Groundwater Impact Assessment Report

Rio Mesa Solar Electric Generating Facility

Riverside County, California

308100-03596

September 2011

WorleyParsons

resources & energy

EcoNomics

GROUNDWATER IMPACT ASSESSMENT

RIO MESA SOLAR ELECTRIC GENERATING FACILITY, RIVERSIDE COUNTY, CALIFORNIA

Mike Tietze, as an employee of WorleyParsons, with expertise in groundwater hydrology, has reviewed the report with the title **Groundwater Impact Assessment Report, Rio Mesa Solar Facility**. Mr. Tietze is Professional Geologist, Certified Engineering Geologist, and Certified Hydrogeologist in the State of California. His signature and stamp appear below.

Michael Tietze, PG, CEG, CHG
September 2011

REGISTERED GEOLOGIST
MIKE TIETZE
No. EG1803
Exp. 4/30/2013
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Principal authors and reviewers included Michael Huma and Mark Trudell.

Michael Huma, Staff Hydrogeologist

Mark Trudell, Ph.D., PG, CHG

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LIST OF ACRONYMS AND ABBREVIATIONS

AMSL	Above mean sea level
AFC	Application for Certification
AFY	acre-feet per year
BEP	Blythe Energy Project
bgs	Below ground surface
BLM	Bureau of Land Management
BOR	United States Bureau of Reclamation
BSEP	Blythe Solar Energy Project
CEC	California Energy Commission
DWR	California Department of Water Resources
ft	foot
ft/ft	feet per foot
ft/day	feet per day
ft^2/day	square feet per day
gpm	gallons per minute
MW	megawatt
NWIS	USGS National Water Information System
PVID	Palo Verde Irrigation District
PVMGB	Palo Verde Mesa Groundwater Basin
PVVGB	Palo Verde Valley Groundwater Basin
RMS	Rio Mesa Solar Generating Facility
TDS	Total Dissolved Solids
USBR	US Bureau of Reclamation
USGS	United States Geological Survey
WRCC	Western Regional Climate Center

1. INTRODUCTION

BrightSource Energy, Inc. proposes to construct the Rio Mesa Solar Generating Facility (RMS) consisting of three 250 megawatt (MW) units, located in the eastern Riverside County in California. The project location is shown on **Figure 1-1** and includes approximately 9,000 acres of land (hereinafter the Site). The RMS project (Project) proposes to use groundwater as a water supply during construction and operation. This *Groundwater Impact Assessment Report* has been prepared by WorleyParsons on behalf of BrightSource Energy to provide information regarding groundwater resources that will be incorporated into an Application for Certification (AFC) to the California Energy Commission (CEC) for the proposed project. The information contained in this report describes the assessment of potential impacts on groundwater resources due to project activities, and potential subsequent impacts on surface water resources and subsidence. The companion report to this report is the *Assessment of Existing Groundwater Conditions Report* prepared by WorleyParsons (2011) which describes the affected hydrogeological environment of the RMS project. Collectively, these reports are intended to meet the CEC's Data Adequacy Standards for groundwater resources evaluation as part of an AFC for a facility that uses groundwater as a water supply.

Specifically, this report includes the following:

- Evaluation of potential project and cumulative effects of groundwater levels near the Site, to nearby groundwater users and relative to the proposed Colorado River Accounting Surface;
- Evaluation of the potential Project effects on basin-wide groundwater flow and balances;
- Evaluation of the potential effects of Project pumping on surface water resources;
- Evaluation of the potential effects of Project pumping on water quality; and
- Evaluation of the potential for Project pumping to cause land subsidence effects.

The remaining sections of this report are organized as follows:

- Section 2 presents a hydrogeological conceptual model for the project;
- Section 3 describes the groundwater flow model development and results including the sensitivity analysis;
- Section 4 discusses the impact assessment;
- Section 5 presents the conclusions of the Report; and
- Section 6 lists the references cited in the report.

2. HYDROGEOLOGIC CONCEPTUAL MODEL

This section presents a summary of our working conceptual understanding of groundwater occurrence and behavior in the Palo Verde Mesa Groundwater Basin (PVMGB) and the Palo Verde Valley Groundwater Basin (PVVGB). This understanding forms the basis of our modeling approach for the project as discussed in the subsequent sections of this report. This summary of hydrogeologic conditions is derived from the detailed hydrogeologic assessment in the companion *Assessment of Existing Groundwater Conditions Report* (WorleyParsons, 2011). Further details on the topics discussed in the subsequent sections are contained in that report.

2.1 Physiographic Setting

The Site is located in the southern portion of the PVMGB, a groundwater basin approximately 353 square miles in area that underlies Palo Verde Mesa in eastern Riverside County. The PVMGB is bounded by nonwater-bearing rocks of the Big Maria and Little Maria Mountains on the North, of the McCoy and Mule Mountains on the west, of the Palo Verde Valley on the east, and of the Palo Verde Mountains on the south (DWR, 1979; Jennings, 1967). Palo Verde Mesa includes a valley north of Blythe that is drained by McCoy Wash to the Colorado River. In addition, in the north and mid portions of Palo Verde Mesa, water flows easterly from the Chuckwalla Valley Basin into the PVMGB.

The PVVGB abuts the PVMGB to the east. The Palo Verde Mountains bound the southern part of the PVVGB, the Palo Verde Dam and the Big Maria Mountains bound the basin on the north, and the eastern boundary is the Colorado River.

2.2 Climate and Precipitation

The climate in the Project Site vicinity is characterized by high aridity and low precipitation with hot summers and generally mild winters (CEC, 2010). Average annual precipitation ranges from around 3 inches in the lower elevations to 6 inches in the higher elevations. At the Blythe Airport weather station the mean annual precipitation (1948 to 2010) is 3.54 inches per year with the maximum annual precipitation for the period of record of 9.16 inches, and maximum month precipitation of 5.92 inches, recorded in August 1951 (WRCC, 2011). Most of the rainfall occurs during the winter months or in association with summer tropical storms (CEC, 2010).Hydrogeologic Setting

2.2.1 Hydrostratigraphy

The Colorado River and the underlying and adjacent alluvial aquifer and valley fill form a complex, hydraulically connected groundwater and surface-water flow system. The principal water-bearing strata in the PVMGB and PVVGB basins are Quaternary Alluvium. The alluvium in the Palo Verde Valley has

been divided into younger and older alluvium. The younger alluvium forms the flood plain of the Colorado River; the older alluvium forms the terraces and alluvial slopes that bound the flood plain (Metzger and others, 1973). The younger alluvium occurs beneath the flood plain in the Valley Basin, and the older alluvium forms the mesa above the flood plain and is also encountered below the younger alluvium on the flood plain. The PVMGB is underlain by the older alluvium. Based on the similarity in lithologies, groundwater elevations, and the general absence of significant vertical hydraulic gradients, the younger and older alluvium is interpreted to comprise a single hydrostratigraphic unit. Water-bearing Quaternary Alluvium sediments in the PVMGB and PVVGB are up to 1,000 feet thick in some places.

The Quaternary-age alluvium is underlain by the Pliocene Bouse Formation, consisting of either lacustrine or estuarine facies; and the Miocene Fanglomerate, consisting of cemented alluvial fan facies of primarily of interbedded clay, silt, and fine. The mountain areas consist of principally coarse-grained angular rock detritus (DWR, 1979). Bedrock beneath the PVMGB and PVVGB has not been fully mapped. The underlying bedrock in the adjacent Chuckawalla Valley Basin to the west exhibits an uneven topography that is likely influenced to some extent by faulting; however, faults are not known to extent upward into the basin fill materials and form a barrier to groundwater flow (Stone 2006; DWR 2004b).

The results of Site-specific investigation (URS, 2011) are consistent with the above understanding. In general, the hydrostratigraphic sequence beneath the Project area is characterized by abundant fine to coarse grained sediments separating sequences of moderate permeability and some high permeability interbeds. Water-bearing sediments identified during site-specific investigation include an upper alluvial aquifer of moderate to high permeability. At the Project Site, these alluvial deposits are present to depths of 305 to 435 feet, as shown in the simplified hydrogeologic cross-section **Figure 2-1** (Stone and Webster, 1976). The alluvial aquifer is underlain by the Bouse Formation at a depth of approximately 270 feet below ground surface (bgs). A relatively competent clay aquitard occurs at the top of the Bouse Formation and separates an interval of about 350 feet of moderately permeable water-yielding sediments from the overlying alluvium.

2.2.2 Groundwater Levels and Flow

In the PVMGB and PVVGB, groundwater occurs within the alluvium, which is contiguous with the Colorado River gravels.

Figure 2-2 shows the groundwater elevation contours for the combined PVMGB and PVVGB. Groundwater in the north portion of the PVMGB flows to the west-southwest towards the McCoy Mountains and away from the Big Maria Mountains. In the mid and southern portions of the PVMGB groundwater flow is to the south and southwest towards the Mule and Palo Verde Mountains. Groundwater in the northern portion of the PVVGB generally flows to the south to southeast towards

the Colorado River and in the mid and southern portions generally to the southwest to west-southwest in the general direction of the flow of the Colorado River. The lateral hydraulic gradient is steeper in the northeastern portion of the PVMGB and decreases in the west and southern part of the basin.

As shown in **Figure 2-2**, a series of groundwater divides and discharge boundaries (base of drainage divides) are evident in the central and southern portion of the PVMGB and western PVVGB. A prominent groundwater mound is present between the Colorado River and the PVMGB and forms a groundwater divide. The discharge boundaries generally coincide with these PVID drains. These groundwater divide and drainage boundaries underlie irrigated lands of the Palo Verde Irrigation District (PVID), which is allocated sufficient Colorado River water to irrigate 104,500 acres of agricultural land in Palo Verde Valley, and additional acreage on the Palo Verde Mesa. Irrigation water diversions to meet this need have historically averaged 950,000 AFY, but in recent years have ranged from approximately 650,000 to 950,000 AFY as a result of implementation of a water transfer program between PVID and MWD. Water is diverted by PVID at Palo Verde Diversion Dam near the northern end of Palo Verde Valley and distributed by a series of canals totaling over 244 miles in length. The application of large amounts of irrigation water produces annual recharge of an estimated 65,000 to 95,000 acre-feet (10%) to the regional groundwater system, and has created a groundwater mound between the Valley and River. In response to increasing groundwater levels in the valley, PVID installed a series of drains over the past several decades to keep groundwater levels from rising into the root zone of crops. Water collected in these drains is returned to the river near the southern end of the Palo Verde Valley. The groundwater divides and discharge boundaries in the above groundwater flow system prevent direct hydraulic communication between the PVMGB and the Colorado River.

URS measured groundwater levels in 19 on-Site wells in January and May, 2011 (URS, 2011). Based on these groundwater level measurements, groundwater at the Site is present at depths ranging from 140 to 160 feet below ground surface (bgs) in the older alluvium. Groundwater in the alluvial aquifer beneath the Site occurs under unconfined conditions. Groundwater surface elevation ranges from approximately 232 feet above mean sea level (AMSL) at the north end of the Site, to approximately 224 feet AMSL at the south end of the Site. The horizontal hydraulic gradient beneath the Site is approximately 0.0003 feet per foot (ft/ft). In the southern portion of the Site, groundwater level data indicate a possible groundwater flow component eastward, away from the Mule mountains. In addition, groundwater level differences between shallow and deeper wells indicate the existence of a vertical downward gradient. Current groundwater levels are approximately at, or within about 2 feet above, the proposed Colorado River Accounting Surface.

2.2.3 Aquifer Properties

Metzger and others (1973) provide the a regional assessment of aquifer characteristics through an evaluation of pumping tests from 42 wells tested in Parker, Vidal, Palo Verde and Cibola valleys. In the Palo Verde valley, they reported transmissivities in the flood plain ranging from 8,500 square feet per day (ft^2/day) up to 1 250,000 ft^2/day. Their data showed that in general, transmissivity values are

higher in the valley than in the mesa area, though wells located in portions of the mesa near the valley boundary or in the northeastern portion of the mesa near McCoy Wash produce large amounts of water, suggesting higher transmissivity conditions in these areas.

In their development of a two-dimensional superposition model for the Parker-Palo Verde-Cibola area, which includes the PVMGB and PVVGB, Leake and others (2008), evaluated published aquifer testing data and through statistical analysis and derived a range of representative transmissivity values from 25 tests conducted along the river. They reported a low value of 6,300 ft^2/day, and an average value of 26,200 feet per day (ft/day). In their model of Colorado River depletion, they selected a storage coefficient of 0.20 to approximate aquifer conditions throughout their model domain.

A numerical groundwater flow model of the PVMGB and PVVGB was constructed by AECOM for the Blythe Solar Energy Project (BSEP) and is a refinement of a portion of the Leake model (AECOM, 2010). In the development and calibration of the BSEP model AECOM estimated that hydraulic conductivity of the alluvial deposits ranges from 1 to 1000 ft/day based on assessment of published and well completion data.

Pumping tests conducted on two water supply wells completed in the younger and older alluvium at the Blythe Energy Project (BEP) yielded transmissivities of 52,054 and 59,637 ft^2/day and hydraulic conductivities of 124 and 130 ft/day (CEC, 2005).

A number of wells were installed on Site as part of the Sun Desert Project (Stone and Webster, 1976). A 12-inch diameter production well (28R003S) screened from approximately 255 to 355 feet bgs, completed mainly in the older alluvium, was installed in the southern portion of the Site. A 97 hour pumping test at a rate of 820 gallons per minute was conducted in April 1976, with three piezometers and four boreholes used as observation wells (Stone and Webster, 1976). Results from the pumping test indicated a transmissivity of approximately 100,000 to 200,000 gallons per day per foot (13,400 to 26,700 ft^2/day), and storage coefficient of 1×10^{-3}. The hydraulic conductivity derived from the transmissivity estimate was 60 to 127 ft/day (Stone and Webster, 1976). URS (2011) reported that this pumping test produced approximately 55 feet of drawdown, from which the calculated specific capacity of the well is approximately 15 gpm/foot.

2.2.4 Groundwater Quality

Groundwater quality in the basin varies both laterally and vertically. The concentration of TDS in the alluvial aquifer at the Site has been measured at approximately 1,800 milligrams per liter (mg/L (URS, 2011). Concentrations of TDS are generally believed to be higher in sediments of the Bouse Formation that underlie the alluvial aquifer (CEC, 2005). Water quality is generally better east of the Site in the PVVGB (NWIS, 2011), likely due to the better water quality of the Colorado River and deep percolation from applied irrigation water.

2.2.5 Groundwater Budget Summary

As discussed in detail in the *Assessment of Existing Groundwater Conditions Report* (WorleyParsons, 2011) the components of recharge and discharge for the groundwater budget in the PVMGB and PVVGB are as follows:

Recharge (Inflows):

- Recharge from Precipitation;
- Subsurface inflow from the Parker Valley and Chuckwalla Valley;
- Agricultural Irrigation Infiltration (deep percolation);
- Irrigation Canal Seepage; and
- Recharge to groundwater from Colorado River seepage (Losing Condition).

Discharge (Outflows):

- Groundwater Pumping (Agriculture and Municipal);
- Consumptive Use – Native Vegetation;
- Groundwater Discharge to the PVID Drains; and
- Groundwater Discharge to the Colorado River (Gaining Condition).

