Pacific Gas and Electric Company®

Yvonne J. Meeks
Site Remediation - Portfolio Manager
Environmental Affairs

6588 Ontario Road
San Luis Obispo, CA 93405

Mailing Address
4325 South Higuera Street
San Luis Obispo, CA 93401

805.546.5243
Internal: 664.5243
Fax: 805.546.5232
E-Mail: YJM1@pge.com

August 4, 2006

Christopher Guerre
Project Manager
California Department of Toxic Substances Control
Permitting and Corrective Action Branch
5796 Corporate Avenue
Cypress, California 90630

Subject: Groundwater Model Report, Section 2
PG&E Topock Compressor Station, Needles, California

Dear Mr. Guerre:

This letter transmits Section 2 (Site Conceptual Model) of the Groundwater Model Report for the PG&E Topock Compressor Station. This document has been prepared in conformance with DTSC's letter dated February 3, 2006, and according the schedule submitted on March 31, 2006. The next submittal of the Groundwater Model Report will be Section 4.4, due to DTSC on August 18, 2006.

If you have any questions, please do not hesitate to call me.

Sincerely,

Brian Schroth /for Yvonne Meeks

Enclosure

cc: Kate Burger/DTSC

Groundwater Model Report
PG&E Topock Compressor Station
Needles, California

Prepared for

Department of Toxic Substances Control

On Behalf of

Pacific Gas and Electric Company

CH2MHILL
155 Grand Avenue, Suite 1000
Oakland, CA 94612

Groundwater Model Report

PG&E Topock Facility

Prepared for

California Department of Toxic Substances Control

on behalf of

Pacific Gas and Electric Company

August 4, 2006

This work plan was prepared under supervision of a California Professional Geologist

Brian Schroth, Professional Geologist No. 7423
Senior Technologist

Contents

Section 2 Appendices

Section 2.0 Acronyms

μg/L	micrograms per liter
afy	acre-feet per year
cfs	cubic feet per second
DTSC	Department of Toxic Substances Control
ft/d	foot per day
gpm	gallons per minute
HSU	hydrostratigraphic unit
msl	mean sea level
HNWR	Havasu National Wildlife Refuge
TWG	Technical Work Group
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey

2.0 Site Conceptual Model

This section presents the site conceptual hydrogeologic model, including descriptions of the hydrogeologic setting, groundwater flow conditions, and groundwater recharge and discharge in the groundwater model area. This discussion is based on the site investigations and monitoring conducted by PG&E under the RFI/RI and IM activities since 2003, as well as published geologic and technical reports relevant to the Topock site. This section provides:

- A general description of the regional and site hydrogeologic setting.
- Description of individual hydrostratigraphic units (HSUs) present at the site.
- Summary of the well testing and methodology used for estimating hydraulic parameters.
- Description and summary of the horizontal and vertical hydraulic gradients observed at the site and general groundwater flow directions.
- Summary of the groundwater budget for the model area, including recharge and discharge, and the effects of current groundwater extraction and injection.

2.1 Hydrogeologic Setting

The Topock site is located in the southern portion of the Mohave Valley, along the California-Arizona border, approximately 15 miles southeast of Needles, California. The project site is bounded by the Chemehuevi Mountains to the south and the Colorado River to the east and north. Figure 1-1 shows the location of the Topock site, the groundwater model domain, and regional features in the study area.

2.1.1 Regional Geology

The Topock site and study area are the Basin and Range geomorphic province, characterized by roughly parallel north/south fault-block mountains, separated by alluvial valleys (Figure 1-1). The dominant geologic feature in the vicinity of the site is the Chemehuevi Mountains, one of several metamorphic and plutonic basement core complexes exposed in southeastern California and western Arizona (Miller et al. 1983; Miller and John 1999). The compressor station and the study area lie upon the north-sloping piedmont terrace along the northern margin of the Chemehuevi Mountains.

