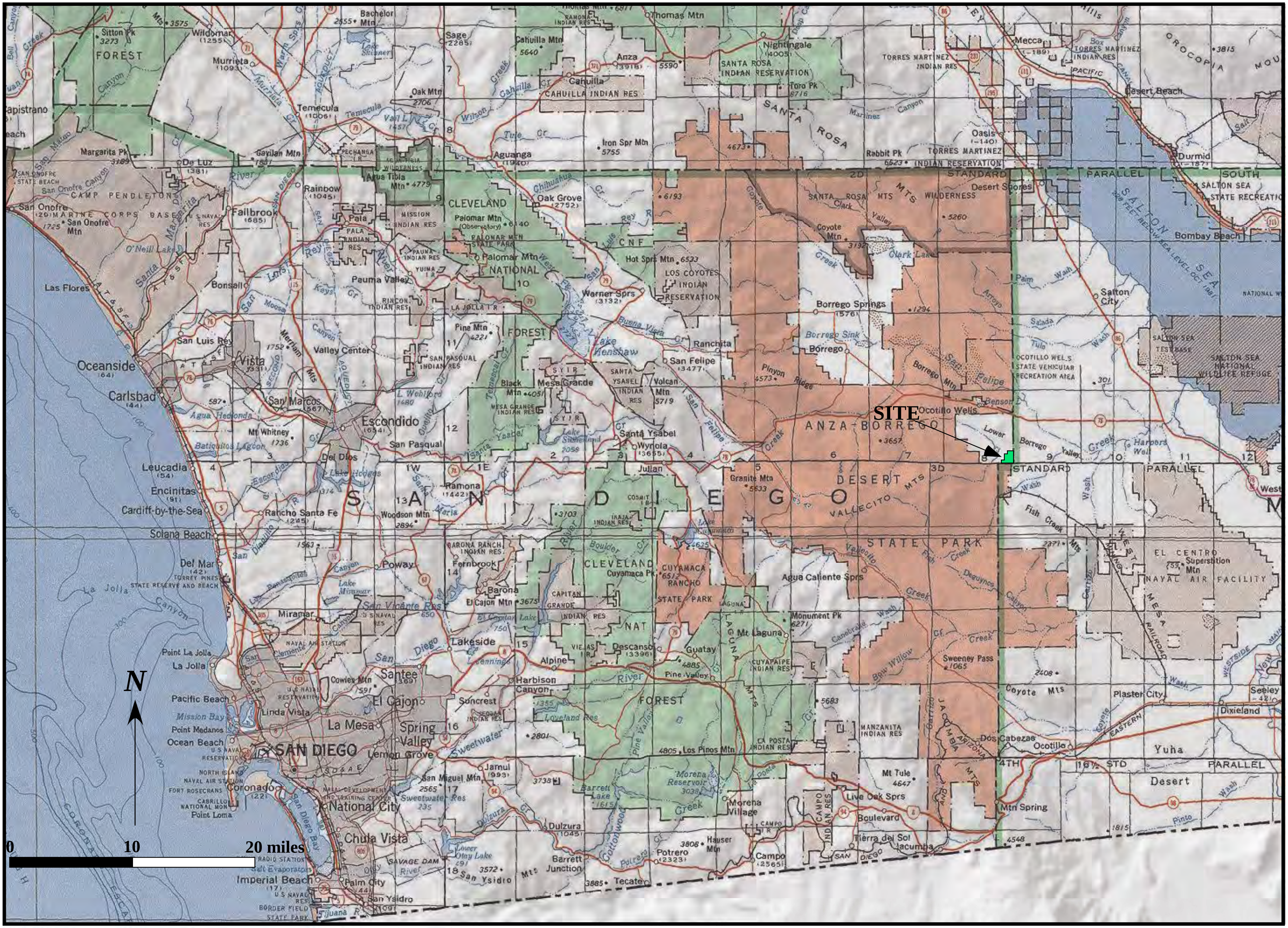



**FIGURE 1 SITE LOCATION**

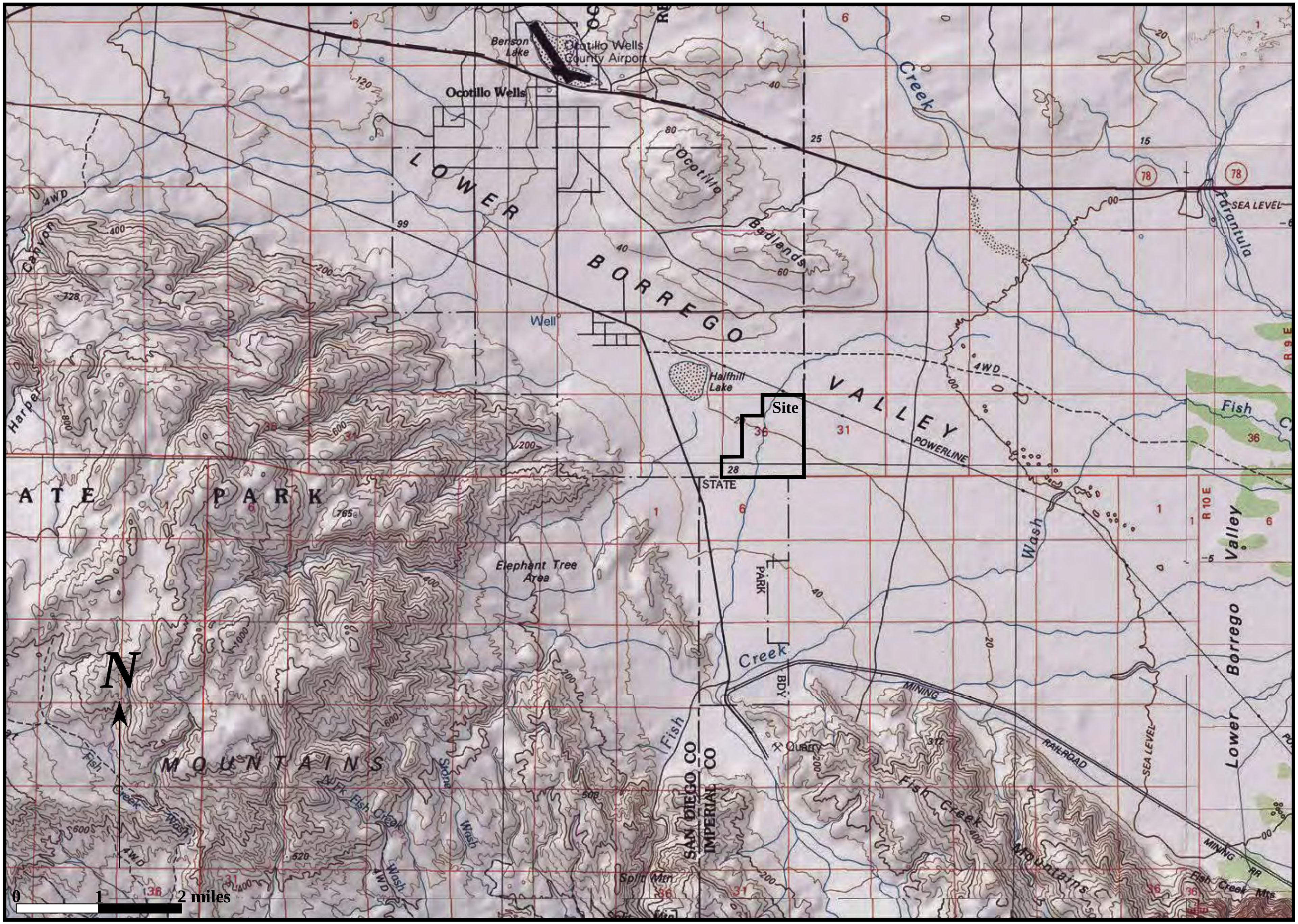
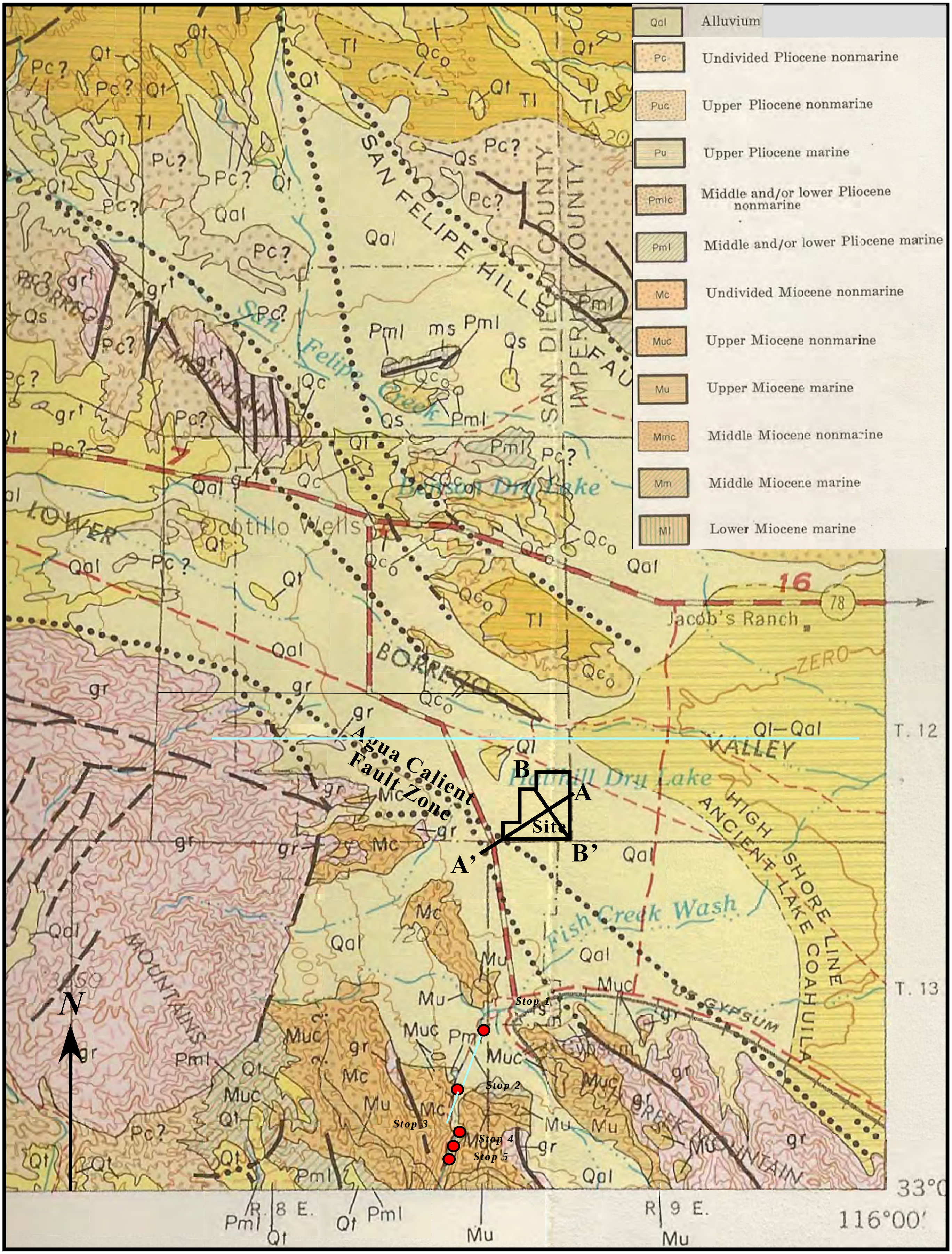



**FIGURE 2**
**REGIONAL SETTING**




0 Miles 2

Approximate Scale

*Modified from the Santa Ana Sheet of the Geologic Map of California Olaf P. Jenkins Editions*