The water budget for these components of the groundwater system for the combined the PVMGB and PVVGB is presented in **Table 2-1.** A groundwater balance of 426,600 acre-feet per year (AFY) is estimated from a balance of the recharge and discharge elements. The key recharge elements of the groundwater balance are irrigation water deep percolation, canal seepage and recharge to groundwater from the Colorado River. These components comprise 98% of the total recharge to the PVMGB and PVVGB. Deep percolation from irrigation and canal seepage represent 44% of total recharge (**Table 2-1**)[1]. The discharge or outflow of groundwater is largely comprised of the measured discharge from PVID drains (84% of total discharge). Thus, the hydrogeologic system is largely driven by deep

[1] Note that outflow/inflow to/from the Colorado River was treated as a residual component in the most recent available water balance (AECOM, 2010), as discussed in Section 6.1.5 of this report. The groundwater elevation contours shown on **Figure 2-2** suggest the river is gaining in the northern half of Palo Verde Valley and losing in the southern half. Further, underflow out of the Valley through the gap above Cibola is assumed to be negligible since most of this water should discharge into the river in the Cibola Valley above the narrows, as previously assumed by Metzger et al. (1973) and Owen-Joyce (1984). These factors suggest that basin-wide, there may be closer balance between groundwater inflow and outflow to/from the river, and recharge derived from deep percolation of irrigation water may be more significant and recharge from infiltration of river water less significant than suggested by the groundwater budget.

percolation of irrigation water and discharge of irrigation water to the PVID drains, both of which are measured to comply with Bureau of Reclamation requirements.

The primary recharge mechanism in the PVMGB and PVVGB is deep percolation of irrigation water (infiltration of irrigation water that becomes groundwater recharge) and infiltration of river water. Groundwater recharge from direct precipitation onto the valley floor or mesa is considered negligible, which is consistent with the approach of Metzger et al. (1973) who considered direct recharge from precipitation to be negligible in areas with mean annual precipitation less than eight inches. Therefore groundwater recharge from precipitation is mainly in the form of mountain front recharge which occurs via deep percolation through the coarser grained proximal alluvial fan deposits and washes that occur near the mountain fronts. .

3. COMPUTER MODELING IMPACT EVALUATION

Potential Project impacts due to groundwater withdrawals depend on complex relationships within the PVMGB and PVVGB between:

- The natural groundwater system;
- Deep percolation from irrigation; and
- Irrigation return flows through drains in irrigated fields. and
- The surface water system.

Consequently, a groundwater flow model is the most comprehensive tool for analyzing the overall effects of groundwater withdrawals.

3.1 Groundwater Flow Model Development

3.1.1 Numerical Modeling Approach

As applied in previous modeling studies in the PVMGB/PVVGB area, WorleyParsons used a superposition modeling approach for impact assessment. Superposition or impact modeling is a robust numerical modeling approach which focuses on evaluation of drawdown as opposed to actual hydraulic head, and allows the modeler to incorporate boundary conditions, variable aquifer parameters, and diverse geological layer geometry. The use of superposition modeling in hydrogeologic literature is well established and this approach has been widely used to evaluate the impacts of water supply pumping.

The most recent groundwater modeling study completed in the area is a two-dimensional groundwater flow model developed by AECOM for the Blythe Solar Energy Project (AECOM, 2010). This model has a domain that includes both the PVMGB and PVVGB of the Palo Verde Valley, as well as the Colorado River. It is a single-layer MODFLOW 2000 model considers only the unconfined alluvial aquifer, including both the Older and Younger Alluvium as one hydrostratigraphic unit based on their hydraulic connection. The relationship of the Site to the domain of this model is shown in **Figure 3-1**. Based on the location of the Project in the southern PVMGB and the anticipated magnitude of groundwater withdrawals, it would be expected that potential effects from project groundwater withdrawals on the groundwater system will be limited to the PVMGB and PVVGB, mainly to the east, north, and south of the Site. The Mule and Palo Verde Mountains to the west form a natural no-flow hydrogeologic boundary that will prohibit propagation of effects to the west of the PVMGB, and therefore anticipated project effects should be limited to within the domain of the BSEP model. Consequently,

WorleyParsons used the existing BSEP model as a starting point for groundwater flow modeling for the Rio Mesa Project. There are several advantages to this approach:

1. The existing model has been vetted by the CEC who have accepted the use of this model and its results for the BSEP application (CEC, 2010);
2. The existing model domain is appropriate for evaluating the effects of the Rio Mesa Project;
3. The existing groundwater withdrawals for the Blythe Solar project can be readily included as well as the Rio Mesa Project withdrawals; and
4. The model is a simple, two-dimensional, calibrated, steady model that could be readily updated with Project information and reconfigured for the Project.

WorleyParsons' approach was to incorporate new geologic and hydrogeologic data collected for the Project into the existing BSEP model, updating the model layer data (hydrostratigraphy). The model was re-gridded to position a refined mesh in the vicinity of the RMS Project wells, while retaining the existing refined grid in the vicinity of the Blythe Solar Project wells. Additional new groundwater elevation data points were added to the calibration target data set in the revised model.

The objectives of the groundwater modeling impact assessment task were to evaluate the following specific potential impacts to groundwater resources resulting from the proposed solar power plant:

- Evaluation of potential project and cumulative effects of groundwater levels near the Site, to nearby groundwater users and relative to the proposed Colorado River Accounting Surface;
- Evaluation of the potential Project effects on basin-wide groundwater flow and balances;
- Evaluation of the potential effects of Project pumping on surface water resources; and
- Evaluation of the potential effects of Project pumping on flow paths that could affect water quality.

3.1.2 Modeling Software Selection

The BSEP PVMGB/PVVGB Groundwater Model was constructed using the MODFLOW2000 model (Harbaugh and others 2000) developed by the USGS, within the BOSS GMS modeling environment. The model files were obtained from CEC. The BSEP model was imported into the Groundwater Vistas® (Version 5.0) modeling environment for use in evaluating RMS groundwater impacts.

The numerical model described below was created for the RMS Project using Groundwater Vistas, a modeling environment that couples a model design system with comprehensive graphical analysis tools (Environmental Simulations, Inc., 2007). Within the Groundwater Vistas environment a two dimensional groundwater flow model was developed using MODFLOW and MODFLOW 2000.

MODFLOW, created by McDonald and Harbaugh (1988) for the USGS, is a block centered Finite difference code groundwater flow model. This versatile code views a three-dimensional system as a sequence of layers of porous material capable of simulating confined, leaky confined, unconfined and water table aquifers. The model is set up as a series of modules where a user can incorporate all attributes of a particular natural system independently, such as evapotranspiration, gaining and losing riverbeds, and recharge. There are many different methods of solution available. MODFLOW 2000 was used because it is one of the newest and most up-to-date versions of MODFLOW and is thoroughly documented (McDonald and Harbaugh, 1988 and Harbaugh et al., 2000).

3.1.3 Model Domain and Boundary Conditions

The RMS numerical groundwater model grid, boundary conditions and hydraulic parameters were based on the BSEP groundwater flow model, and modified according to the RMS conceptual model and groundwater budget, and updated using geologic and groundwater elevation data documented in the Existing Groundwater Conditions Assessment Report (WorleyParsons, 2011). The model domain corresponds to the combined the PVMGB and PVVGB, extending eastward up to and including the Colorado River, westward to the edge of the PVMGB defined by the truncation of alluvial sediments at the outcrop of bedrock in mountains and hills. Also on the western edge of the model domain is the boundary with the neighboring Chuckwalla Valley Basin. The northern and southern limits of the model domain were the boundaries with the Parker Valley and Cibola Valley basins, respectively. The model domain covers approximately 459.8 square miles and measures approximately 37.2 miles from north to south and 23.7 miles from east to west.

The model has a variable-spaced, block-centered, finite-difference grid. The grid is refined in the vicinity of the four BSEP pumping wells and three RMS pumping wells, as shown in **Figure 3-1**. Minimum refined grid spacing is 20 feet in the vicinity of the BSEP wells and 50 feet in the vicinity of the RMS wells. Grid spacing expands away from the pumping wells to a maximum grid size of 2,000 by 2,000 feet. The entire grid is 268 rows by 226 columns for a total of 48,288 cells in one layer. The model domain and revised discretization is shown on **Figure 3-1**.

The model as developed by BSEP consists of one layer that incorporates both the Older Alluvium and Younger Alluvium, which together form a single hydrostratigraphic unit as described by WorleyParsons (2011). Additional geologic data obtained for the RMS Project, particularly in the vicinity of the Project Site, was used to develop a refined structure for the base of alluvium, as shown in **Figure 3-2**. The thickness of combined alluvial deposits was estimated by subtracting ground surface elevation from the structural surface of the base of alluvium. Because of uncertainties in interpolation of these two surfaces in areas with sparse data, negative thickness values resulted in some locations, however a minimum thickness of 2 feet was applied to avoid this problem. The thickness of alluvium used in the model is shown in **Figure 3-3**. The base of alluvium structure grid and alluvium thickness grid were imported into the RMS model, replacing the corresponding surfaces in the original BSEP model.

Boundary conditions used in the RMS model were consistent with the groundwater budget in **Table 2-1**, and were the same as those in the BSEP model, with the exception of mountain front recharge. Because the model is a superposition (impact-only model) not all components of the groundwater budget are simulated explicitly, since the focus of the modeling is the magnitude of changes resulting from project pumping. The main boundary conditions in the model are summarized as follows:

- No Flow Boundary conditions, where the flux across a boundary is equal to zero, were used at all impermeable bedrock contacts around the perimeter of the basin.
- Subsurface inflows from the Parker Valley and Chuckwalla Valley are simulated using wells that introduce water to the appropriate boundary cells, shown in **Figure 3-1**.
- Mountain front recharge from precipitation was revised to reflect the groundwater balance developed in WorleyParsons (2011). In addition to the mountain front recharge cells in the northern part of the PVMGB that were used in the BSEP model, additional mountain front recharge cells were applied for the Mule Mountains and the Palo Verde Mountains in the southern part of the PVMGB. A uniform recharge rate was applied to all mountain front recharge cells in the model to achieve a total recharge rate of approximately 5,300 AFY as developed in the Groundwater Budget. Application of uniform mountain front recharge is consistent with the approach used in the BSEP model (AECOM, 2010).
- Deep percolation from agricultural irrigation is applied at a uniform recharge rate across the irrigated valley floor and mesa cells, as specified in the BSEP model.
- The Colorado River was modeled using river boundary cells, as shown in **Figure 3-1**. Transects provided by the United States Geological Survey (Wiele, et al., 2008) for select locations along the river reach through the Palo Verde Valley were used for river bottom elevation, and the river bottom elevation was linearly interpolated between these data points for all river cells along the eastern boundary of the model domain. The river boundary cells are a head-dependent boundary condition that allow water to enter or exit the river according to the head difference between the groundwater elevation and the river surface elevation, and in proportion to the hydraulic conductivity and thickness of the river bed layer, which is represented by a conductance term. The Colorado River conductance used in the RMS model was estimated by calibration of the BSEP model to be 1.15E5 ft^2/day. This value of conductance is approximately one-half the conductance value estimated by the USGS (Leake and others 2008), 2.3E5 ft^2/day.
- PVID drains were simulated by drain boundary cells, as shown in **Figure 3-1**. The bottom of the PVID drains were set at depth of 20 feet below ground surface and linearly interpolated from digital elevation data, as in the BSEP model. Drain boundary cells are also a head-dependent boundary condition; however, they only allow groundwater to exit the model, which occurs when the head in the adjacent model cell(s) is higher than the water elevation in the drain cell.

3.1.4 Hydraulic Parameters

The hydraulic conductivity distribution used in the RMS model started with the calibrated hydraulic conductivity distribution from the BSEP model and was then adjusted during recalibration of the RMS model. The calibrated hydraulic conductivity values range from a low of 1.0 ft/day in the northern portion of McCoy Wash in order to match very high water levels and steep gradient in that area. The hydraulic conductivity values for areas adjacent to and west of the river were the highest, along with portions of the BSEP site and areas along the valley mesa boundary. Lower estimates of hydraulic conductivity were modeled in the western-most areas of the valley and in the area of the gap between the Mule and McCoy Mountains on the west. An area of higher hydraulic conductivity is also indicated in the northernmost portion of the valley to accommodate the westerly directed flow of groundwater from Parker Valley as it appears to wrap around the bedrock knob into the Palo Verde Valley. The final calibrated hydraulic conductivity distribution for the RMS model is shown in **Figure 3-4.**

The storage coefficient in the alluvial aquifer was assigned a uniform value of 0.20, which is consistent with the unconfined conditions, and in agreement with the value used in the USGS model of the basin (Leake and others 2008) and the BSEP model (AECOM, 2010).

3.1.5 Model Calibration

The original BSEP model, used as the starting point for RMS modeling, was calibrated to steady state conditions for average groundwater elevations over the period of 1980 to 2009. After modifications were made to the BSEP model by WorleyParsons, as described previously, the model calibration was re-visited and recalibration was conducted by the trial and error method, adjusting hydraulic conductivity in selected areas to reduce residuals and improve calibration statistics. The dataset of wells and groundwater elevations used for the *Assessment of Existing Groundwater Conditions Report* (WorleyParsons 2011) were brought into the model as calibration targets. A total of 127 wells were used for calibration targets. The calibration target data set is listed in **Appendix 1**.

Calibration statistics for the final calibrated model are provided below. Typically used calibration goals are summarized as follows:

- Residual standard deviation divided by range in less than 10 percent;
- Absolute residual mean divided by range in less than 10 percent;
- Residual mean divided by range in target heads less than 5 percent; and
- Limited spatial bias in the distribution of residuals.

Table 3-1. Calibration Statistics, Final Calibrated RMS Model

Residual Mean	Residual Standard Deviation	Absolute Residual Mean	RMS Error	Minimum Residual	Maximum Residual	Range in Target Heads	Residual Standard Deviation/Range (<10%)	Absolute Residual Mean/Range (<10%)	Residual Mean/Range (<5%)
-0.88	3.53	2.98	3.64	-9.74	5.91	55.91	6.3%	5.3%	-1.6%

The calibration statistics in **Table 3-1** show that the calibrated model meets all of the calibration goals. **Figure 3-5** is a plot of modeled versus observed hydraulic heads, which shows good agreement between modeled and target groundwater elevations, and no appreciable bias in the modeled heads. It is important to note that no model calibration is unique, especially in a steady state model, and that other combination of parameters could also provide reasonable model calibration.

Figure 3-6 shows the groundwater elevation contours of observed (target) data and the modeled groundwater elevation contours, for comparison. Qualitatively, the groundwater elevation contours for the two data sets are similar. Both maps show the generally southward groundwater flow direction in the PVVGB, and in the southern part of the PVMGB. The main differences in the two contour maps are in the western part of the PVMGB. The modeled groundwater elevation show more prominent southeastward component of groundwater flow, reflecting mountain front recharge from the Big and Little Maria Mountains, and inter-basin underflow from the Chuckwalla Valley. The observed groundwater elevation map does not show this southeastward component of groundwater flow in this area, however field data in this portion of the PVMGB are extremely sparse. Both the observed and modeled groundwater elevation contour maps show the series of groundwater drainage divides and groundwater discharge boundaries (base of drainage divides) in the southern PVMGB discussed earlier that result from deep percolation of irrigation water and return flows in drains in the irrigated portions of the Palo Verde Valley between the Colorado River and Palo Verde Mesa.