Figure 2-1 presents a generalized geologic map of the Topock Compressor Station and surrounding areas. The geologic features shown on Figure 2-1 include the principal geologic units, geologic contacts, and geologic faults mapped in the study area, compiled from the following sources: Metzger and Loeltz (1973), John (1987), and Howard et al. (1997). The oldest rocks in the Topock area are exposed in the Chemehuevi Mountains and include Precambrian and Mesozoic-age metamorphic and igneous rocks, primarily metadiorite, gneiss, and granite (pTbr unit on Figure 2-1). Miocene-age sedimentary and volcanic rocks—associated with the tectonic uplift and faulting in the region—were deposited on the metamorphic and plutonic bedrock complex (John 1987; Miller and John 1999). Distinctive, reddish-brown, cemented conglomerate of Miocene age (Tmc unit on Figure 2-1) is exposed locally in the study area. As shown on Figure 2-1, the near-surface geologic units in the study area include Tertiary- and Quaternary- to Recent-age alluvial fan deposits, Pliocene lacustrine deposits, and Tertiary- and Quaternary- to Recent-age fluvial deposits of the Colorado River. A summary and description of the individual HSUs present in the study area are provided in Section 2.2.

2.1.1.1 Geologic Structure

The most prominent geologic structural feature in the study area is a Miocene-age, low-angle normal fault (referred to as a detachment fault) that forms the northern boundary of the Chemehuevi Mountains (Figure 2-1). The Chemehuevi detachment fault is part of a series of low-angle detachment faults exposed within and surrounding the Chemehuevi Mountains that separate lower plate Precambrian and Mesozoic-age metamorphic and plutonic rocks from overlying upper plate pre-Tertiary metamorphic/plutonic, and Miocene volcanic and sedimentary rocks (John 1987; Howard et al. 1997). The detachment faulting is related to the formation of a series of northeast-trending antiformal bedrock arches bounded by synformal troughs that resulted from crustal extension that occurred in Miocene time, approximately 23 to 15 million years ago (Howard and John 1987; Howard et al. 1997).

The surface expression of the Chemehuevi detachment fault is evident as the pronounced northeast-southwest lineament that can be traced along the northern boundary of the Chemehuevi Mountains, terminating at the abrupt bend in the Colorado River east of the compressor station (Figure 2-1). The surface trace of the detachment fault is partially concealed by younger alluvial deposits in the southwestern portion of the study area.

A major unconformity separates the bedrock formations from the overlying unconsolidated alluvial/fluvial deposits (Metzger and Loeltz 1973). As noted above, faulting and deformation is confined to the metamorphic and plutonic bedrock complex and the consolidated Miocene conglomerate. In the area east of the compressor station, the thick-bedded Miocene conglomerate has structural dip up to 40° to the northeast beneath the unconformity. Overlying alluvial deposits comprising the piedmont terraces are undeformed and have gentle structural dip of approximately 5° to 10° to the north.

The structure of the bedrock in the study area has been further modified by past period(s) of channel-cutting and erosion by the ancestral Colorado River. Based on the results of a 2004 seismic survey conducted on the Colorado River at the Topock site, a pronounced paleochannel cut into the Miocene bedrock formations exists under the present channel of the Colorado River in the area northeast and east of the PG&E Topock Compressor Station. The survey data indicate a local bedrock rise, or saddle, in the area beneath the railroad and I-40 bridges. Farther south of the site, where pre-Tertiary bedrock outcrops, the Colorado River is confined to a relatively narrow channel cut into bedrock at Topock Gorge. Alluvial aquifer material exists above the bedrock profile continuously throughout the river area. The structure of the bedrock surface is further discussed in Section 2.1.5.

2.1.2 Mohave Hydrologic Basin

Figure 2-2 shows the groundwater basins and regional groundwater flow directions in the study area. Following the nomenclature of Anderson and Freethey (1992), the study area is within the Mohave groundwater basin, which is bisected by the Colorado River. The Sacramento Valley groundwater basin lies to the east, in Arizona. Sacramento Wash is the principal surface drainage in the Sacramento Valley basin and enters the Colorado River at Topock, Arizona. As described by Metzger and Loeltz (1973) and other groundwater resource reports (Anderson et al 1992; Anderson 1995), groundwater in the Mohave basin occurs in the Tertiary and younger alluvial basin deposits, which include the highly-productive Pleistocene to recent fluvial deposits associated with the Colorado River. Based on hydrogeologic investigations and published reports, bedrock water-bearing zones locally occur where bedrock formations are weathered or fractured. No areas or locations have been identified in the Mohave groundwater basin where saturated bedrock formations are capable of significant storage, or sustained production or yield.