**FIGURE 3**
**REGIONAL GEOLOGIC MAP**

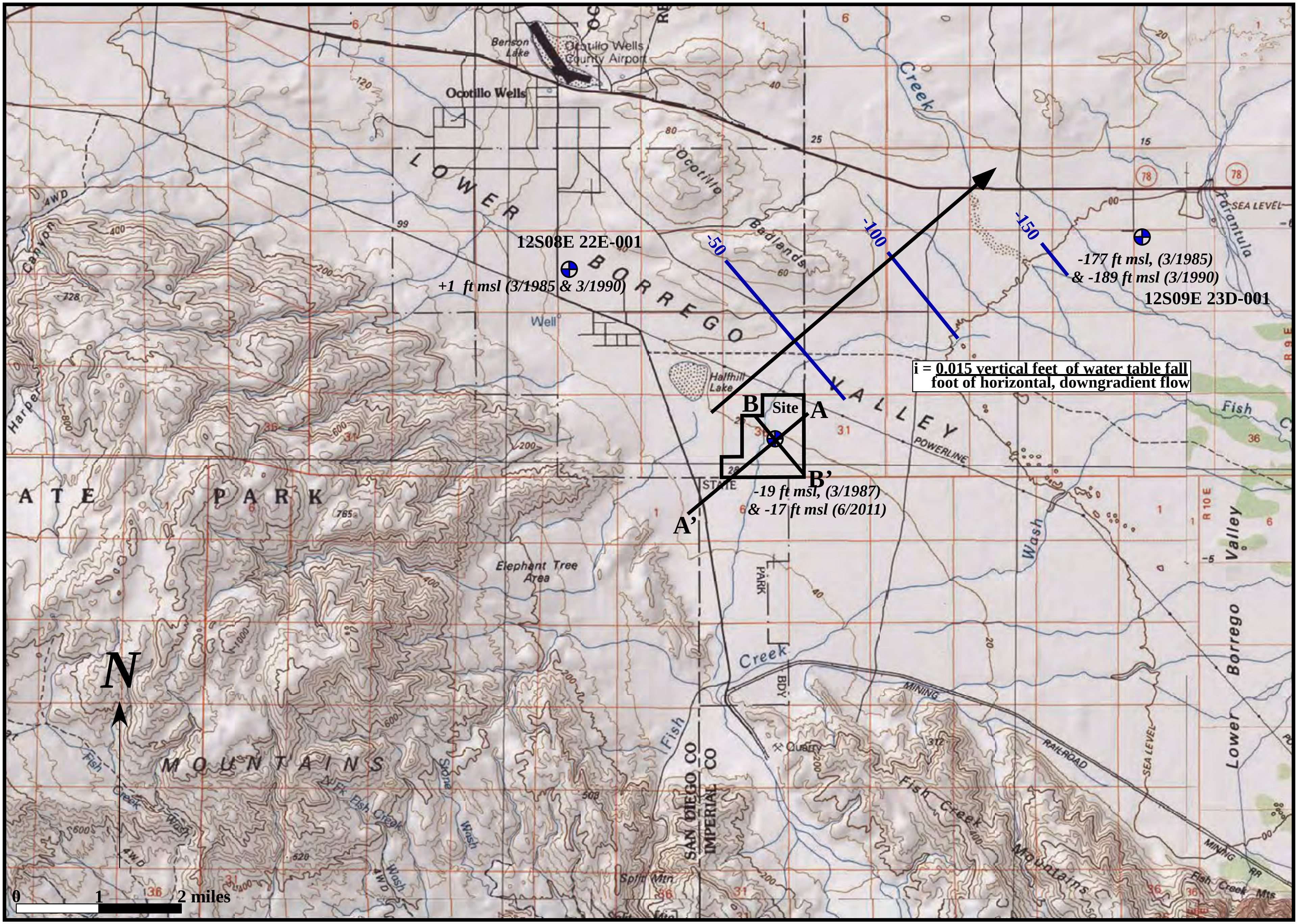



**FIGURE 4**
**REGIONAL GROUNDWATER FLOW CIRCA MID-1980s**

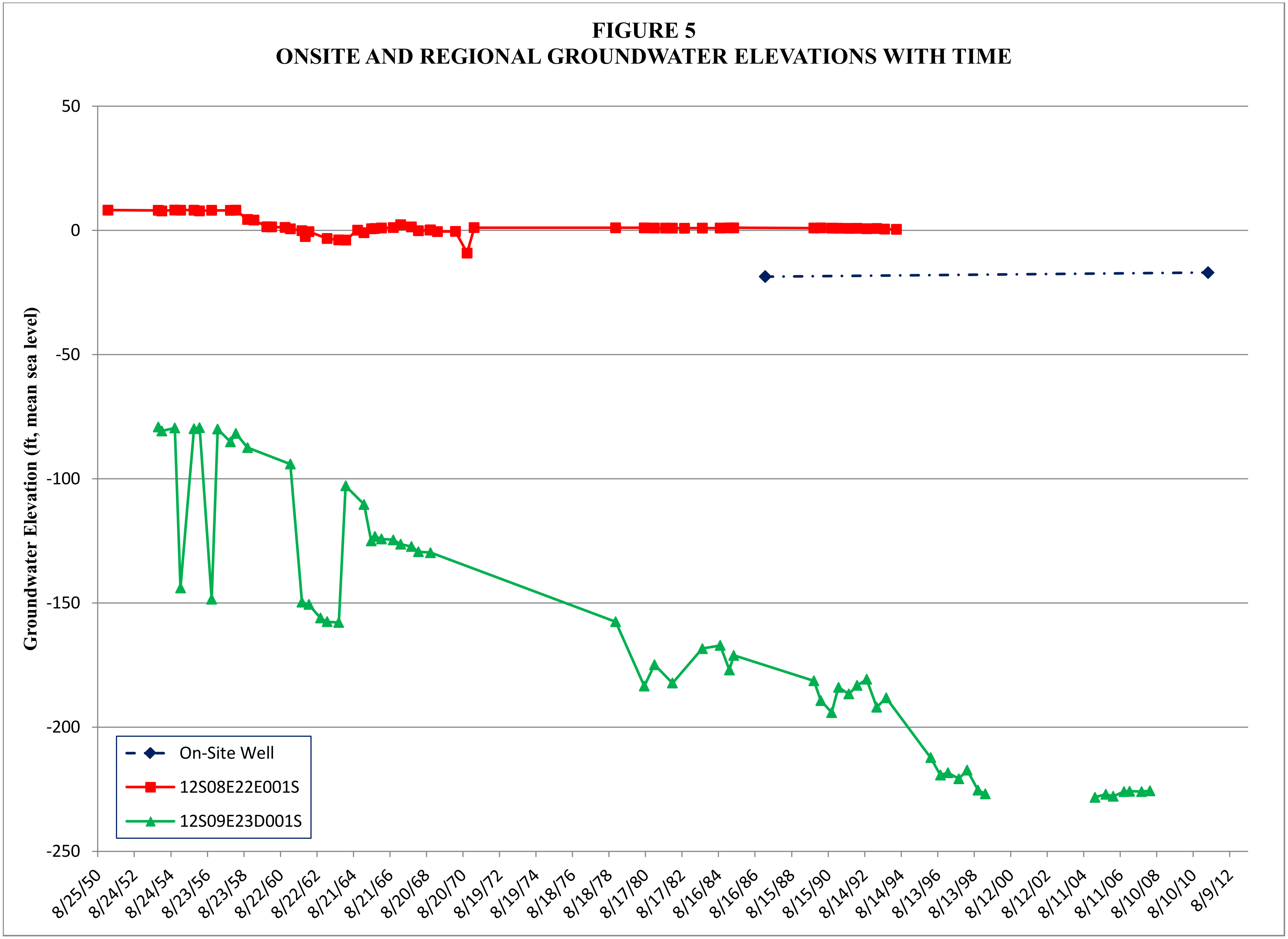


FIGURE 5
ONSITE AND REGIONAL GROUNDWATER ELEVATIONS WITH TIME
Groundwater Elevation (ft, mean sea level)
50
0
-50
-100
-150
-200
-250
8/25/50
8/24/52
8/24/54
8/23/56
8/23/58
8/22/60
8/22/62
8/21/64
8/21/66
8/20/68
8/20/70
8/19/72
8/19/74
8/18/76
8/18/78
8/17/80
8/17/82
8/16/84
8/16/86
8/15/88
8/15/90
8/14/92
8/14/94
8/13/96
8/13/98
8/12/00
8/12/02
8/11/04
8/11/06
8/10/08
8/10/10
8/9/12
On-Site Well
12S08E22E001S
12S09E23D001S