3.1.6 Transient Model Set-up: BSEP and RMS Pumping

Once the steady state model was calibrated, a transient version of the model was developed to include BSEP pumping and RMS pumping, thereby considering the cumulative effects of both projects. The transient model used the 33 one-year stress periods from the BSEP model. The first stress period (year 1, 2011) was a non-pumping stress period and represented steady state conditions as the baseline for comparison of drawdown and changes in flows due to pumping. Initially only BSEP pumping was simulated to establish a baseline for evaluating effects of RMS pumping. The BSEP pumping schedule during construction and operations with four wells was the same as modeled by AECOM (2010), and is summarized in the **Table 3-2** below.

The pumping schedule for RMS pumping was taken from information provided by BrightSource Energy (2011) and simplified somewhat to match the model stress periods. RMS construction is planned to start in Q4 2013 and be completed by Q2 2016. In the transient model, construction pumping at 400

AFY is implemented 2014, 2015 and 2016 (3 years). The operational period of the Project is phased in over two years, with one unit starting in Q4 2015, a second in Q1 2016, third Q2 2016. In the transient model, operational pumping at 260 AFY is implemented from 2016 to 2041 (25 years). Three production wells are proposed to be located in the common area of the RMS Site. Tentative locations are shown in **Figure 3-7**. The final location of these wells remains to be determined. Each well will be designed to operate at 50 percent of the of the operational water demand on a rotating basis. In the model, pumping was simulated as continuously pumping at one-third the total demand (i.e., 133.3 AFY during construction, and 86.7 AFY during operations). However, hydraulically, the net result on drawdown will be the same due to the principle of superposition and the long term averaging of drawdown. Additional potable water supply wells may also be constructed in the common area. Because these wells will pump water at a combined rate of only 5 AFY (less than 2 percent of the total groundwater demand), their water demand was modeled using the primary production wells for the project.

The transient modeling was conducted in two stages. In the first stage, only BSEP pumping was simulated. Then RMS pumping was added to the model in a separate transient run. The pumping schedule simulated in the transient model is given below:

Table 3-2. Transient Model Set-up

Stress Period	Year	BSE, 4 Wells Pumping AFY	RMS, 3 Wells Pumping AFY
1	2011	0	0
2	2012	820	0
3	2013	820	0
4	2014	970	400
5	2015	1120	400
6	2016	1270	400
7	2017	600	260
8	2018	600	260
9	2019	600	260
10	2020	600	260
11	2021	600	260
12	2022	600	260
13	2023	600	260
14	2024	600	260
15	2025	600	260
16	2026	600	260
17	2027	600	260
18	2028	600	260
19	2029	600	260
20	2030	600	260
21	2031	600	260
22	2032	600	260
23	2033	600	260
24	2034	600	260
25	2035	600	260
26	2036	600	260
27	2037	600	260
28	2038	600	260
29	2039	600	260
30	2040	600	260
31	2041	600	260
32	2042	600	0
33	2043	600	0

In the second transient model run that simulated both for BSEP plus RMS pumping, four virtual monitoring wells were simulated (monitoring wells MW-1, MW-2, MW-3 and MW-4) and used to produce synthetic hydrographs of predicted groundwater level response in key locations. MW-1, MW-2 and MW-3 are located in the 50-foot grid cell immediately east of each of the three RMS pumping wells, as shown in **Figure 3-7**. MW-4 is located in the northeastern-most corner of the RMS Site near the common area, approximately at the edge of the Palo Verde Mesa, to show drawdown response over time adjacent to the Palo Verde Valley.

3.1.7 MODPATH Particle Tracking Simulation

The USGS particle tracking program MODPATH Version 3.2 (Pollock, 1994) was used for forward particle tracking in order to help identify the origin and flow path of groundwater in the southern part of the model domain. The MODPATH simulation started with the hydraulic head distributions for each of the 33 transient stress periods from the final transient simulation of both BSEP and RMS pumping. For the particle tracking simulation, one particle was placed in the center of each model cell in the southern portion of the model domain, approximately south of Interstate 10. Each particle was tracked forward in time over the 33 years of model simulation. Over the course of the simulation, most particles are captured by boundary condition cells such as drain cells or wells. By following the trace of each particle's flowpath, one can identify where each particle originated in the model domain, and its final disposition if captured by a boundary cell, at which point it exits from the model and is no longer tracked. The particle traces also outline the groundwater flow paths in the model domain, and help to illustrate groundwater flow lines, divides between local groundwater flow systems and groundwater captured by pumping wells, such as those for the project.

3.2 Groundwater Modeling Results

As noted above, RMS pumping in the transient model continues until 2041, which represents 28 years of RMS pumping (3 years construction plus 25 years operations), and corresponds to 31 years of simulation time and also 31 stress periods. Consequently, transient modeling results are discussed at the end of Year 31 in the transient model, that is, the end of RMS pumping, even though the simulation continues to the end of year 33, which includes all of the BSEP pumping.

3.2.1 Drawdown Due to RMS Pumping

Contours of drawdown in response to RMS pumping after 31 years of simulation time (end of RMS pumping) are shown in **Figure 3-8**. **Figure 3-8** shows that drawdown from RMS pumping (mapped to 0.2 feet of drawdown) is mainly limited to the Mesa Basin but does extend in to the Palo Verde Valley approximately ½ mile. Drawdown greater than 0.5 feet is limited to the Palo Verde Mesa. Maximum drawdown near the RMS pumping wells is 1.3 feet at the end of pumping. Because this drawdown is relatively small, modeling of other pumping scenarios using additional on-Site wells during construction was deemed to be unwarranted.

Drawdown impacts form BSEP pumping are shown in AECOM 2010 and are not predicted to extend to the RMS Site. This was also observed during the current modeling study.

3.2.2 Groundwater Level Response to RMS Pumping Over Time

Hydrographs for the four simulated monitoring wells (MW-1 to MW-4), showing groundwater level response over time, are given in **Figures 3-9.** Simulated static water levels in the three monitoring well

locations are 225.5 ft AMSL (MW1, westernmost), 225.4 ft AMSL (MW2, middle) and 225.3 ft AMSL (MW3, easternmost). During construction pumping, maximum drawdown ranges from 2.8 to 3.1 feet. Once construction pumping is competed and operational pumping begins, the groundwater level recovers by 0.7 to 0.8 feet, then begins a gradual decline over time due to operational pumping. The proposed Accounting Surface at the RMS wells is approximately 225.2 feet (ft) AMSL, based on USGS mapping (WorleyParsons, 2011). Therefore, less than 1 foot of freeboard above the proposed Accounting Surface is inferred near the proposed RMS production well locations under non-pumping conditions, and water levels are shown to fall below the Accounting Surface during pumping.

3.2.3 Particle Tacking Results

The particle tracking simulation results after 31 years of particle transport are shown in **Figure 3-10**. The particle traces for particles that are captured by the RMS wells, representing the capture zone of the RMS wells, are shown in blue. The largest portion of the capture zone is to the west of the wells, toward the basin boundary with the Mule Mountains. A mass balance on this portion of the model domain indicates that 109 AFY is derived from this portion of the capture zone, suggesting that the remaining 151 AFY of the total 260 AFY pumped is derived from the relatively small portion of the capture zone to east and southeast of the pumping wells.

The particle traces shown in **Figure 3-10** also highlight the local groundwater flow systems in this portion of the Palo Verde Mesa and Valley Groundwater Basins. Particle traces can be seen to converge on the PVID drains, which act as local discharge boundaries (base of drainage boundaries). Similarly, particle traces diverge in the area between drains, representing drainage divides at the recharge end of the local groundwater flow systems. These divides represent deep percolation of irrigation water that recharges the local groundwater flow system and creates the groundwater mounds that develops between drains. The analysis highlights the existence of prominent mounds between the drains in the irrigated areas of Palo Verde Valley.

In this context of local-scale groundwater flow systems controlled by discharge at drains and irrigation recharge between drains, **Figure 3-10** shows that the alluvial aquifer groundwater in the vicinity of the RMS site that is not captured by the RMS wells is captured by the westernmost PVID drain. Moreover, even after 28 years of RMS pumping, no groundwater from the PVID drain or areas further to the east is intercepted by the RMS wells. This suggests that all groundwater pumped by the RMS will be tributary groundwater to the Palo Verde Mesa Basin, with no contribution from the Palo Verde Valley Basin or the Colorado River.

3.2.4 Effects on Surface Water

Based on analysis of the mass balance for each type of boundary cell in MODFLOW, pumping at the Site will not affect surface water flows in the Colorado River. The modeled steady state flow rate to

PVID drains under non-pumping or baseline conditions is predicted to decrease by 0.07 % after 31 years. A change of this magnitude would not be measureable or observable.

3.3 Sensitivity Analysis

A sensitivity analysis was conducted for key model parameters to assess uncertainty in the calibrated model and in model predictions caused by uncertainty in the model parameters. As previously investigated by AECOM (2010) in the development of the original BSEP model, the key model parameters to evaluate are hydraulic conductivity distribution and drain conductance. Consequently, sensitivity analysis was conducted for the following cases:

- Hydraulic conductivity 2 times the bases case values;
- Hydraulic conductivity one-half the bases case values;
- Drain conductance 2 times base case values; and
- Drain conductance one-half the bases case values.

The results of the sensitivity analysis showing the variation in flows to drain and river boundaries are given in **Table 3-3** (annual flow rates) and **Table 3-4** (cumulative flows after 31 years). The results show that doubling hydraulic conductivity produces an 18 % increase in groundwater discharge flows to the drain cells, and a 43% decrease in groundwater discharge flows to the river cells (both annual flow rates and cumulative flows). Conversely, one-half the base case hydraulic conductivity yields a 13% reduction in drain cell flows and a 52% increase in river cell flows (both annual flow rates and cumulative flows). Consequently, the base case model results for drain flows are likely within about plus or minus 20%, and river flows within about plus or minus 50%, given the potential uncertainty in hydraulic conductivity.

The sensitivity analysis results for drain conductance show that doubling the drain conductance increases drain cell flows by 16% cells and decreases in river cell flows by 5% (both annual flow rates and cumulative flows). Decreasing drain conductance by one-half results in a 16% decrease in drain cell flows and a 23% increase in river cell flows. Consequently, the base case model results for drain flows are likely within about plus or minus 16%, and river flows within about plus or minus 5 to 20%, given the potential uncertainty in drain conductance.

4. CONCLUSIONS

4.1 Extent and Distribution of Drawdown Affects

Figure 3-8 shows that drawdown from RMS pumping will be limited to the Mesa Basin to areas very close to the Site. Contoured drawdown extends into the Palo Verde Valley approximately ½ mile; however, drawdown greater than 0.5 feet is limited to the Palo Verde Mesa. Maximum drawdown near the RMS pumping wells is 1.3 feet at the end of pumping. The maximum observed drawdown will occur during construction pumping and is predicted to be approximately 3 feet near the pumping wells. Because this drawdown is relatively small, modeling additional scenarios with additional on site pumping wells during construction is not deemed to be necessary in order to evaluate Project impacts.

Drawdown impacts form BSEP pumping are shown in AECOM 2010 and are not predicted to extend to the RMS Site. This was also observed during the current modeling study. This is because groundwater levels in the area are dominated by recharge from deep percolation of irrigation water. Therefore, cumulative drawdown effects are not anticipated.

4.2 Well Interference Impacts

Drawdown imposed by a well on another nearby pumping well can have adverse affects on the performance of that well and is referred to as interference drawdown or well interference. These effects can include a well going dry, the need to lower pump intakes, well damage or increased electrical or maintenance costs. **Figure 3-8** does not indicate the presence of any existing wells within the contoured drawdown cone associated with RMS pumping. Drawdown at the closest nearby wells is predicted to be less than 0.2 feet. This is within the range of naturally occurring background fluctuations. Based on the relatively small amount of drawdown predicted, Project pumping will not cause any nearby wells to go dry, be damaged, or require pumps to be lowered. For Blythe Energy Project I and Blythe Energy Project II which are located north of the Site in the same basin, CEC adopted a threshold of significance of 5 feet for all well interference impacts, including increased electrical and maintenance costs (CEC, 2005). We believe this threshold is appropriate for the Project, and therefore conclude that well interference impacts will be less than significant.

4.3 Water Budget Changes

Model mass balance analysis indicates that 109 AFY of the pumped groundwater is derived from area between the Site and the Mule Mountains and the remaining 151 AFY is derived from the relatively small portion of the capture zone to east and southeast of the pumping wells. Pumping at the Site will not affect surface water flows in the Colorado River. The modeled steady state flow rate to PVID

drains under non-pumping or baseline conditions is predicted to decrease by 0.07 % after 31 years. A change of this magnitude would not be measureable or observable. Because the groundwater flow system is dominated by deep percolation of irrigation water and discharge of shallow groundwater in the PVID drains, further changes to the basin water budget are not anticipated.

4.4 Water Quality Impacts

The particle tracking analysis indicates that water pumped from the well originates from a capture zone that extends west to the Mule Mountains as well as a short distance to the east. Water quality data obtained from NWIS (2011) indicate that water quality may be expected to improve to the east of the Site in the Palo Verde Valley. No data are available that would indicate groundwater quality varies between the Site and the Mule Mountains. We therefore conclude it is unlikely that groundwater pumping for the Project will adversely affect water quality. .

4.5 Impacts to Surface Water

Particle tracking analysis indicates the project wells will not capture or withdraw surface water from the PVID drains or Colorado River, and that the water captured by the wells is tributary water. Mass balance analysis of the model results indicates Project pumping will not affect Colorado River flows. The modeled steady state flow rate to PVID drains under non-pumping or baseline conditions is predicted to decrease by 0.07 % after 31 years. A change of this magnitude would not be measureable or observable, and therefore would not constitute an adverse or significant impact.

4.6 Impacts to Springs, Seeps, Vegetation

There are no known springs or seeps near the Site. The depth to groundwater at the Site is over 100 feet and it may generally be expected that vegetation (including phreatophytes) at the Site is not dependant on groundwater from the alluvial aquifer. In addition, the predicted drawdown related to Project pumping is relatively small compared to the natural seasonal and long term changes in groundwater level. We therefore conclude that impacts to springs, seeps and vegetation will be less than significant.

4.7 Impacts During Dry and Critically Dry Years

SB 610 makes changes to the Urban Water Management Planning Act to require additional information in Urban Water Management Plans if groundwater is identified as a source available to the supplier. The information required includes a copy of any groundwater management plan adopted by the supplier, a copy of the adjudication order or decree for adjudicated basins, and if non-adjudicated, whether the basin has been identified as being overdrafted or projected to be overdrafted in the most current California Department of Water Resources (DWR) publication on that basin. If the basin is in

overdraft, that plan must include current efforts to eliminate any long-term overdraft. A key provision in SB 610 requires that any project subject to the California Environmental Quality Act supplied with water from a public water system be provided a specified water supply assessment, except as specified in the law. Included in the assessment is an evaluation of impacts resulting from use of groundwater in dry and critically dry years (defined as three drought years in succession). Although not directly applicable to this Project, evaluation of dry year response is helpful in describing potential project impacts.