2.1.3 Colorado River and Surface Features at Topock Site

The primary surface water feature at the Topock site is the Colorado River and its adjacent wetlands and marshes. Figure 2-2 shows the geomorphic setting of the Colorado River and major drainages and surface water features in the region. The river system upstream of Topock, Arizona is characterized by the wide Mohave Valley floodplain, marsh, and alluvial valley. Downstream of Topock, the river traverses the exposed bedrock of the Chemehuevi Mountains of California and the northern portion of the Mohave Mountains in Arizona. The river channel narrows in the area of the Topock Gorge (Figure 2-1). Sacramento Wash is the principal dry wash surface drainage to the Colorado River from the Sacramento basin in Mohave County, Arizona (Rascona 1991). Lake Havasu, formed in 1938 with the construction of Parker Dam, extends approximately 24 miles upstream from the city of Parker, Arizona.

The Colorado River, Topock Marsh, floodplain and other surface features at the Topock site are shown on a 2005 aerial photograph, Figure 2-3. This figure shows the locations of the PG&E Topock Compressor Station, the current IM groundwater extraction area (MW-20 bench and adjacent floodplain), and the IM No. 3 groundwater treatment facility and associated injection area. Also shown on Figure 2-3 is the approximate outline of the area where chromium concentrations in groundwater exceed the California maximum contaminant level of 50 micrograms per liter (μg/L).

The Colorado River channel ranges from approximately 600 to 700 feet wide in the area upstream of the bridge crossing at Topock. According to the United States Bureau of Reclamation (USBR), when profiled near the site in 1994, the river channel was typically less than 9 feet deep with a maximum depth of 21 feet. The last major dredging in this area occurred in 1960 (Metzger and Loeltz 1973).

The flow of the Colorado River is very dynamic, fluctuating seasonally and daily largely due to upstream flow regulation. The flow of the Colorado River at the Topock site is primarily controlled by water releases at Davis Dam on Lake Mohave, approximately 33 miles upstream. River levels at the site fluctuate by 2 to 3 feet per day, and flows vary anywhere from 4,000 to 25,000 cubic feet per second (cfs) according to the dam releases, producing a sinusoidal hydrograph each day.

Topography in the Topock site is abrupt, rising from around 450 feet above mean sea level (msl) along the Colorado River to over 1,200 feet msl within one mile to the south and southwest. The Chemehuevi Mountains and drainage area to the south exceed 2,000 feet msl in elevation. Figure 2-4 shows the surface topography in the primary portion of the site. The land surface is characterized by moderate to deeply-dissected alluvial terraces, with elevations ranging from 650 to 500 feet msl, extending northward to the Colorado River floodplain. One of the largest incised channels is Bat Cave Wash, a north-south dry wash (ephemeral stream) adjacent to the Topock Compressor Station. Bat Cave Wash flows only briefly following intense rainfall events and drains to the Colorado River (Figure 2-4).

The Colorado River flows along the eastern and northern boundary of the site at an approximate average elevation of 455 feet msl. Locally, a floodplain borders both sides of the Colorado River, though the river no longer floods due to upstream dams and flow regulation. Topography on the floodplain is subtle with elevations typically less than 40 feet above the river elevation. The width of the floodplain adjacent to the site averages 500 feet and narrows to the south of the site as the river enters the Topock Gorge where the shoreline becomes consolidated Miocene and pre-Tertiary-aged bedrock.

2.1.5 Bedrock Elevation Map

Figure 2-5 shows the structure elevation contour map of the Miocene Conglomerate bedrock surface that underlies Alluvial Aquifer in the Topock site area. The bedrock surface elevation map reflects the results of drilling information through June 2006 and other available regional information.

Table 2-1 lists the available drilling and well information from the completed RFI/RI investigations and other studies at the Topock site. Table 2-1 also identifies the investigation borings that encountered Miocene or older bedrock. The bedrock structure map shown on Figure 2-5 incorporates the results of the most recent IM 2006 drilling program (CH2M HILL 2006a) and the seismic survey conducted by the United States Geological Survey (USGS) on the Colorado River in September 2004. The locations where the bedrock elevations are estimated from projections from drilling or seismic information are noted on Figure 2-5.

Based on the results of the 2006 drilling, the depth to Miocene bedrock was found to be deeper than previously inferred, especially in northern portion of the project site. The bedrock surface map used in the groundwater model has been updated from previous interpretations.