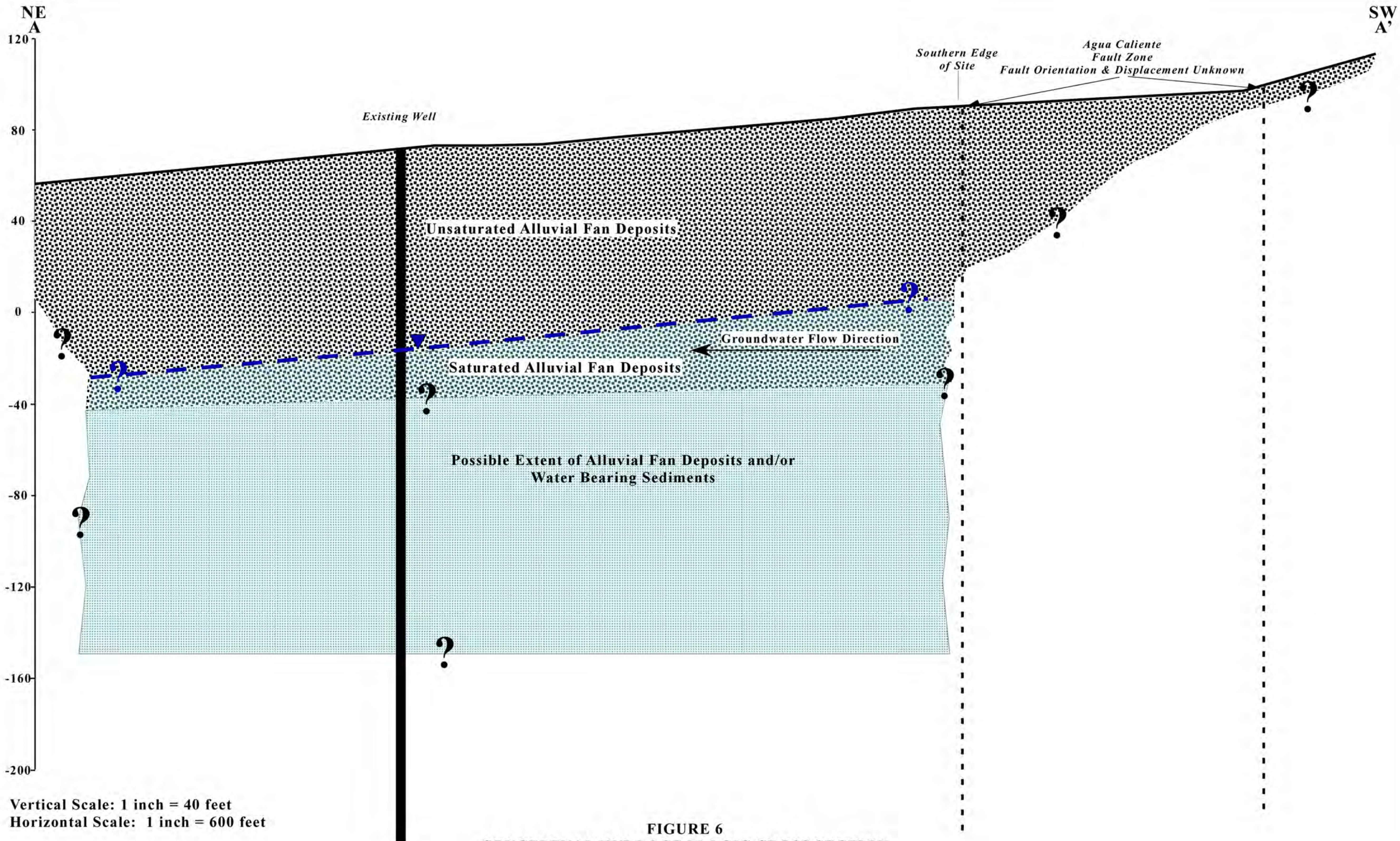
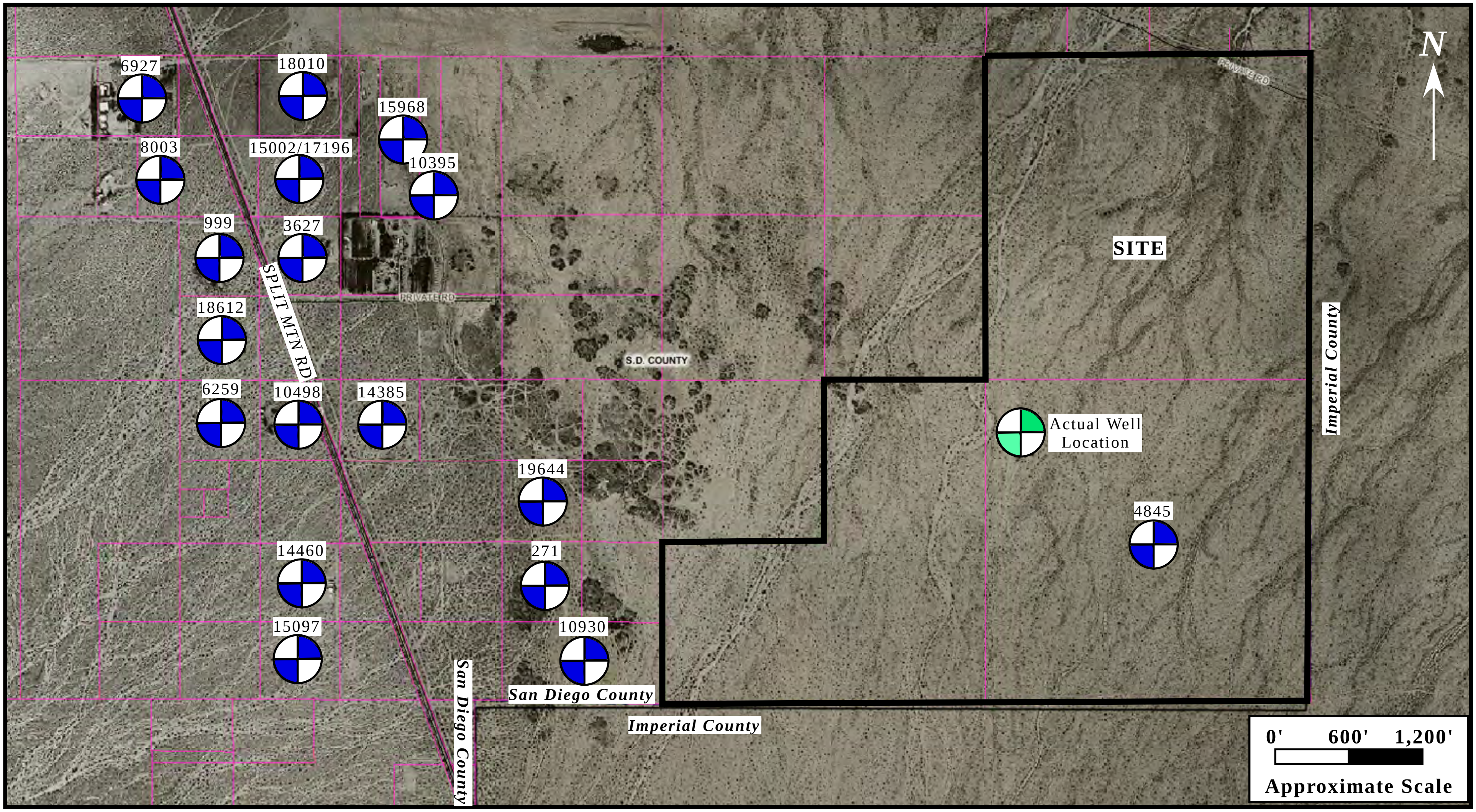