In terms of baseline water level trends, comparison of hydrographs for wells in the basin to precipitation records does not indicate distinct trends indicative of climatic influence during dry or critically dry years (WorleyParsons, 2011). This may be due to the fact that groundwater levels in the PVMGB are strongly influenced by irrigation with surface water and groundwater pumping in the area generally does not increase during dry years. Therefore, groundwater budget deficits are not anticipated during dry and critically dry years. We therefore conclude the cumulative water level impacts during critically dry and critically dry years will be less than significant.

4.8 Subsidence

Ground subsidence can occur as a result of water level decline in aquifer systems. When the fluid pressure in an aquifer is reduced as a result of changes in the groundwater level, a shift in the balance of support for the overlying materials causes the “skeleton” of the aquifer system to deform slightly. Reversible deformation occurs in all aquifer systems as a result of the cyclical rise and fall of groundwater levels associated with short and longer term climatic cycles. Permanent ground subsidence can occur when pore water pressures in the aquifer fall below their lowest historical point, and the particles in the aquifer skeleton are permanently rearranged and compressed. Soils particularly susceptible to such consolidation and subsidence include compressible clays in overdrafted confined aquifer systems that have experienced significant drawdown on the order of tens or hundreds of feet. Based on the small amount of drawdown predicted to result from groundwater pumping for the project, significant subsidence is not anticipated.

5. REFERENCES

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TABLES

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Table 2-1

Groundwater Budget for the Palo Verde Mesa and Valley Basins
Palo Verde Mesa Groundwater Basin

RECHARGE (INFLOW)	**acre-feet per year**
UNDERFLOW from the CHUCKWALLA BASIN	1,000
UNDERFLOW from PARKER VALLEY	1,200
AGRICULTURE RETURN - MESA	3,800
AGRICULTURE RETURN - VALLEY	57,000
POTW RETURN	750
MOUNTAIN FRONT	5,300
IRRIGATION CANAL LEAKAGE	125,000
RIVER DISCHARGE TO GROUNDWATER (LOSING CONDITION)	230,550
BEDROCK	0
TOTAL (INFLOW)	**424,600**
DISCHARGE (OUTFLOW)	**acre-feet per year**
UNDERFLOW OUT of the PALO VERDE and CIBOLA VALLEY	0
GROUNDWATER PUMPING AGRICULTURE - MESA	1,000
GROUNDWATER PUMPING MUNICIPAL and DOMESTIC	8,100
GROUNDWATER DISCHARGE TO COLORADO RIVER (GAINING	50,000
CONSUMPTIVE USE - NATIVE VEGETATION	8,500
GROUNDWATER DISCHARGE THROUGH PVID DRAINS	357,000
TOTAL (OUTFLOW)	**424,600**
WATER BALANCE	**0**

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TABLE 3-3. SENSITIVITY ANALYSIS RESULTS, ANNUAL FLOW RATES

(A) Hydraulic Conductivity (K)

Case	Flow Rate, AFY Model Year 31 Drains	River	NOTES	
Base Case K	308,997	2,919	BSE + RMS	Well Pumping
2 x Base K	364,434	1,657	BSE + RMS	Well Pumping
1/2 Base K	262,234	5,447	BSE + RMS	Well Pumping

(B) Drain Conductance

Case	Flow Rate, AFY Model Year 31 Drains	River	NOTES	
Base Case Conductance	308,997	2,919	BSE + RMS	Well Pumping
2x Base Conductance	359,453	2,760	BSE + RMS	Well Pumping
1/2 Base Conductance	252,804	3,541	BSE + RMS	Well Pumping

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TABLE 3-4. SENSITIVITY ANALYSIS RESULTS, CUMULATIVE FLOW RATES

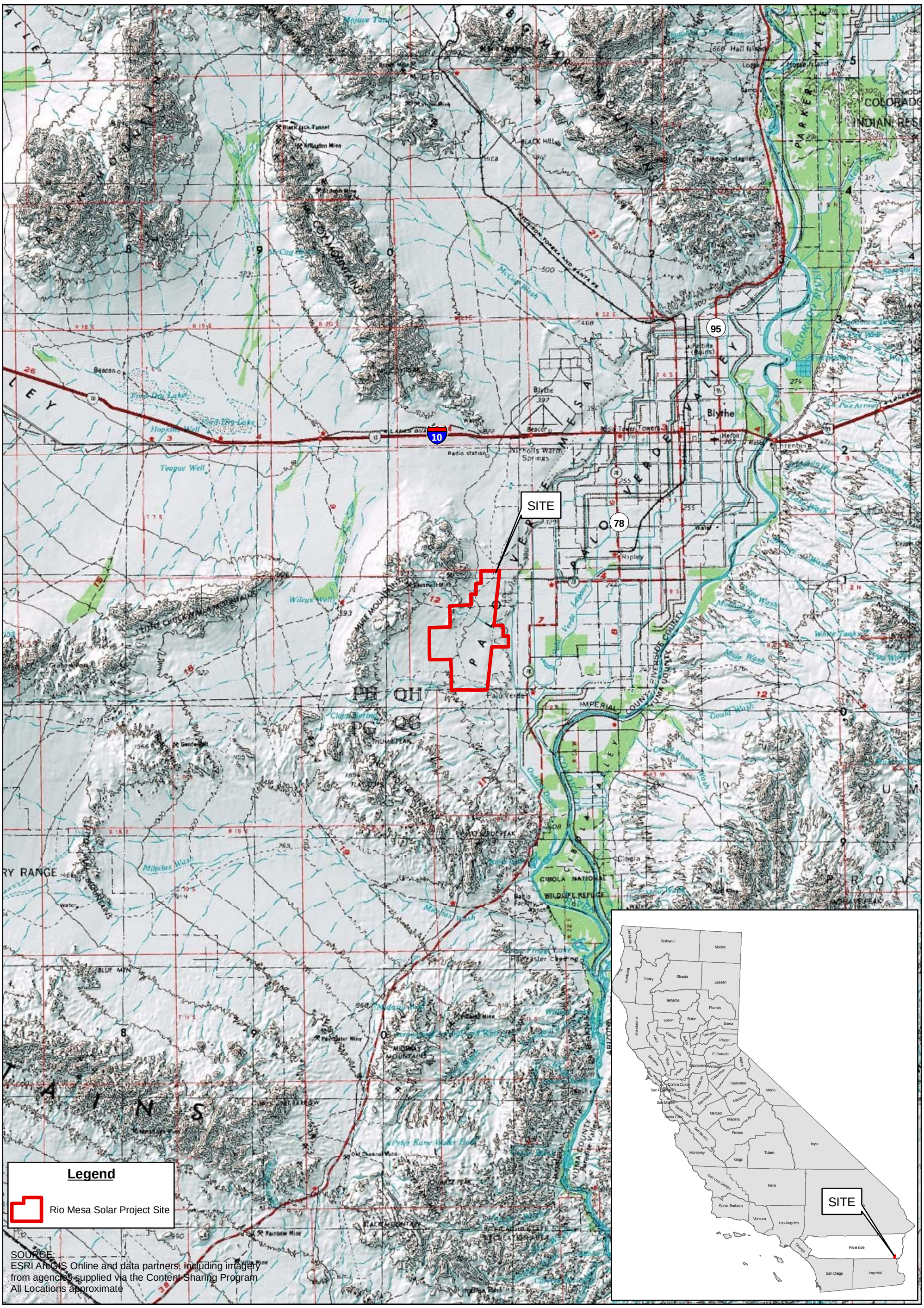
(A) Hydraulic Conductivity (K)

Case	Cumulative Flow, AF Model Year 31 Drains	River	NOTES	
Base Case K	9.5829E+06	9.0480E+04	BSE + RMS	Well Pumping
2 x Base K	1.1302E+07	5.1375E+04	BSE + RMS	Well Pumping
1/2 Base K	8.1327E+06	1.6885E+05	BSE + RMS	Well Pumping

(B) Drain Conductance

Case	Flow Rate, AFY Model Year 31 Drains	River	NOTES	
Base Case Conductance	9.5829E+06	9.0480E+04	BSE + RMS	Well Pumping
2x Base Conductance	1.1147E+07	8.5548E+04	BSE + RMS	Well Pumping
1/2 Base Conductance	7.8408E+06	1.0979E+05	BSE + RMS	Well Pumping

FIGURES



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RIO MESA SOLAR
POWER PROJECT

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RIO MESA SOLAR
PROJECT LOCATION

SWL	MT	9/2011
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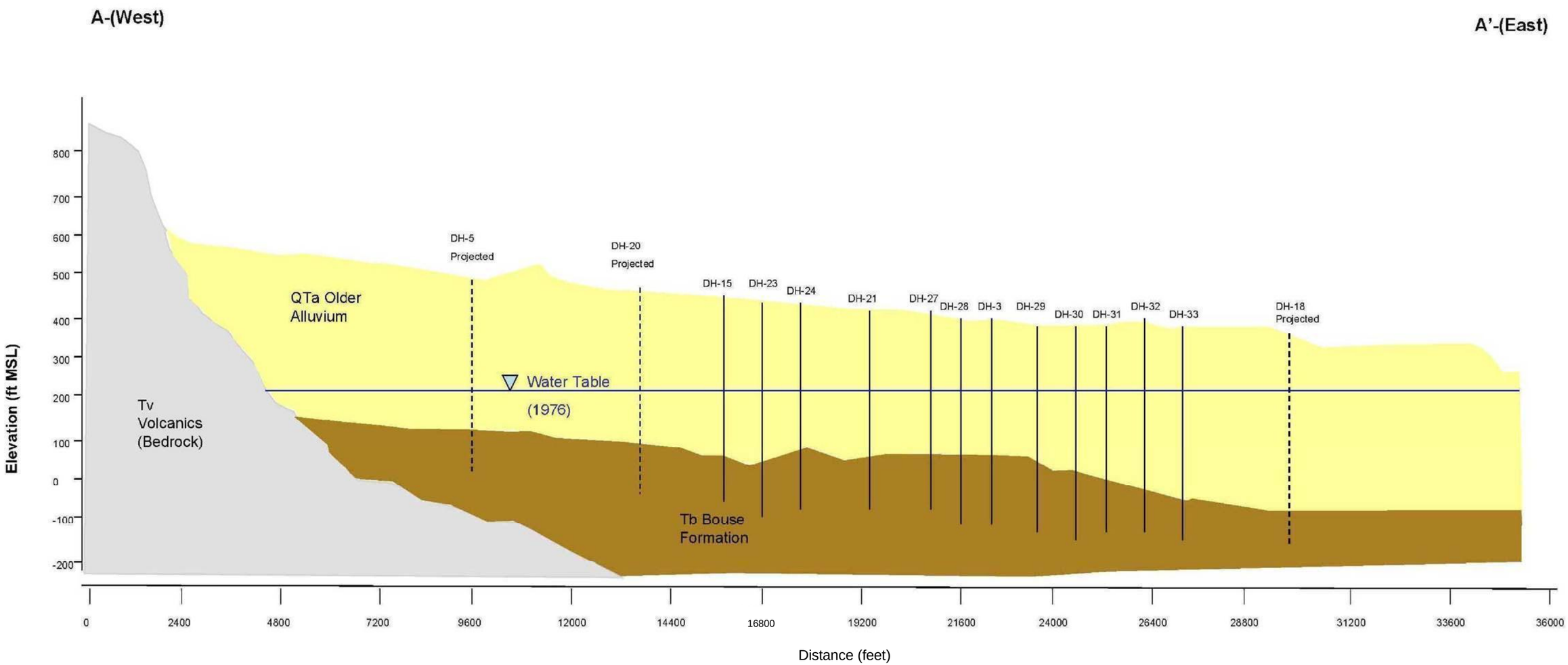

Vertical Exaggeration 10x

Modified from Stone and Webster, 1976

RIO MESA SOLAR
POWER PROJECT

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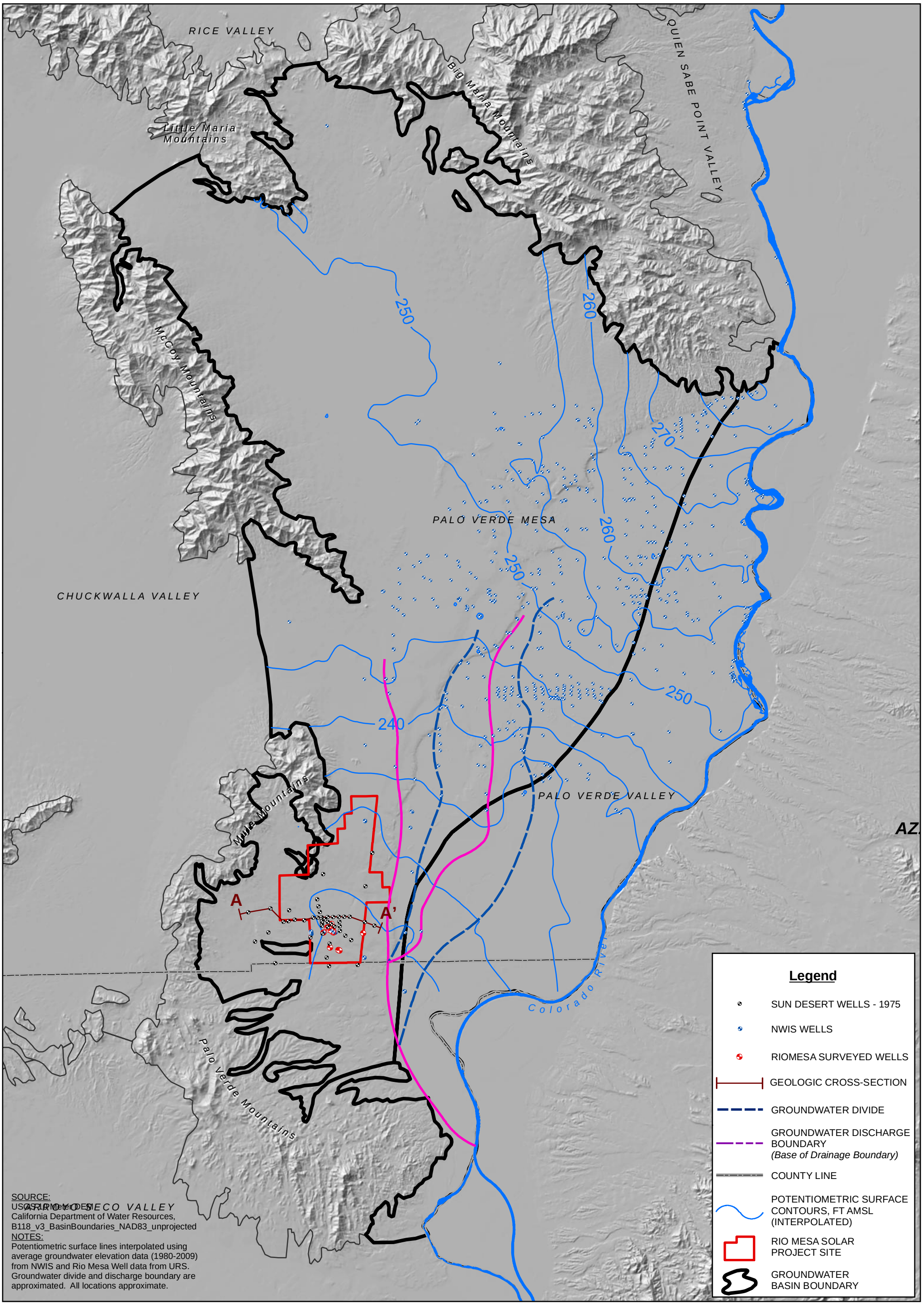
SIMPLIFIED GEOLOGIC CROSS-SECTION A - A', RMS SITE