2.2 Site Hydrogeology and Hydrostratigraphic Units

Groundwater occurs under unconfined to semi-confined conditions within the alluvial fan and fluvial sediments beneath most of the Topock site. The saturated portion of the alluvial fan and fluvial sediments are collectively referred as the Alluvial Aquifer. In the floodplain area adjacent to the Colorado River, the fluvial deposits interfinger with, and are hydraulically connected to, the alluvial fan deposits. The unconsolidated alluvial and fluvial deposits are underlain by the Miocene Conglomerate and pre-Tertiary metamorphic and igneous bedrock with very low permeability; therefore, groundwater movement occurs primarily in the overlying unconsolidated deposits.

The geology and stratigraphic units encountered in the vicinity of the Topock site are shown in map view in Figure 2-1 and described in Table 2-2. The stratigraphic units that are saturated in at least some areas of the model domain are termed *hydro*stratigraphic units (HSUs) and are highlighted in Table 2-2. It should be noted, however, that the divisions between the HSUs do not correspond to any aquitards dividing the aquifer. The Alluvial Aquifer at the Topock site is considered to be hydraulically undivided. In this section, the overall site conceptual hydrogeologic model is presented and the HSUs are summarized.

Figure 2- 6 shows the locations of hydrogeologic cross-sections to illustrate the site conceptual model. Figure 2-7 (Cross-Section A) extends from upper Bat Cave Wash northeastward to the Colorado River. Key wells shown include the former injection well PGE-8 (completed in metamorphic/igneous bedrock), monitoring well clusters MW-24, MW-20, MW-39, MW-36, and MW-34 on the floodplain, and the currently active IM extraction wells (TW-3D, PE-1). Also shown on Figure 2-7 is the erosional/depositional contact of the fluvial sediments across the bedrock surface and the Basal Alluvium and Tertiary Alluvium deposits.

Figure 2-8 (Cross-Section B) extends from the IM No. 3 injection area eastward to the Colorado River and Arizona shoreline. Key features shown on this cross-section include the elevation and structure of the Miocene bedrock surface (see structure map, Figure 2-5), the thickness variation of the Alluvial Aquifer, and the inferred depth and distribution of fluvial deposits underlying the current Colorado River channel and floodplain. Additional cross-sections to illustrate the hydrogeology and HSUs in the IM performance monitoring area are included in Appendix A.

2.2.1 Description of Hydrostratigraphic Units

The primary geologic formations and stratigraphic units at the Topock site and study area are summarized below. Additional description and characteristics of the individual HSUs are presented in Table 2-2.

2.2.1.1 Bedrock (pTbr and Tmc)

The consolidated rock that underlies the Alluvial Aquifer consists of Pre-Tertiary metamorphic and igneous rock (primarily grayish metadiorite, gneiss, and granitic rocks) and the Miocene Conglomerate (red-brown conglomerate and gravelly sandstone). Both bedrock formations are locally fractured but generally produce very little water, based on purge records from the bedrock monitoring wells at the site (MW-23, MW-48, and MW-24BR). The two formations were modeled as a single bedrock unit in the model. Some areas may produce modest quantities of water locally. The former injection well, PGE-8, was able to produce approximately 26 gallons per minute (gpm) for a period of 26 hours during initial testing in 1969. There is an upward hydraulic gradient between bedrock and Alluvial Aquifer groundwater.

2.2.1.2 Tertiary Alluvium (Toa1 and Toa2)

The Tertiary Alluvium is a moderately-consolidated mixture of sandy gravel and silty/clayey gravel that forms the base of the Alluvial Aquifer to the west of the river floodplain. A lower (Toa1) and upper (Toa2) unit have been identified through the interpretation of spinner velocity logs and geophysical logs. The Toa1 and Toa2 subdivision is based on hydraulic permeability contrasts observed in well testing and variations in geophysical log responses. Hydraulic properties for each unit were assigned in the model.

2.2.1.3 Basal Alluvium (Toa0)

A basal depositional unit of the Tertiary Alluvium has been identified in some deeper wells (previously referred to as either "Basal Saline unit" or "reworked Miocene Conglomerate"). Review of the site drilling and geophysical logging indicates that alluvial deposits are generally comparable in terms of deposition, weathering, induration, and lower permeability, and hence best grouped as a single HSU; designated as Basal Alluvium. As documented in the 2006 IM drilling program (CH2M HILL 2006a), recent investigations indicate that Toa0 deposits are thicker and more extensive than previously mapped, especially in the northern floodplain area.