FIGURE 6
CONCEPTUAL HYDROGEOLOGIC CROSS SECTION
PARALLEL TO GROUNDWATER FLOW DIRECTION

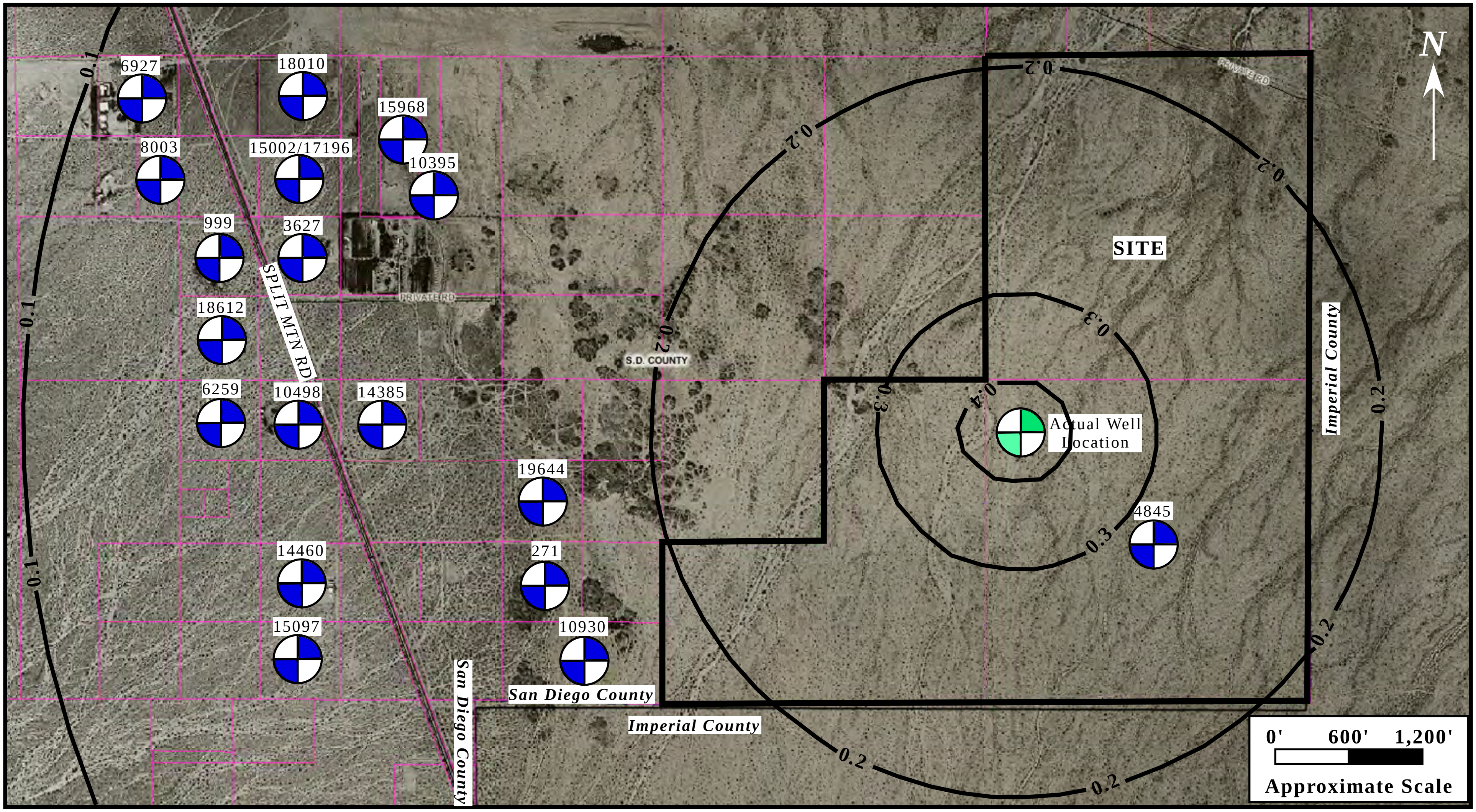



**EXPLANATION**

4845 San Diego County Environmental Health Dept. Well Drilling Permit Number

Symbol Indicates That a San Diego County Well Drilling Permit Has Been Issued to That Parcel. Specific Well Location is Unknown.

**FIGURE 7**
**OFF-SITE PARCELS WITH**
**SAN DIEGO COUNTY WATER WELL PERMITS**




**EXPLANATION**

4845 San Diego County Environmental Health Dept. Well Drilling Permit Number

Symbol Indicates That a San Diego County Well Drilling Permit Has Been Issued to That Parcel. Specific Well Location is Unknown.