SWL	MT	9/2011
308038-03598		**2-1**



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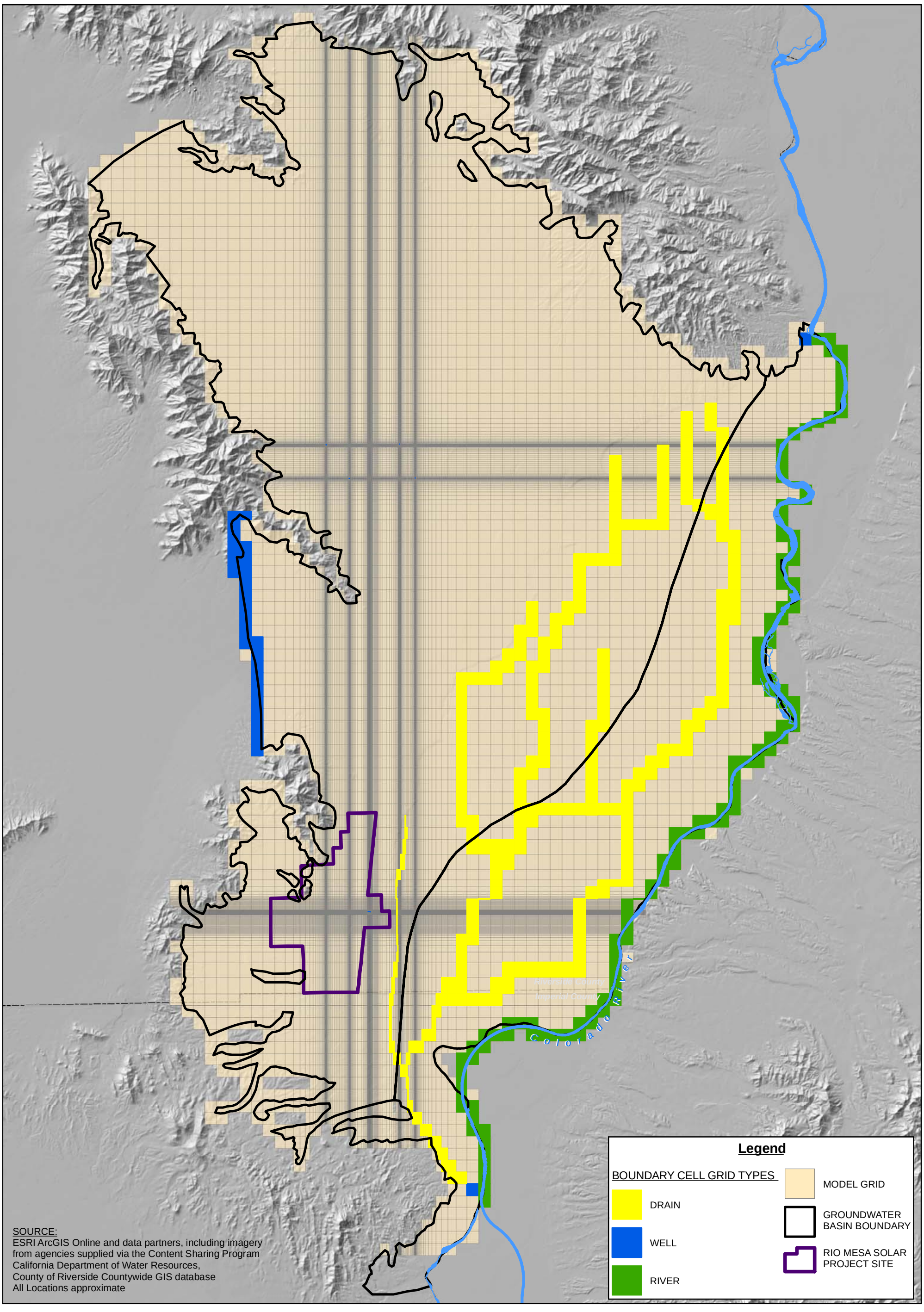
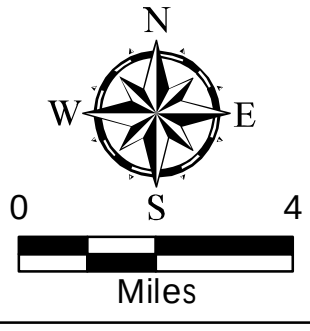
SWL	MT	9/2011
308038-03598	2-2	

GROUNDWATER ELEVATION CONTOUR MAP
PALO VERDE MESA AND VALLEY GROUNDWATER BASINS



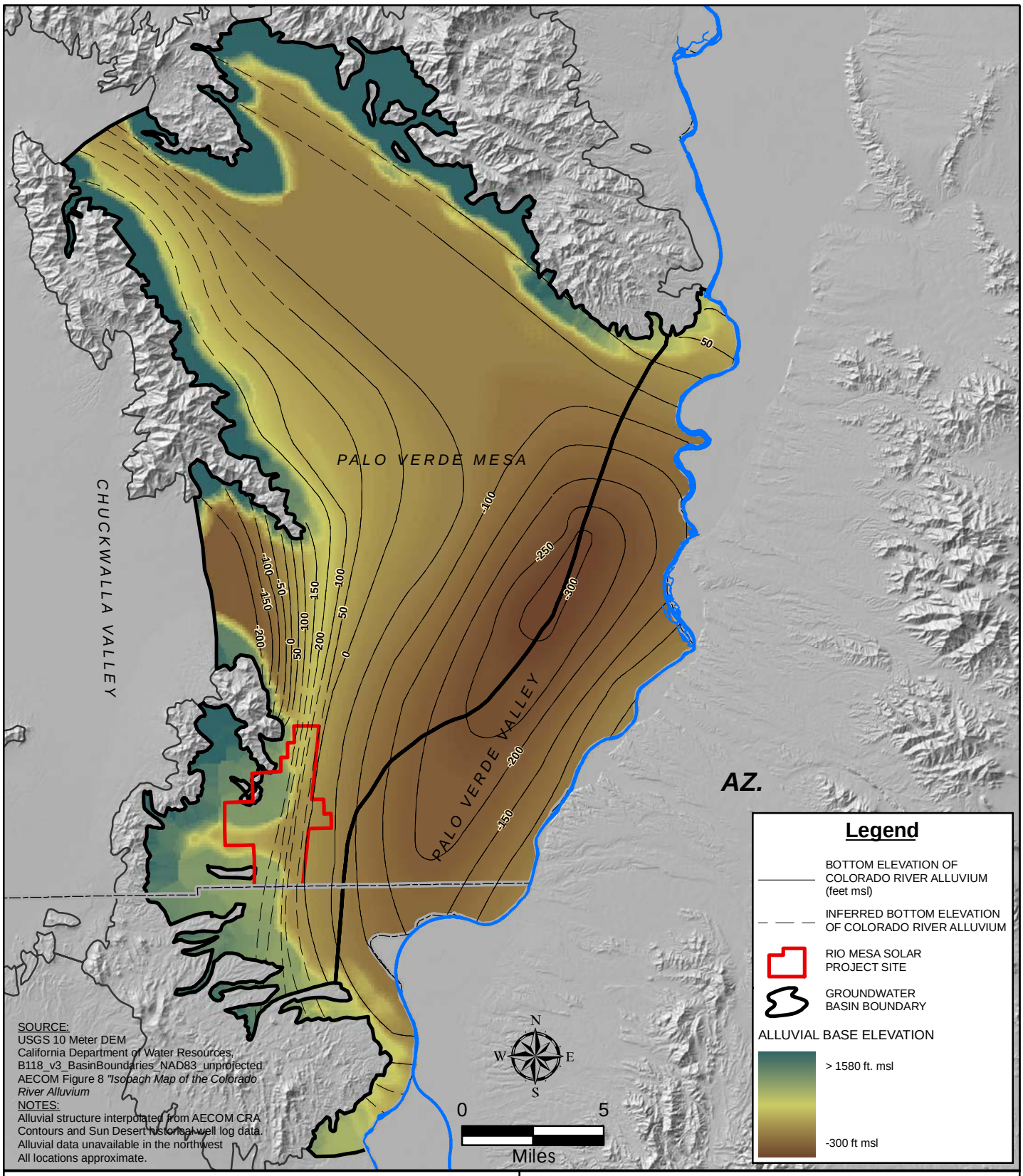


RIO MESA SOLAR
POWER PROJECT

WorleyParsons
resources & energy

RIO MESA SOLAR PROJECT MODEL DOMAIN, MODEL GRID AND BOUNDARY CONDITIONS

SWL	MT	9/2011
308038-03598		**3-1**



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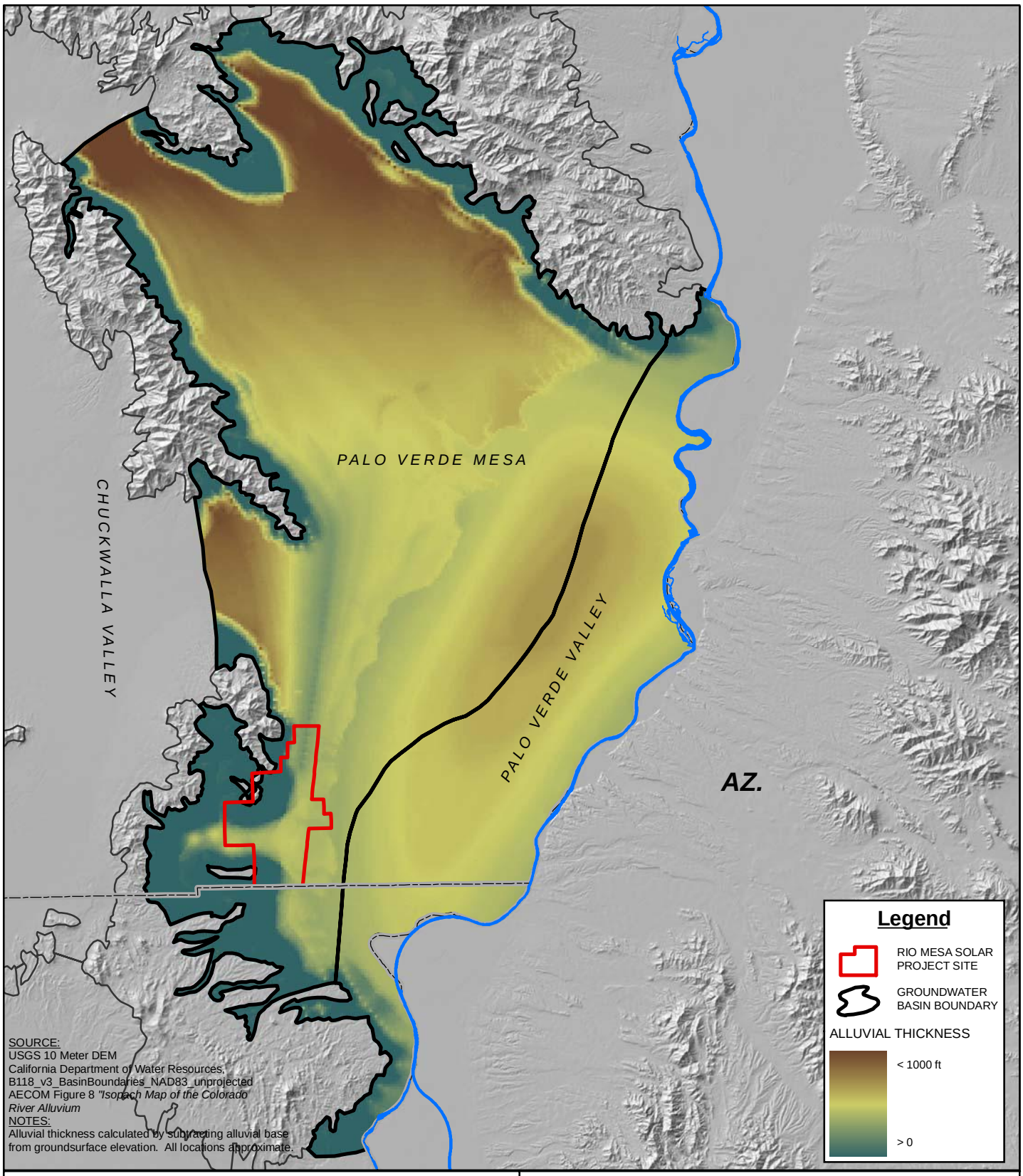
STRUCTURE CONTOUR MAP OF THE
BASE OF ALLUVIAL DEPOSITS

SWL	MT	9/2011
308038-03598		3-2



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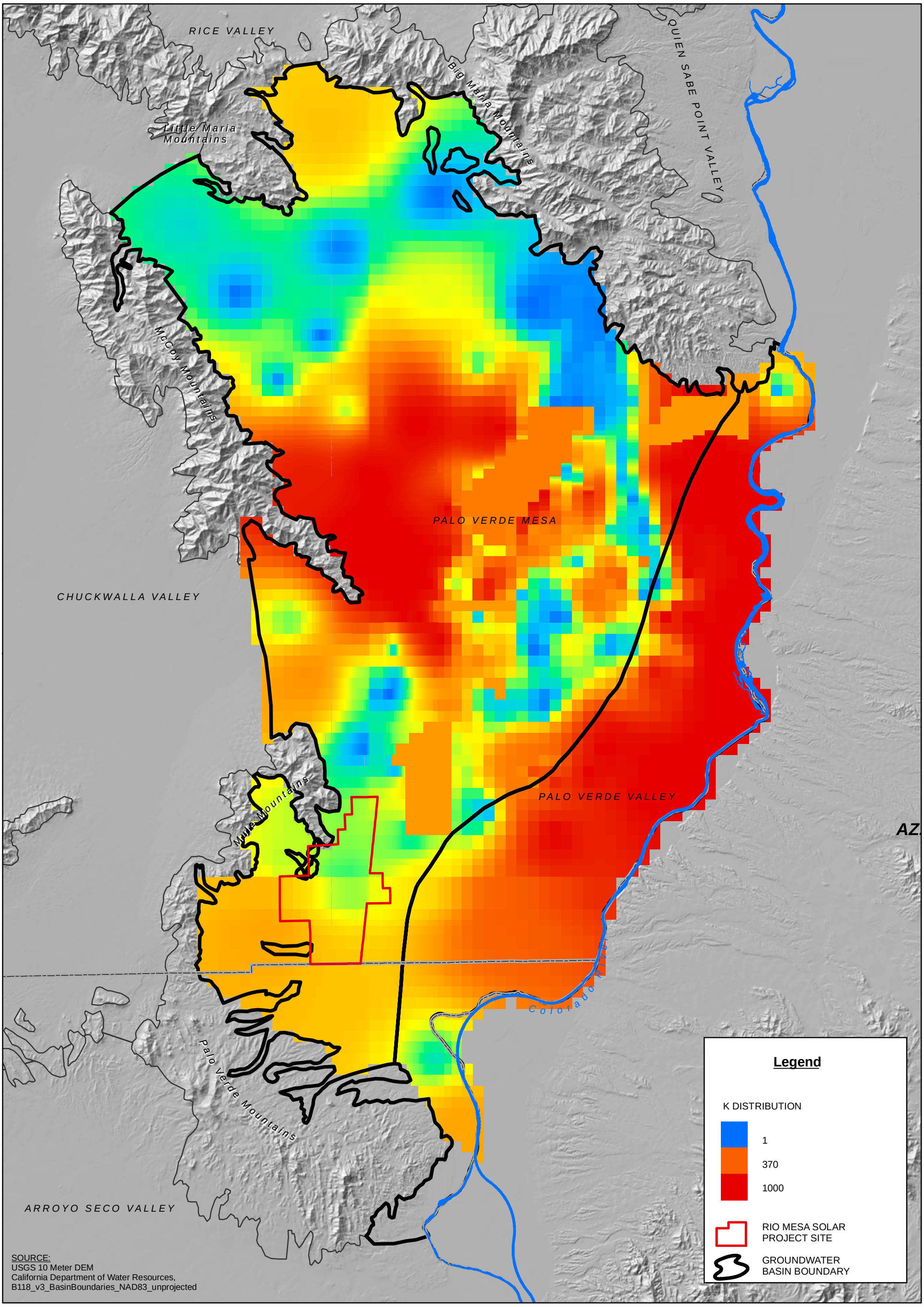
ISOPACH MAP THICKNESS
OF ALLUVIAL DEPOSITS