Geophysical induction logs generally indicate much higher salinity in the Basal Alluvium unit, and boring logs note the presence of more reddish material that is often (though not always) finer grained than most of the Toa1. For modeling purposes, Toa0 is extended as the basal unit of the Tertiary Alluvium in areas of the model domain beyond the drilling control.

2.2.1.4 Bouse Formation (Tb)

The Bouse Formation, which consists of interbedded clay, claystone, and sandstone, is exposed in dissected alluvial terraces and local outcrops only in the western portion of the project area (Figure 2-1). Where present, the Bouse unit separates the Tertiary Alluvium from younger (Quaternary age) alluvial deposits. The Bouse represents a lacustrine (lakebed) deposit left by a large Pliocene lake that covered a large portion of Mohave Valley (Howard and others, 1997). Most of the Bouse was eroded away by the Colorado River during Pleistocene and Holocene time. The Bouse Formation is preserved in outcrops on the western and eastern flanks of the historical river floodplain. Though outcrops of Bouse are present west of the Topock site at Park Moabi, no saturated Bouse has been encountered in site boring logs. Remnants of the Bouse Formation are inferred to occur within the saturated zone to the north of the site and have been incorporated into the model in these areas.

2.2.1.5 Quaternary Alluvium (Qoa)

Quaternary alluvial deposits of the moderately dissected alluvial fan overlie the Bouse Formation. The Qoa is virtually indistinguishable from Toa deposits where the Bouse is not present to separate the two (Metzger and Loeltz 1973). This is true in the site borings, though a few subtle distinctions have been made mainly through geophysical log interpretation. However, in outcrop, the Qoa is distinguished from older Tertiary Alluvium by alluvial terrace/wash slopes with moderate angle (i.e., 45-degree slopes). Although only a limited thickness of saturated Qoa exists at the Topock site, the 2006 IM drilling observations indicate the Qoa is present in the saturated zone in the northern portion of the project area (refer to cross-sections in Appendix A), and hence, is included as the shallowest HSU in the model area.

2.2.1.6 Fluvial (River) Deposits (Qr units)

Colorado River deposits dominate the subsurface from the Topock floodplain eastward to the edge of Topock Bay and Topock Marsh. Thickness ranges from near zero to approximately 250 feet. The maximum thickness has been observed in the river seismic survey conducted by the USGS (Peter Martin, Technical Work Group meeting communications 2004). The many borings and geophysical logs in the Topock floodplain have provided a detailed picture of the variable thickness and grain size of the deposits. Four model HSUs were assigned: Qr0, Qr1, Qr2, and Qr3 from oldest to youngest. The Qr0 represents the channel-fill fluvial sediments that occur below the approximate elevation of 360 feet msl (see Figure 2-8). Hydraulic properties for each of the fluvial HSUs were assigned in the model.

Older fluvial sediments, designated as Qrg and Qrs in Table 2-1, are exposed in surface outcrops at the Topock site. These deposits (assumed Pleistocene-age) occur solely above the water table and have not been incorporated in the groundwater model. Similarly, the dredged sand on the floodplain and surficial alluvial deposits (grouped as Younger Alluvium, Table 2-1), occur above the average water table at the site and have not been incorporated in the groundwater model.

2.2.2 Distribution and Thicknesses of HSUs in the Groundwater Model

The thicknesses of individual HSUs were generated by plotting and contouring the unit thickness data at known points (i.e., well and boring locations). These localized contours were then merged with the estimated thicknesses across the model domain. Initial isopachs were smoothed and recontoured to both honor observed data and to ensure that the total elevation of the bedrock surface plus all HSUs at a point added up to a maximum elevation of 455 feet msl, which is the average elevation of the groundwater table at the site. Thus, for model purposes, the uppermost portion of a HSU was truncated above the groundwater table. Isopach maps of each of the individual HSUs described in Section 2.2.2 and Table 2-1 are provided in Appendix B. An expanded Miocene bedrock surface map for the full groundwater model area is also provided in Appendix B. Hydraulic properties were assigned to HSUs within each group, as discussed below.

As previously described, the Alluvial Aquifer is comprised of unconsolidated fluvial and alluvial deposits (HSUs) that are hydraulically connected. The distribution and thickness of the total Alluvial Aquifer is shown on Figure 2-9. In the IM site area, the saturated thickness of the Alluvial Aquifer ranges from less than 30 feet in the southern floodplain (MW-32 location), to 260 feet in the IM No. 3 injection area, and more than 350 feet in the northern floodplain (MW-49 location). The thickness of the Alluvial Aquifer averages approximately 100 feet at IM extraction well area (MW-20 bench/central floodplain). The Alluvial Aquifer thins to the south and pinches out where the Miocene Conglomerate bedrock surface is shallower than elevation 455 feet msl. Based on the projected bedrock surface, the areas north of the Topock site, the total saturated alluvial/fluvial basin deposits are more than 2,000 feet thick (see groundwater model area isopach maps in Appendix B).