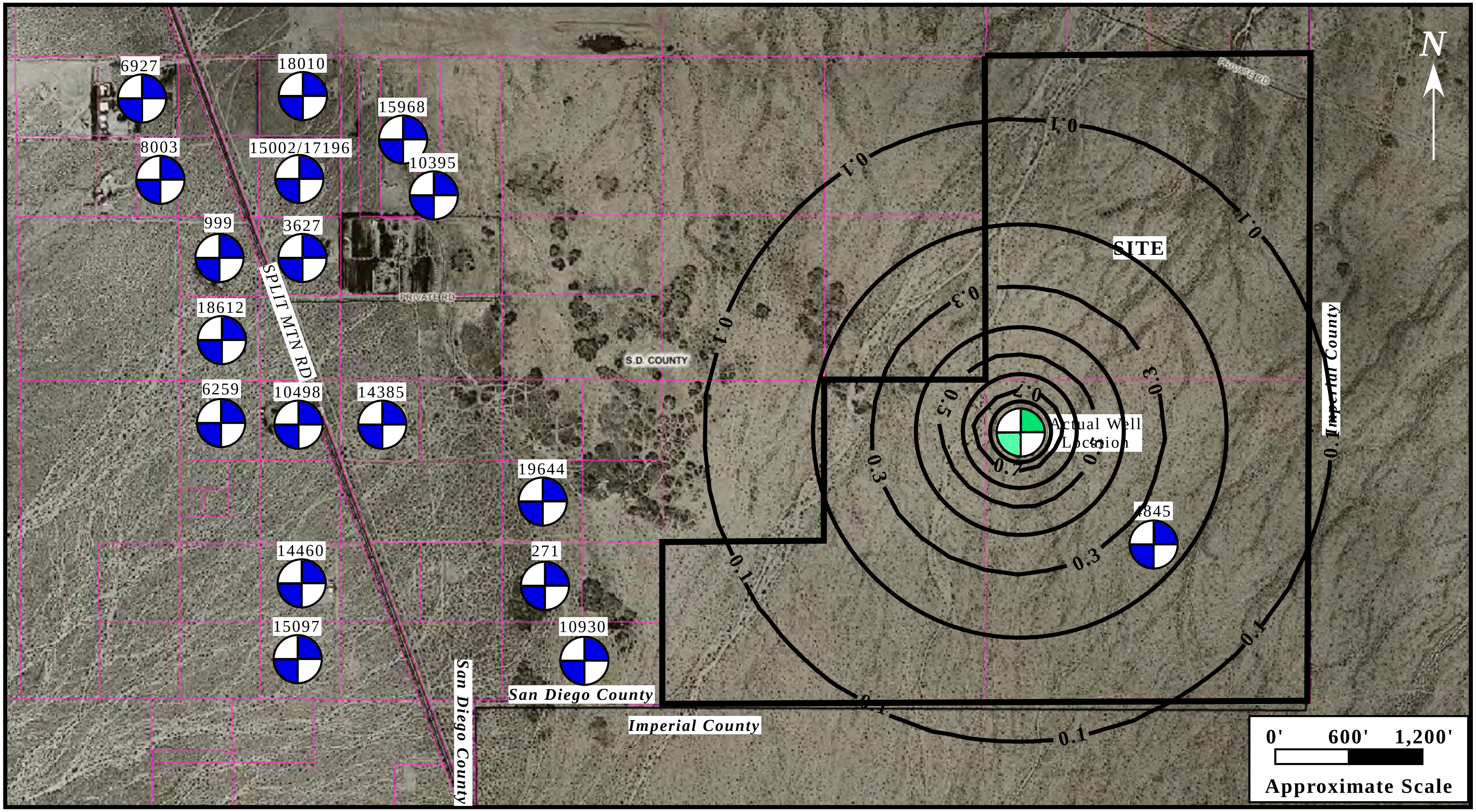
0.2'

Estimated Drawdown, Neuman Unconfined Method, AquiferWin32 Analytical Solution

**Groundwater Pumping**
**Simulation Parameters**

**Hyd. Conductivity = 28 feet per day**
**Aquifer Thickness = 20 feet**
**Specific Yield = 0.05**
**Storativity = 6 x $10^{-4}$**
**Pumping Rate = 1.9 gpm**
**Period of Pumping = 5 years**

**FIGURE 8**
**ESTIMATED GROUNDWATER DRAWDOWN**
**THREE ACRE-FEET OF PUMPING PER YEAR**
**AFTER FIVE YEARS**




**EXPLANATION**

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0.2'

**Estimated Drawdown, Neuman Unconfined Method, AquiferWin32 Analytical Solution**

**Groundwater Pumping**
**Simulation Parameters**

**Hyd. Conductivity = 28 feet per day**
**Aquifer Thickness = 20 feet**
**Specific Yield = 0.05**
**Storativity = 6 x $10^{-4}$**
**Pumping Rate = 6.0 gpm**
**Period of Pumping = 5 weeks**

**FIGURE 9**
**ESTIMATED GROUNDWATER DRAWDOWN**
**SIX GALLONS PER MINUTE OF PUMPING**
**AFTER FIVE WEEKS**

# APPENDIX A

# ON-SITE DRILL LOG

**QUADRUPLICATE**
**Use of comply with local requirements**

orig. w/ ? sent to EC. 11/10/87 CKD

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

# WATER WELL DRILLERS REPORT

*Do not fill in*

No. 202789

Notice of Intent No. 197938

Local Permit No. or Date ____

State Well No. ____

Other Well No. ____

**(1) OWNER:** Name Janet Gleason

Address 6833 Castejon

City La Jolla Zip 92037

**(2) LOCATION OF WELL** (See instructions):

County San Diego Owner's Well Number ____

Well address if different from above Split MOuntain Rd.

Township 12 S Range 8E Section 36

Distance from cities, roads, railroads, fences, etc. see attached

Probable Base of Alluvial Fan Deposits (Wiedlin)

**WELL LOCATION SKETCH**

12/18/87 Slab poured around well pending good sample

12/18/87

**(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 ☐ MUD Air ☐
Other ☐ Bucket ☐

**(6) GRAVEL PACK:**

Yes ☒ No ☐ Size 5/16"x#16

Diameter of bore 8 3/4"

Packed from 3½ yds. ft.

**(7) CASING INSTALLED:**

Steel ☒ Plastic ☒ Concrete ☐

**(8) PERFORATIONS:**

Type of perforation or size of screen

| Casing From ft. | Casing To ft. | Dia. in. | Gage or Wall | Perforations From ft. | Perforations To ft. | Slot size |
|---|---|---|---|---|---|---|
| 0 | 20 | 8 5/8 | .188 | 102 | 112 | |
| 0 | 300 | 5 | cl.200 | 248 | 270 | |
| | | | | 298 | 303 | |

**(9) WELL SEAL:**

Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 20 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 93 ft. 7" 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 150 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 303 ft.

| from ft. | to ft. | Formation (Describe by color, character, size or material) |
|---|---|---|
| 0 | 2 | Loose sand |
| 2 | 18 | Silty sand |
| 18 | 22 | Consolidated sand |
| 22 | 31 | Sand, drills loose |
| 31 | 67 | Semi consolidated sand |
| 67 | 86 | Sand, dirty and tight |
| 86 | 95 | Sand, w/occasional rocks, clean and loose |
| 95 | 102 | Consolidated sand, very dirty |
| 102 | 112 | Sand, medium to coarse, loose |
| 112 | 175 | Consolidated sand, w/clay |
| 175 | 185 | Gray silts |
| 185 | 193 | Brown silts, w/clay lenses |
| 193 | 205 | Semi-consolidated, rocks @ 202 |
| 205 | 230 | Consolidated sand, high clay |
| 230 | 238 | Semi-consolidated, higher sand |
| 238 | 246 | Consolidated sand, high clay |
| 246 | 275 | Cleaner sand,drills loose rocks @ 248 ft. |
| 275 | 302 | Consolidated sand w/small loose areas. |
| 302 | 303 | Clay |