SWL	MT	9/2011
308038-03598	3-3	



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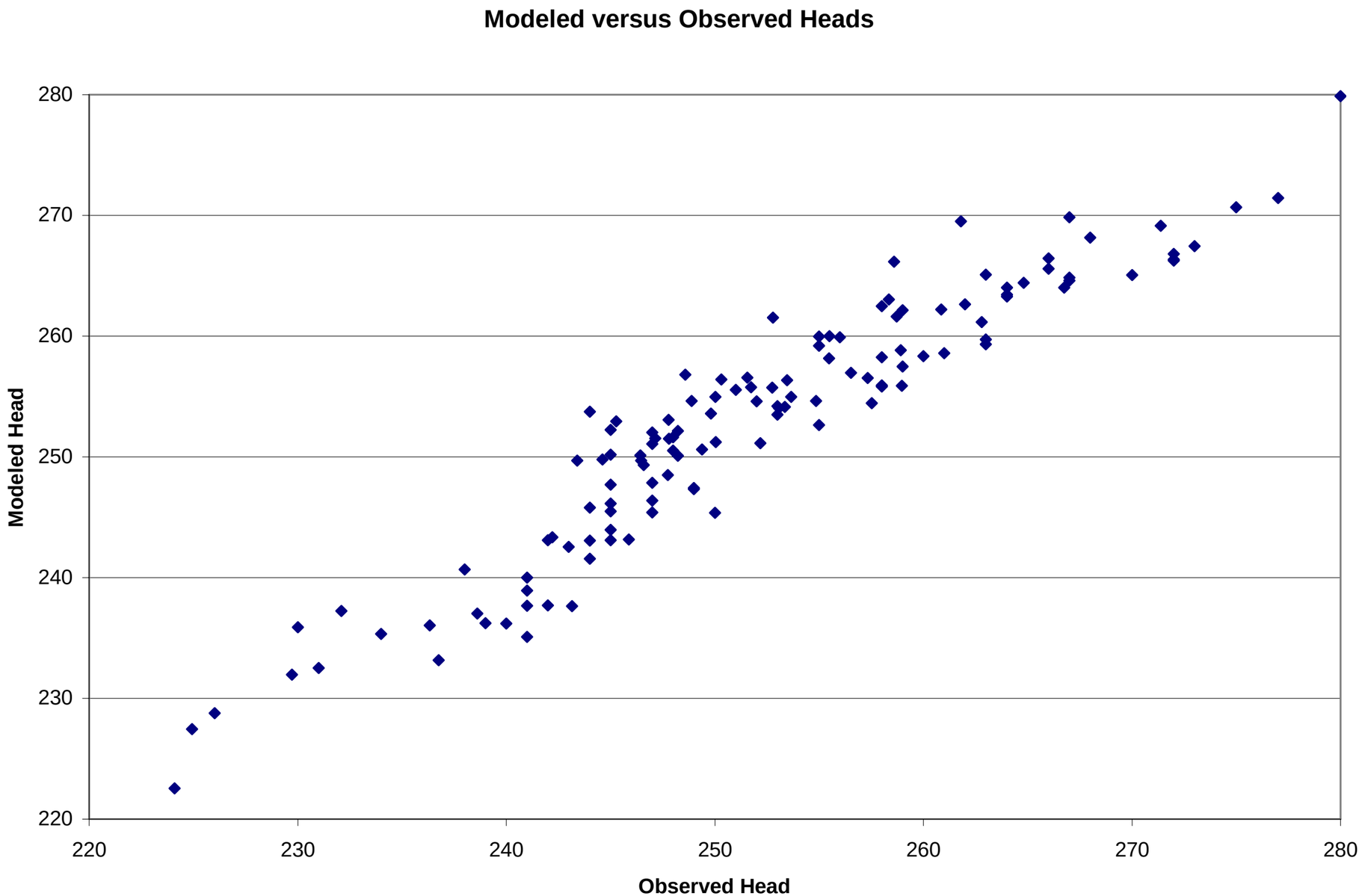
HYDRAULIC CONDUCTIVITY DISTRIBUTION, CALIBRATED MODEL

SWL	MT	9/2011
308038-03598		**3-4**



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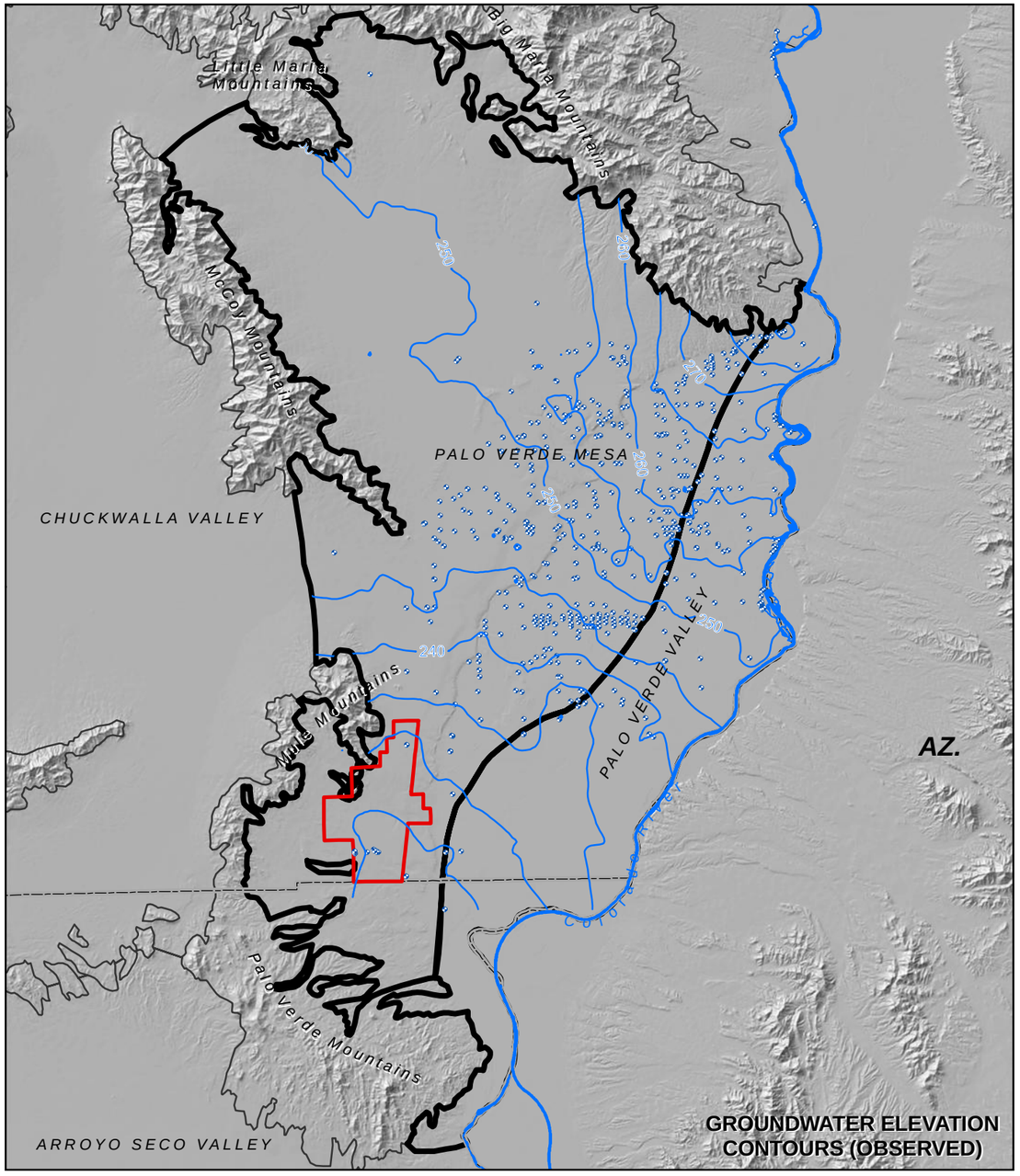
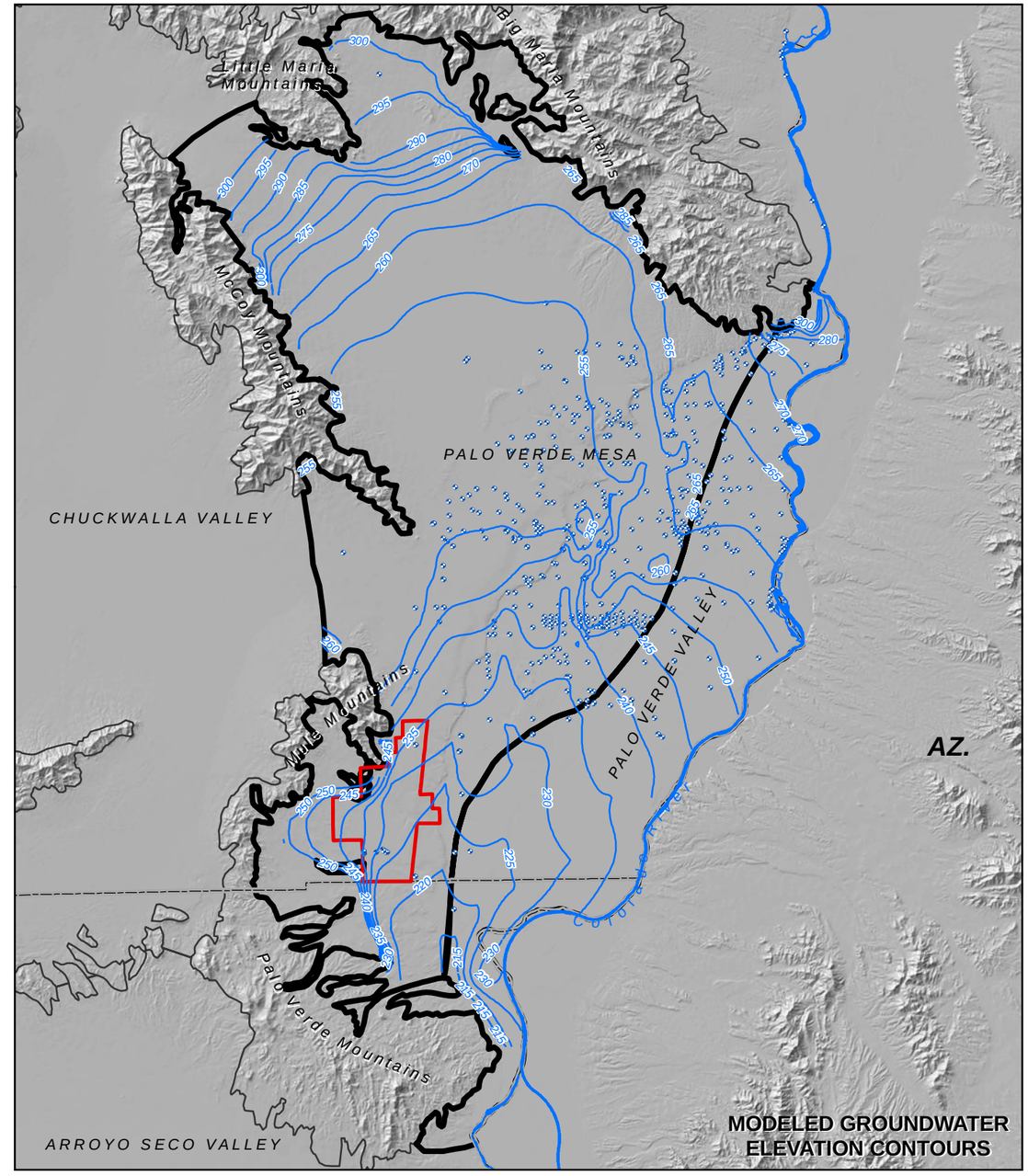
MODELED VERSUS OBSERVED HEADS

SWL	MT	9/2011
308038-03598		**3-5**





SOURCE:
USGS 10 Meter DEM
California Department of Water Resources,
B118_v3_BasinBoundaries_NAD83_unprojected
NOTES:
Observed groundwater elevation contours interpolated using historical well log data from NWIS and Rio Mesa Well data from URS. Modeled contours interpolated in Groundwater Vistas. Elevations in ft amsl

Legend

- COUNTY LINE
- RIO MESA SOLAR PROJECT SITE
- GROUNDWATER ELEVATIONS (OBSERVED) AND MODELED GROUNDWATER ELEVATIONS
- GROUNDWATER BASIN BOUNDARY

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RIO MESA SOLAR
POWER PROJECT