Figure 2-10 shows the distribution and combined thickness of the fluvial HSUs of the Alluvial Aquifer. The fluvial deposits within the saturated zone are confined to the areas bordering the Colorado River and underlying the Topock Marsh.

2.3 Hydraulic Testing and Parameters

This section summarizes the hydraulic testing activities at the Topock Site and aquifer parameters that were calculated from the test data. An historical summary of the testing is presented here. For distribution of pre-calibration parameter estimates in the model, refer to Section 4.4.

2.3.1 Methods of Measuring Parameters

Aquifer parameters may be estimated by observing changes in groundwater levels in response to any stress on the aquifer. This stress may take the form of pumping, injection, rapid insertion or removal of a fixed volume or “slug,” or changing levels in a nearby surface water body (such as the Colorado River) in communication with the aquifer. All of these methods have been used to estimate aquifer parameters at the Topock Site. Table 2-3 summarizes the well and aquifer tests conducted and analyzed through June 2006 that have been used in the groundwater model (see Table 2-2 for screen intervals and other well information). Pumping and injection tests are considered to be higher-quality data sets than slug tests because slug tests affect only the area immediately surrounding the well and, therefore, may measure properties of the filter pack along with those of the aquifer material.

Long-term pumping tests have been conducted in wells in the area surrounding MW-20 (the 20-bench) on several occasions. As more wells have been added to the floodplain over time, the amount of available data for each test has increased; therefore, the most recent tests are considered the most valuable. In May 2006, tests were run by pumping recently-installed test wells TW-4 and TW-5, and observations were recorded using transducers in nearby wells, including new well clusters MW-44, -46, -47, -49, and -50. The results of this testing are discussed in Section 4.4 and are considered the most valuable data with which to assign hydraulic properties to the groundwater model.

Response of groundwater levels to changing levels in the Colorado River have been used to help better fit parameters to HSUs. Analytical solutions have been developed that take account of the distance of the well from the river, groundwater level change relative to that of the river, and lag time between river and groundwater changes. However, these solutions are of limited use for assigning hydraulic properties in the model because they only provide a ratio of transmissivity to storativity, not the individual values. The best use of recorded river and groundwater level data has proven to be in the groundwater model calibration stage, where river stage is imposed as a changing boundary condition and observed changes in groundwater levels are matched by adjusting aquifer parameters. This method is discussed in more detail, along with current results, in Section 5.0.

Spinner tests (or velocity logs) were used to measure relative production from different depths in the aquifer at wells IW-2 and IW-3. While this method does not provide direct measurement of aquifer hydraulic properties, it can provide an estimate of the relative permeability of different aquifer zones.

In May 2006, hydraulic testing was conducted at three newly-installed wells (TW-4, TW-5, and MW-51/MW-26; see Figure 1-2). [NOTE – As of July 2006, analysis and evaluation of the TW-4, TW-5, and MW-51/MW-26 hydraulic tests are currently underway. The results of this analysis will be incorporated in the groundwater model and documented in the final version of this Modeling Report.]

2.3.2 Hydraulic Conductivity and K_h/K_v Ratios of HSUs

Hydraulic conductivity (K)—a measure of the ease with which groundwater flows through a given aquifer material—has been estimated based on aquifer tests and previous versions of the groundwater model. Similarly, the ratio of horizontal to vertical hydraulic conductivity (K_h/K_v) has also been calculated from observed data.

The current estimated distribution of hydraulic conductivity is discussed and illustrated in Section 4.4. In general, horizontal hydraulic conductivity ranges between 1 foot per day (ft/d) and several hundred ft/d, with values typically in the 10 to 50 ft/d range. Estimates from past hydraulic tests are listed in Table 2-3. The K_h/K_v ratio for each HSU in the floodplain area was varied during calibration of past models, and the range and averages are provided in Table 2-4. These values infer that flow would tend to be more horizontal in Qr2 compared to other HSUs in the floodplain, given the higher K_h/K_v ratios calculated for this unit. [NOTE – The distribution of K will change during model calibration and this section may be updated in the Final Report.]