Work started 2/18 1987 Completed 3/6 1987

**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 90236

License No. 305739 Date of this report 3/6/87

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

# APPENDIX B

# GROUNDWATER DRAWDOWN SIMULATION DIGITAL FILES

# ATTACHMENT A

# ADDITIONAL GROUNDWATER DRAWDOWN CALCULATIONS

Wiedlin & Associates, Inc.
P.O. Box 910462
San Diego, CA 92191-0462
858.259.6732 · fax 858. 259.6094
Applications in Groundwater Science

January 8, 2012

Planning & Development Services
Attn: Jim Bennett, County Groundwater Geologist
5510 Overland Avenue
San Diego, CA 92123

**Subject: Additional Groundwater Drawdown Analyses, Ocotillo Wells Solar Project; Major Pre-Application Case Number 3992 11-003 (MPA), 6953 Split Mountain Road, Borrego Springs, California**

Dear Mr. Bennett:

This document provides additional groundwater drawdown analyses for the above referenced project. These additional analyses were prepared based on our telephone conversation in late December 2012 where it was agreed that the initial groundwater drawdown analyses indicated de minimus affect on groundwater resources was likely and that demonstration of a slightly greater extraction would likely prove useful with respect to the long term operation of the proposed project.

## SCOPE OF ANALYSES

Similar to the initial drawdown analyses presented in W&A's November 8, 2012 Preliminary Hydrogeologic Analysis, two drawdown analyses were prepared. The estimates were derived using an analytical model of unconfined aquifer groundwater flow based on S.P. Neuman's 1972 publication, *Theory of Flow in Unconfined Aquifers Considering Delayed Response of the Water Table* as applied through the aquifer test and groundwater modeling software program, AquiferWin32, Version 4.04 by Environmental Simulations, Inc. AquiferWin32 digital output files for hydraulic head and drawdown calculations are provided in Attachment A-3 (Compact Disk).

One analysis prepared herein was conducted using an average annual groundwater extraction rate of five acre-feet per year, equivalent to continuous pumping rate of 3.1 gallons per minute (gpm), with drawdown evaluated after five years of pumping. In the November 8, 2012 analyses, the annual groundwater extraction rate was three acre-feet per year and 1.9 gpm. The second analysis prepared herein was conducted to reflect short term acute drawdown as groundwater demand for operations and maintenance is expected to be episodic. For the second analysis, the groundwater pumping rate was increased from 6.0 gpm in the November 8$^{th}$ analysis to 10 gpm for the current analysis over a five week pumping period.

The remaining hydrogeologic parameters for the drawdown analyses were held constant compared to the November 8$^{th}$ work. For reference these parameters include the following:

Hydraulic Conductivity = 28 feet per day
Aquifer Thickness = 20 feet
Specific Yield = 0.05 (dimensionless)
Storativity = 6 x $10^{-4}$ (dimensionless)

## FINDINGS

For the long term drawdown analysis with a pumping rate of 3.1 gpm over five years, groundwater drawdown at the closest off-site location to the on-site well is slightly greater than 0.6 feet (Attachment A-1). This compares to a drawdown of slightly less than 0.4 feet at the same location at 1.9 gpm as reported in the November 8th analysis. Drawdown at the pumping well, not accounting for well inefficiency, is approximately 1.4 feet after five years of pumping. This compares to a drawdown of less than 0.8 feet at the pumping well when pumping at 1.9 gpm over the course of five years.

For the short term drawdown analysis, after five weeks of pumping at 10 gpm groundwater drawdown of approximately 1 foot was calculated at the closest off-site location to the on-site well. This compares to a drawdown of slightly less than 0.6 feet at 6 gpm as reported in the November 8th analysis. Drawdown at the pumping well, not accounting for well inefficiency, is estimated at approximately 4.8 feet. This compares to a drawdown of approximately 3.4 feet at the pumping well when pumping at 6 gpm over the course of five weeks as reported in the November 8th report.

## CONCLUSIONS

Groundwater drawdown, induced by pumping at long term and short term rates that are slightly greater than the water consumption estimates prepared for the site, are expected to be well below the county threshold of five feet for alluvial aquifers. Based on experience monitoring groundwater production at other major use permit sites, providing a safety factor for groundwater consumption can be very helpful for site operations as unexpected water use related to site infrastructure issues will likely arise from time to time and water demand estimates, are in fact just estimates. Provided that impacts to pumping slightly more groundwater does not create a significant impact, it is suggested that the terms of the MUP account for this uncertainty. In the case of this project, it appears that the hydrogeologic conditions surrounding the site will most likely accommodate this contingency.