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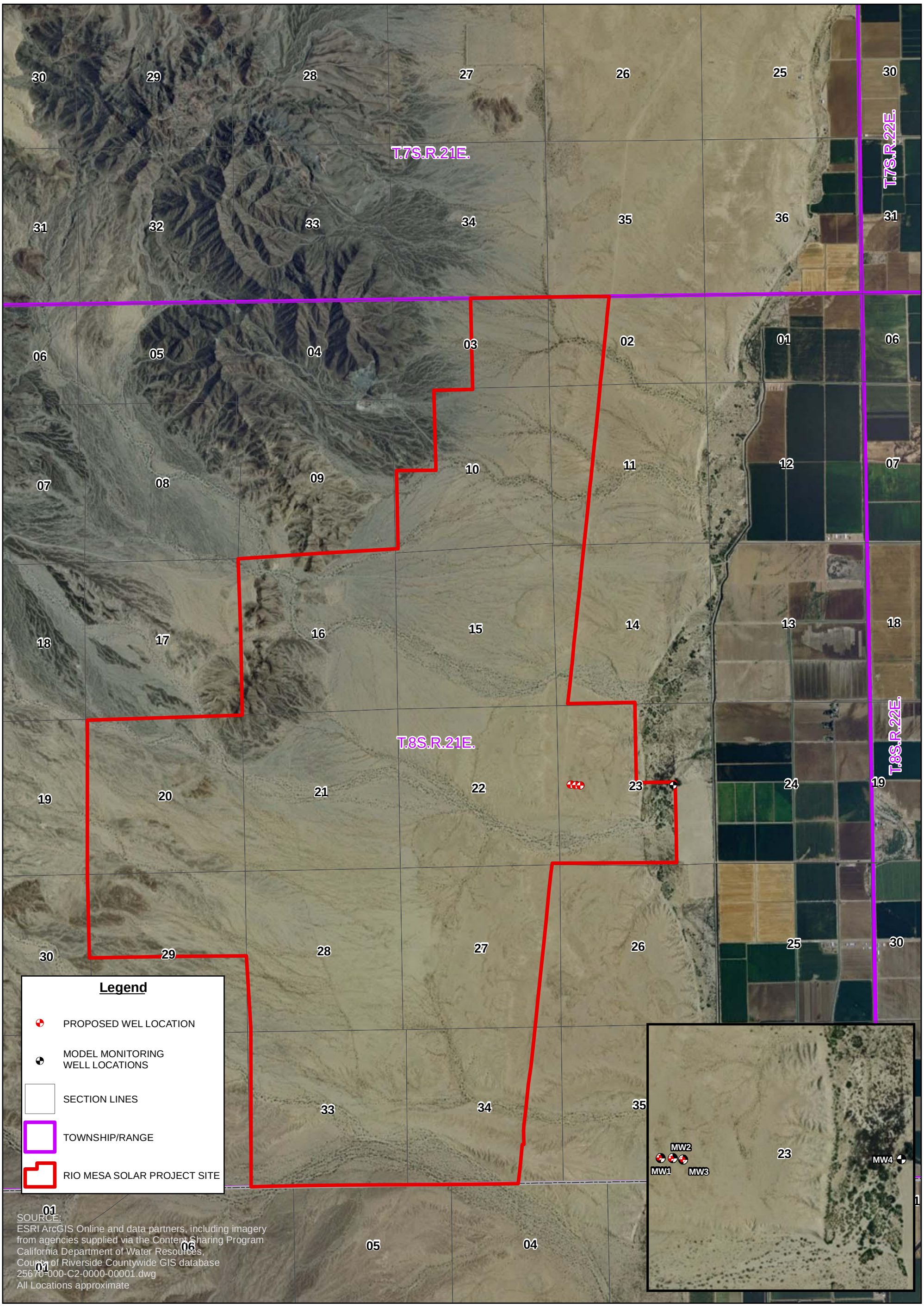
GROUNDWATER ELEVATION CONTOURS (OBSERVED) AND MODELED GROUNDWATER ELEVATION CONTOURS

SWL	MT	9/2011
308038-03598		3-6



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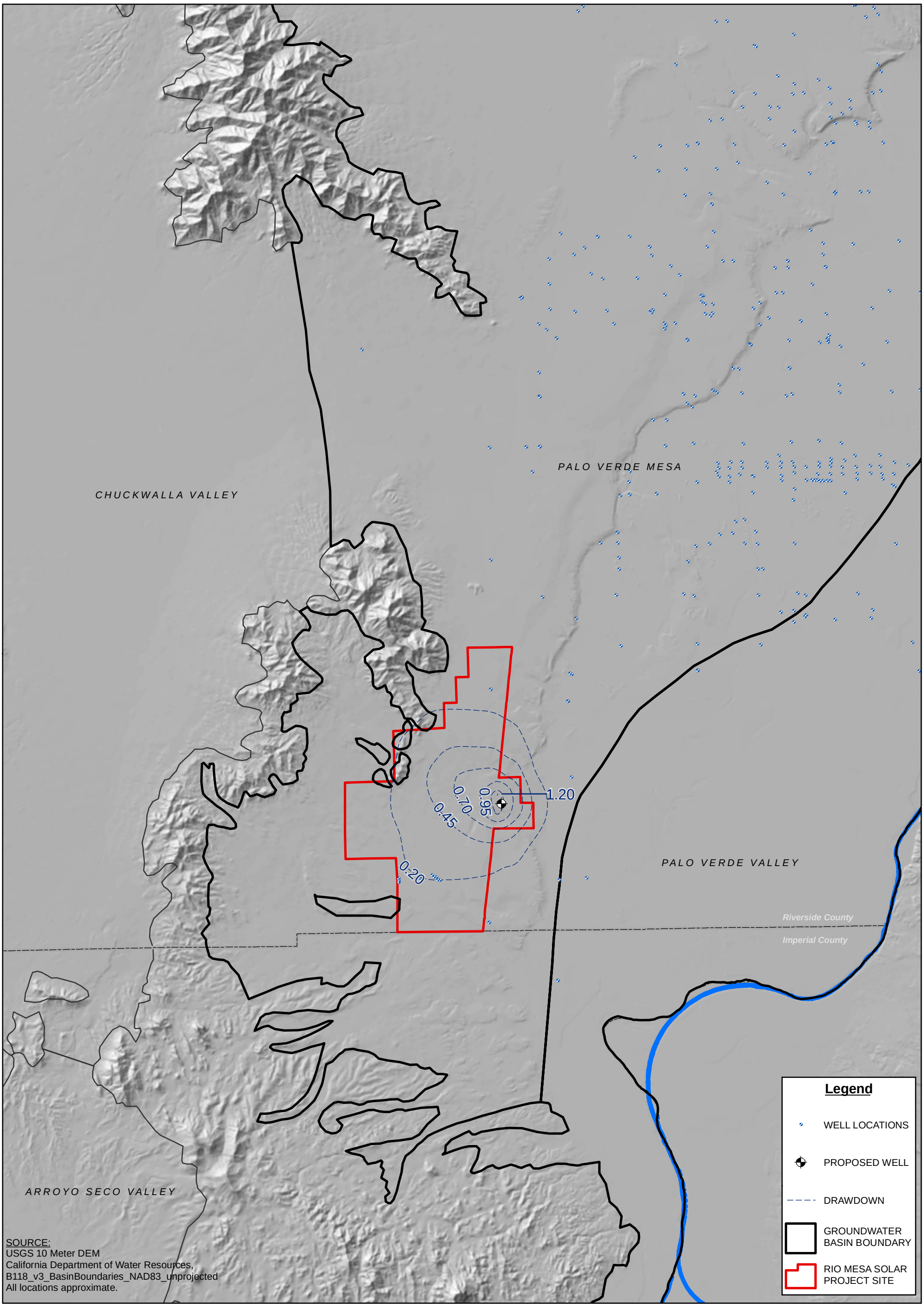
SITE PLAN SHOWING RMS PUMPING WELLS AND SIMULATED MONITORING WELLS

SWL	MT	9/2011
308038-03598		**3-7**



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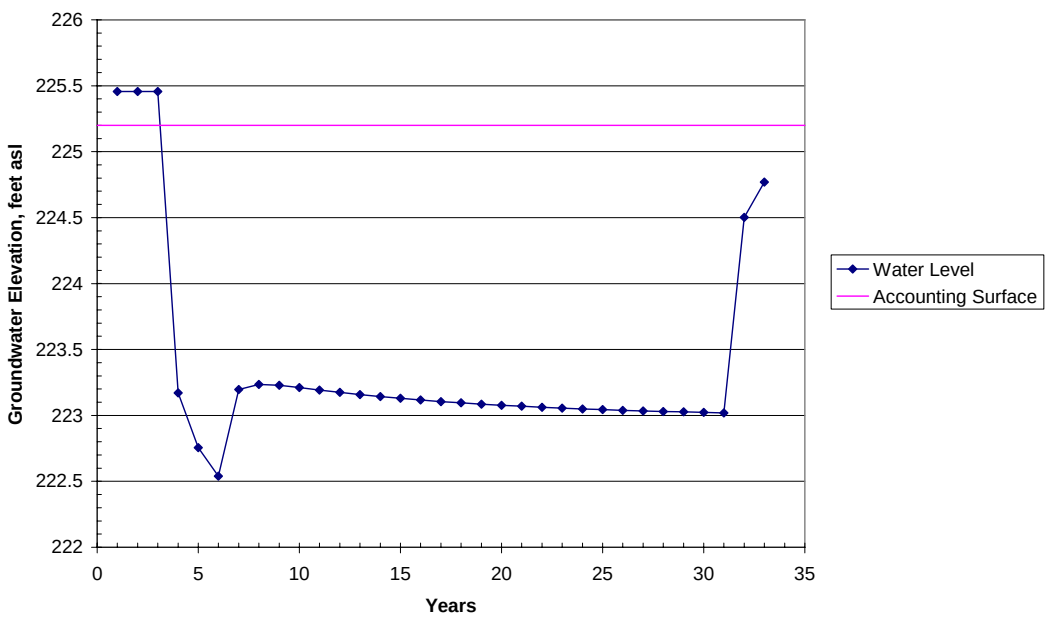
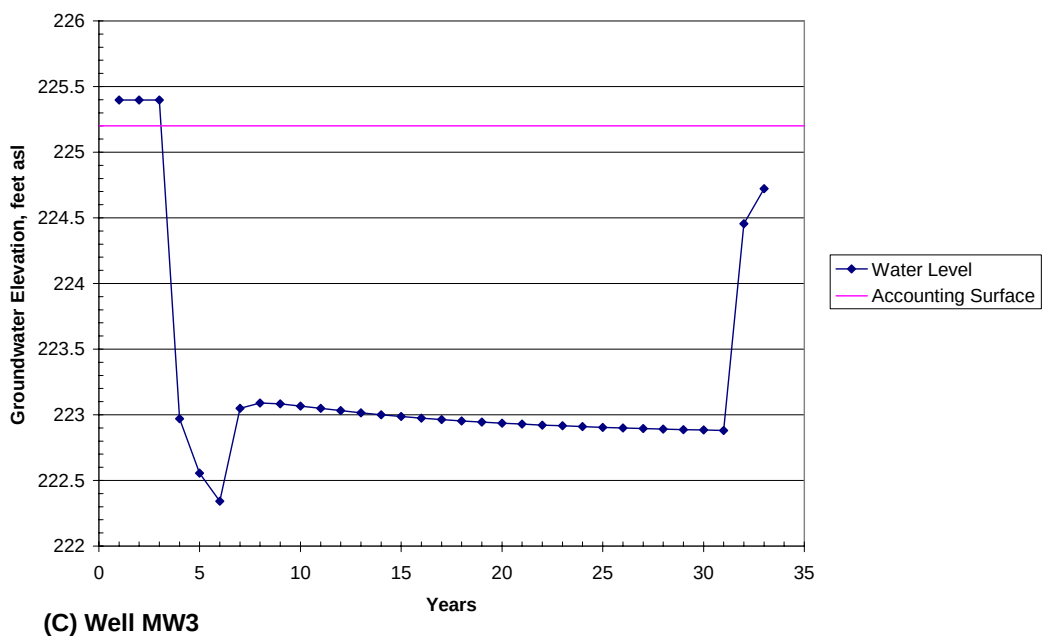
DRAWDOWN CONTOUR MAP
YEAR 31 AT END OF RMS PUMPING