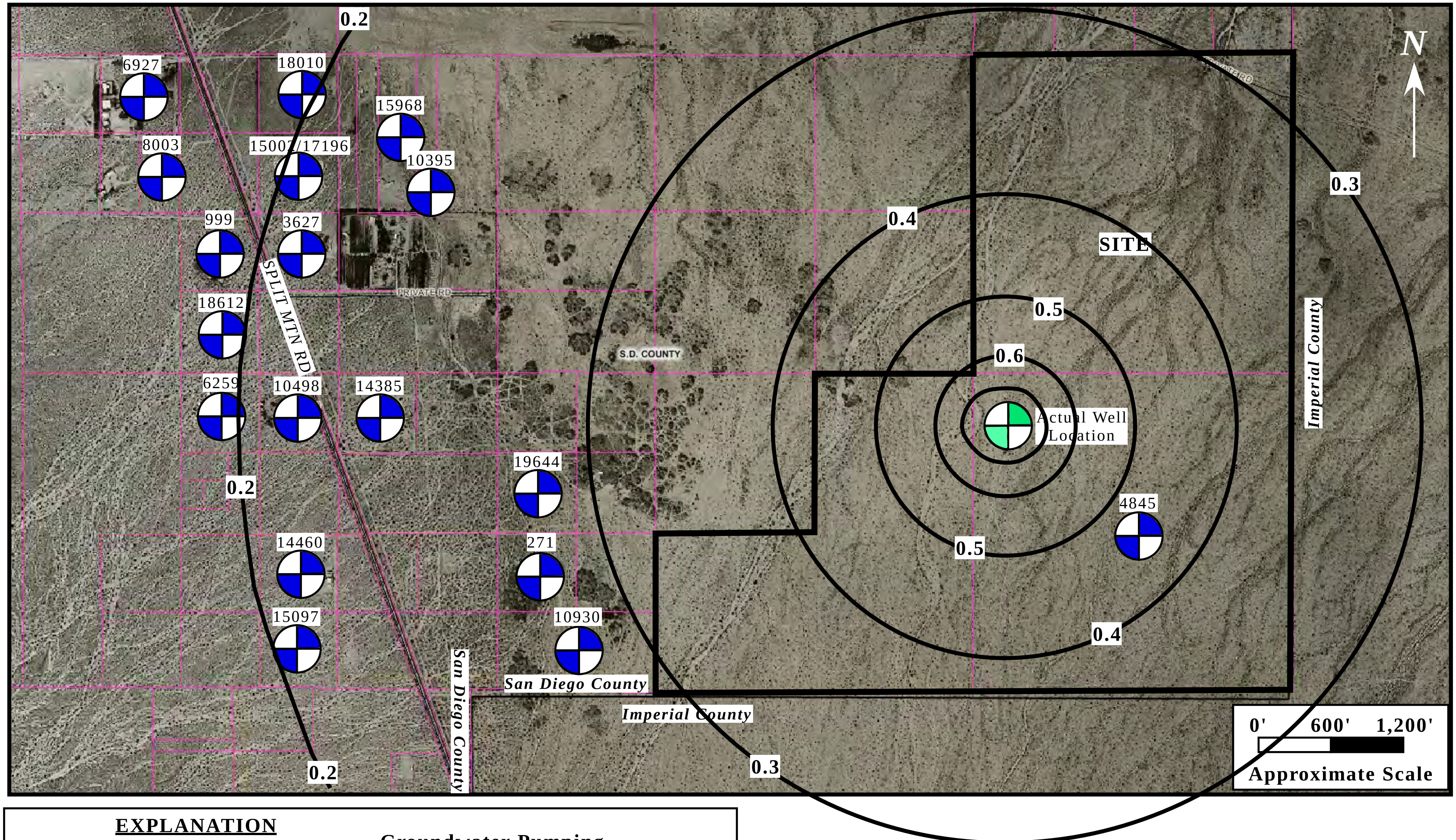
Sincerely,

Matthew P. Wiedlin

Professional Geologist
Matthew P. Wiedlin
No. 97
Certified
Hydrogeologist
State of California

Matthew P. Wiedlin
California Certified Hydrogeologist, No. 97

Attachments: A-1 and A-2, Estimated Groundwater Drawdown Maps, A-3 CD of Groundwater Drawdown Simulation Digital Files




**EXPLANATION**

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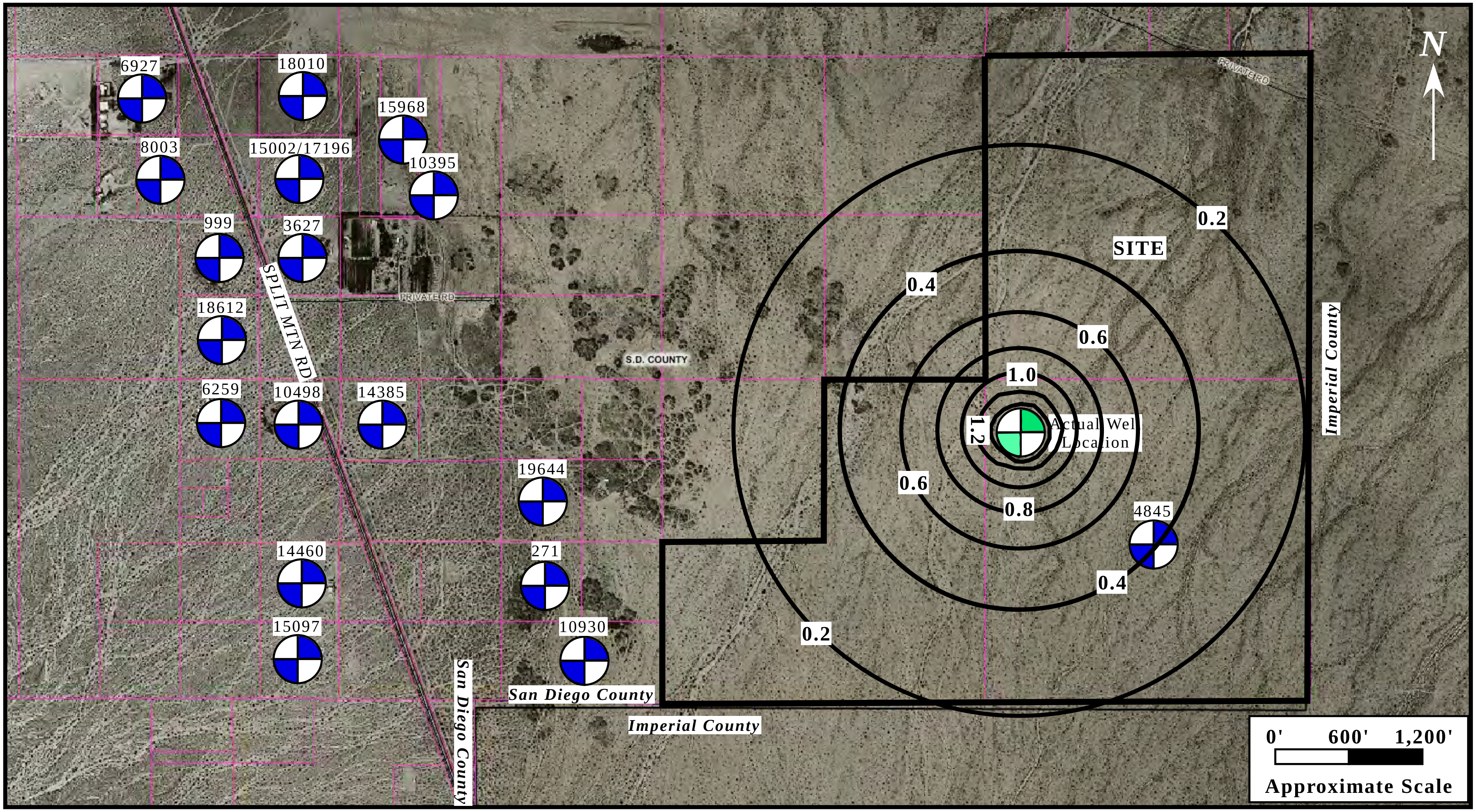
0.2'

**Estimated Drawdown, Neuman Unconfined Method, AquiferWin32 Analytical Solution**

**Groundwater Pumping Simulation Parameters**

**Hyd. Conductivity = 28 feet per day**
**Aquifer Thickness = 20 feet**
**Specific Yield = 0.05**
**Storativity = 6 x $10^{-4}$**
**Pumping Rate = 3.1 gpm**
**Period of Pumping = 5 years**

**FIGURE A-1**
**ESTIMATED GROUNDWATER DRAWDOWN**
**FIVE ACRE-FEET OF PUMPING PER YEAR**
**AFTER FIVE YEARS**

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**Groundwater Pumping**
**Simulation Parameters**

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**Aquifer Thickness = 20 feet**
**Specific Yield = 0.05**
**Storativity = 6 x $10^{-4}$**
**Pumping Rate = 10.0 gpm**
**Period of Pumping = 5 weeks**

**FIGURE A-2**
**ESTIMATED GROUNDWATER DRAWDOWN**
**10 GALLONS PER MINUTE OF PUMPING**
**AFTER FIVE WEEKS**