SWL	MT	9/2011
308038-03598		**3-8**

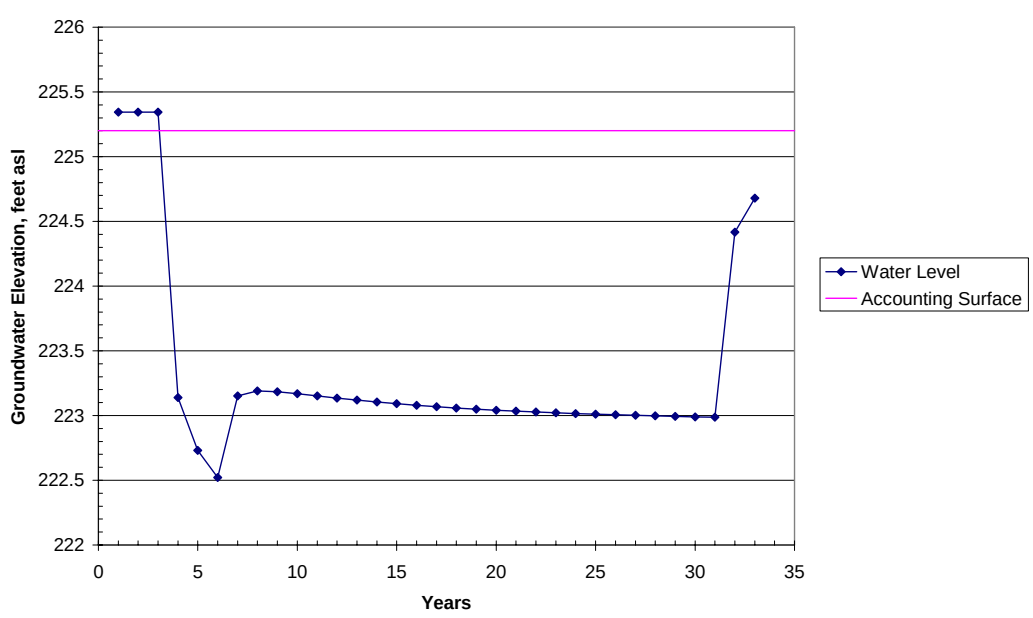
(A) Well MW1



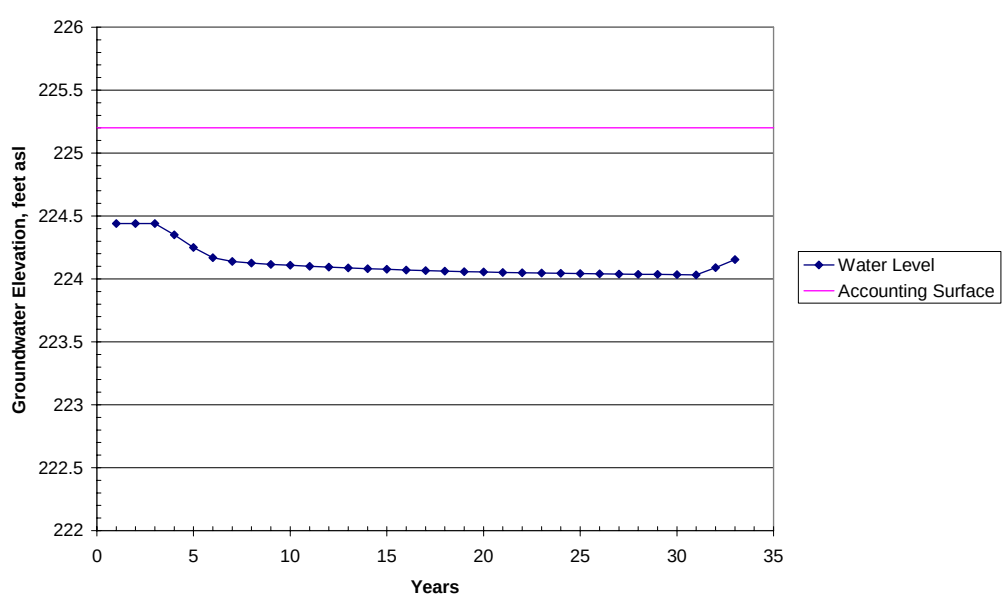
(B) Well MW2



(C) Well MW3



(D) Well MW4



Riverside County
Imperial County

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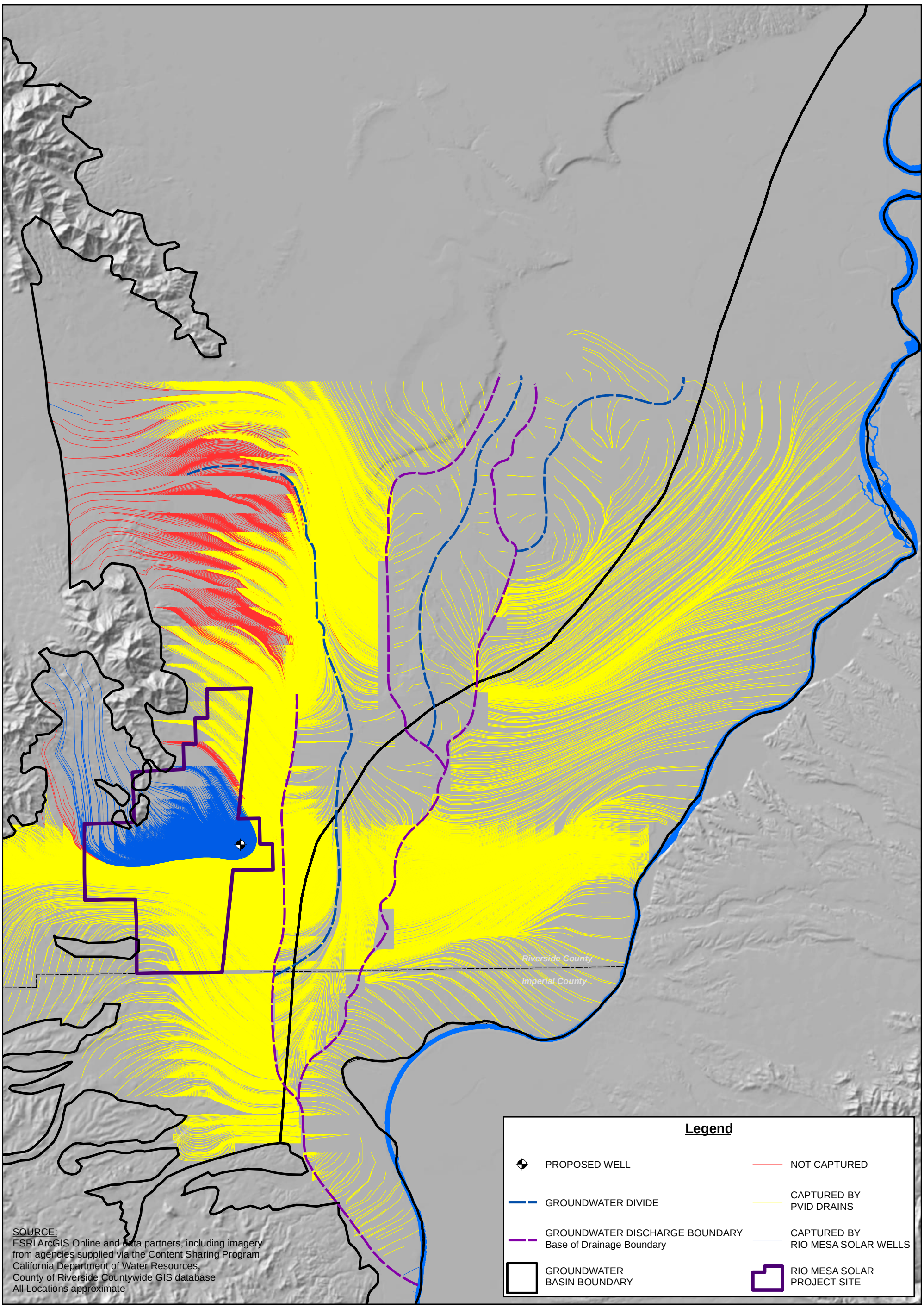
HYDROGRAPHS OF GROUNDWATER LEVEL RESPONSE OVER TIME FOR SIMULATED MONITORING WELLS

SWL	MT	9/2011
308038-03598		**3-9**



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RIO MESA SOLAR PROJECT
PARTICLE TRACKING SIMULATION RESULTS WITH
GROUNDWATER RECHARGE AND DISCHARGE DIVIDES

SWL	MT	9/2011
308038-03598		**3-10**

APPENDICES

Groundwater Elevation Targets and Target Groundwater Elevation, Steady State Groundwater Flow Model

State Well ID	X Coordinate	Y Coordinate	Average (1980-2009) Groundwater Elevation Target ft AMSL	Modeled Head ft AMSL	Residual
_	7009415.6	2110068.1	224.94	227.45	-2.51
005S022E21H001S	7039273.8	2212551.7	250.02	254.96	-4.94
005S022E28Q001S	7038311.2	2203540.0	257.53	254.46	3.07
005S022E34P001S	7042805.8	2198059.4	248.89	254.64	-5.75
005S022E36G001S	7053454.3	2202356.3	251	255.55	-4.55
005S022E36H003S	7055416.7	2202057.1	258.96	255.90	3.06
005S023E26J001S	7082120.4	2206250.9	280	279.86	0.14
005S023E26P001S	7078324.0	2205885.7	277	271.45	5.55
005S023E33J001S	7070874.7	2201519.1	272	266.25	5.75
005S023E34A003S	7076107.7	2203969.2	271.38	269.15	2.23
005S023E34E003S	7071870.5	2202647.3	272	266.82	5.18
005S023E34M001S	7071990.8	2200425.2	272	266.35	5.65
005S023E34Q003S	7074863.3	2200471.6	273	267.44	5.56
005S023E35R001S	7081640.0	2199469.8	275	270.68	4.32
006S021E25A002S	7023774.4	2176028.2	247.14	251.52	-4.38
006S021E36G001S	7023910.9	2170019.6	246.43	250.14	-3.71
006S022E01R001S	7056130.3	2193299.6	259	257.49	1.51
006S022E02P002S	7047017.8	2194026.1	253.66	254.96	-1.30
006S022E09G001S	7039409.6	2190312.0	253.35	254.15	-0.80
006S022E10H002S	7044385.5	2190331.7	254.86	254.64	0.22
006S022E11H003S	7050877.7	2191954.6	252.75	255.73	-2.98
006S022E12C001S	7052907.0	2192304.4	257.32	256.53	0.79
006S022E12J002S	7054979.0	2189402.9	256.52	256.96	-0.44
006S022E12N001S	7051142.8	2187864.4	258	255.93	2.07
006S022E13Q003S	7054858.8	2182665.4	258	255.83	2.17
006S022E15E001S	7041072.4	2185710.1	253.08	254.05	-0.97
006S022E16G001S	7038843.0	2185048.7	244	253.74	-9.74
006S022E18A001S	7030201.8	2186294.9	245.27	252.96	-7.69
006S022E20A001S	7035502.6	2182269.2	247.79	253.07	-5.28
006S022E23L001S	7048748.7	2178628.5	253	254.21	-1.21
006S022E26B002S	7050038.6	2177233.1	255	252.63	2.37
006S022E26E003S	7046357.4	2174649.5	252	254.61	-2.61
006S022E26Q001S	7048921.7	2172869.2	253	253.49	-0.49
006S022E28H001S	7039496.3	2175354.1	248	251.61	-3.61
006S022E29J001S	7034951.5	2173871.1	252.18	251.14	1.04
006S022E30M001S	7025601.0	2174005.6	247	251.06	-4.06
006S022E32F002S	7031831.5	2170005.3	246.47	249.70	-3.23
006S022E32K003S	7033470.0	2168529.6	246.59	249.34	-2.75
006S022E33C003S	7038443.5	2170796.5	249.39	250.62	-1.23
006S022E33F001S	7038176.7	2169567.5	248.22	250.09	-1.87
006S022E34F001S	7042701.3	2170348.3	244.62	249.79	-5.17
006S022E34R002S	7046474.7	2166968.8	248	250.52	-2.52
006S022E35R001S	7050582.5	2167183.2	247.8	251.49	-3.69
006S022E35R007S	7050491.5	2167060.7	250.05	251.24	-1.19

Groundwater Elevation Targets and Target Groundwater Elevation, Steady State Groundwater Flow Model

State Well ID	X Coordinate	Y Coordinate	Average (1980-2009) Groundwater Elevation Target ft AMSL	Modeled Head ft AMSL	Residual
006S023E04D001S	7066946.0	2198827.9	270	265.07	4.93
006S023E05E001S	7061475.0	2197427.0	266	265.57	0.43
006S023E05H002S	7065446.1	2197489.9	267	264.85	2.15
006S023E05P001S	7062804.7	2193505.5	263	265.11	-2.11
006S023E08H001S	7065717.7	2191024.5	264	263.29	0.71
006S023E09C001S	7069329.5	2193529.6	264.8	264.42	0.38
006S023E11R001S	7082235.2	2188966.1	268	268.16	-0.16
006S023E12M012S	7083684.9	2190769.2	261.79	269.52	-7.73
006S023E12P041S	7085046.6	2189699.8	267	269.85	-2.85
006S023E15D002S	7072558.3	2187231.8	266.75	264.01	2.74
006S023E17C002S	7063413.9	2188116.9	267	264.59	2.41
006S023E17D005S	7061930.9	2187810.4	260.85	262.20	-1.35
006S023E17R001S	7067111.0	2183161.7	264	264.02	-0.02
006S023E20D001S	7061977.2	2181665.0	260	258.33	1.67
006S023E20N001S	7062125.3	2177623.7	263	259.71	3.29
006S023E20R002S	7067358.5	2172955.6	266	266.45	-0.45
006S023E21L001S	7069287.4	2179254.0	264	263.45	0.55
006S023E22R001S	7077340.1	2178069.7	262	262.64	-0.64
006S023E27D001S	7073658.8	2177706.5	258	262.48	-4.48
006S023E28F002S	7069613.8	2175235.6	258.34	263.03	-4.69
006S023E29C004S	7064681.9	2176390.4	258.72	261.61	-2.89
006S023E29R001S	7067441.2	2173058.1	258.6	266.18	-7.58
006S023E31B001S	7060352.7	2172036.1	261	258.59	2.41
006S023E32D001S	7062380.6	2172168.8	263	259.33	3.67
006S023E32G001S	7065709.0	2170301.0	262.8	261.16	1.64
006S023E32L002S	7064454.9	2169371.3	256	259.90	-3.90
006S023E33D001S	7067710.9	2171535.7	259	262.14	-3.14
006S023E33F001S	7069668.1	2170798.7	255.5	260.01	-4.51
006S023E33K001S	7071115.3	2169699.9	255	259.21	-4.21
006S023E35N001S	7078943.9	2167885.7	255	259.97	-4.97
007S021E01C001S	7021953.0	2167211.2	243.41	249.68	-6.27
007S021E05C002S	7001428.0	2166018.4	248.22	252.16	-3.94
007S021E14B001S	7018756.5	2155744.2	247.74	248.51	-0.77
007S021E36D001S	7020473.5	2139891.7	236.33	236.04	0.29
007S022E02R005S	7051783.1	2162299.0	253.46	256.35	-2.89
007S022E03H001S	7046519.4	2164037.8	245.87	243.15	2.72
007S022E04H001S	7041190.7	2163956.8	245	243.11	1.89
007S022E05R002S	7035326.8	2161331.5	242.2	243.34	-1.14
007S022E08M001S	7032134.1	2158564.9	242	243.11	-1.11
007S022E10A001S	7046182.8	2161151.8	245	245.50	-0.50
007S022E13E001S	7053429.9	2154844.0	249	247.43	1.57
007S022E13G001S	7055054.7	2153757.4	247	245.41	1.59
007S022E13J003S	7056345.9	2152362.2	250	245.37	4.63
007S022E13M001S	7052106.1	2152903.1	247	246.38	0.62

Groundwater Elevation Targets and Target Groundwater Elevation, Steady State Groundwater Flow Model

State Well ID	X Coordinate	Y Coordinate	Average (1980-2009) Groundwater Elevation Target ft AMSL	Modeled Head ft AMSL	Residual
007S022E14E001S	7047016.8	2153633.5	245	252.25	-7.25
007S022E14G002S	7049633.7	2154078.0	247	252.01	-5.01
007S022E14J001S	7050836.8	2152883.5	247	247.85	-0.85
007S022E14P001S	7048307.7	2152238.0	245	250.17	-5.17
007S022E14Q002S	7050086.2	2152164.1	245	247.69	-2.69
007S022E15B001S	7045390.8	2154821.7	244	245.80	-1.80
007S022E15F001S	7044140.3	2153589.7	241	240.01	0.99
007S022E15J001S	7045684.8	2152197.9	244	243.07	0.93
007S022E15N002S	7042715.6	2152658.3	241	237.66	3.34
007S022E16H001S	7040323.6	2154138.6	244	241.56	2.44
007S022E16K001S	7039077.5	2152603.4	243	242.54	0.46
007S022E17P001S	7032503.1	2150786.8	243.15	237.64	5.51
007S022E18Q001S	7028697.0	2150629.5	241	238.93	2.07
007S022E19K001S	7028375.9	2146726.8	238.61	237.03	1.58
007S022E21P003S	7039168.7	2146539.7	242	237.68	4.32
007S022E22N001S	7041807.3	2145568.5	240	236.20	3.80
007S022E25A001S	7057722.5	2145509.9	245	243.97	1.03
007S022E27L002S	7043710.8	2142868.0	234	235.33	-1.33
007S022E30B001S	7028539.8	2144056.6	239	236.24	2.76
007S022E33D001S	7036472.6	2140029.6	241	235.09	5.91
007S022E34H003S	7045617.5	2138297.7	230	235.89	-5.89
007S022E35E010S	7048155.8	2137841.2	232.09	237.23	-5.14
007S022E36D002S	7053740.0	2140292.3	238	240.66	-2.66
007S023E01D005S	7083515.0	2167171.8	252.78	261.53	-8.75
007S023E03C001S	7074991.9	2166406.2	258	258.26	-0.26
007S023E04D001S	7069028.9	2166876.6	255.48	258.17	-2.69
007S023E06Q005S	7060320.0	2161754.6	258.92	258.84	0.08
007S023E09D001S	7068425.3	2161761.8	251.74	255.78	-4.04
007S023E14C007S	7081030.7	2156143.0	251.56	256.56	-5.00
007S023E14C014S	7081181.6	2156751.8	248.58	256.80	-8.22
007S023E14F008S	7081270.0	2155479.5	250.31	256.41	-6.10
007S023E16A001S	7072441.7	2156660.6	249.81	253.58	-3.77
007S023E18F001S	7059031.3	2153819.4	249	247.33	1.67
007S023E29D001S	7063304.9	2145799.6	245	246.13	-1.13
008S021E01Q001S	7023554.8	2131752.6	231	232.52	-1.52
008S021E12E003S	7023172.6	2128916.6	229.72	231.97	-2.25
008S021E25N001S	7022260.4	2110068.3	224.09	222.53	1.56
008S021E28Q002S	7008852.5	2110582.5	226.02	228.77	-2.75
008S022E04N002S	7036844.6	2132150.5	236.75	233.17	3.58