2.3.3 Storativity

Storativity (S; aka storage coefficient) represents the volume of water released from a unit area of aquifer material per unit drop in head. Storativity values are somewhat time-dependant, as the release of water is not instantaneous. As such, values derived from a test or stress to an aquifer will depend on the duration of that test. Values from longer-duration tests are typically larger than those for shorter-duration tests. Additionally, storage values are larger in unconfined aquifers where dewatering of a portion of the aquifer occurs in response to a drop in water levels. This dewatering does not occur in confined aquifers.

Estimation of S in the groundwater model was based on the simulation of three events: (1) injection testing at IW-2 and IW-3, (2) water level recovery from the cessation of extraction at wells TW-2S and TW-2D, and (3) aquifer response to monthly Colorado River stage fluctuations. The duration of tests 1 and 2 was on the order of hours, while that for the response to stage fluctuations was on the order of months. The existing groundwater model was used to evaluate S for these three events, and values were assigned based on model layer not HSU. For simulations, storativity was one to three orders of magnitude larger in the upper model layer (0.006 to 0.075) than in layers 2 through 5 (0.000014 to 0.00022) (Table 2-5). The values from the longer duration test were about one order of magnitude larger than those from the other tests in the upper layer but lower or roughly equal in the lower model layers (Table 2-5). The S values of most HSUs are reflective of the values calculated in the upper model layer, where most of the HSUs occur.

In general, storativity was not a sensitive parameter in matching test data, so the values provided in Table 2-5 should be considered approximations. Adjustment of these distributions was performed with the benefit of recent testing at wells TW-4 and TW-5, and results are discussed in Section 4.4.

2.4 Groundwater Gradients and Flow

2.4.1 Horizontal Gradient

Figures 2-11 through 2-13 present groundwater elevation contour maps for the three depth intervals of the Alluvial Aquifer. Figure 2-11 presents data for shallow wells from manual water level measurements taken as a snapshot on the morning of June 14, 2006. Consistent with previous sitewide maps of shallow wells, flow outside of the pumping center is easterly towards the Colorado River, whereas flow on the floodplain is westerly or landward towards the pumping center (PE-1 and TW-3D). Induced horizontal gradients are stronger on the floodplain than regionally.

Figure 2-12 presents groundwater elevation data taken with pressure transducers during the month of June for the mid-depth interval, along with the contours from the June 2006 Performance Monitoring Report. Also shown are the groundwater elevations from the Compliance Monitoring Program wells in the East Mesa of the site. Strong landward gradients towards the pumping center are evident in the floodplain. Mounding from injection in to IW-2 is evident in the East Mesa wells (data not contoured). As stated above, horizontal gradients induced by IM extraction are stronger on the floodplain than regionally.

Figure 2-14 presents groundwater elevation data taken with pressure transducers during the month of June for wells in the deep interval, along with the contours from the June 2006 Performance Monitoring Report. Also shown are the groundwater elevations from the Compliance Monitoring Program wells in the East Mesa of the site. Induced landward gradients are evident throughout the floodplain, while mounding is present close to the injection well IW-2. Horizontal gradients are stronger on the floodplain than regionally.

The floodplain cross-section shown on Figure 2-15 presents vertical and horizontal gradients from the river towards the pumping wells TW-3D and PE-1. Again, strong landward gradients from the Colorado River towards the pumping center are observed.

2.4.2 Vertical Gradients in Well Clusters

Several monitoring well clusters are available at the Topock site to evaluate vertical hydraulic gradients within the Alluvial Aquifer and between bedrock and the Alluvial Aquifer. Table 2-6 presents a summary of the vertical hydraulic gradients measured at eight well cluster locations at the Topock site, including well clusters in the floodplain, the MW-20 bench extraction area, and the IM-3 injection area. For this summary, vertical hydraulic gradients were calculated at 24 individual well pairs (eight well clusters). The data summarized in Table 2-6 represent average water levels based on half-hour-interval pressure transducer measurements.

Throughout the majority of the study site, vertical hydraulic gradients were observed to be primarily upward (Table 2-6). The strongest upward gradients were observed between the deep and shallower wells at MW-49 (May-June 2006 data). The gradients and details of groundwater flow in the region of extraction system are well characterized in the recent 2006 IM performance monitoring reports (CH2M HILL 2006b and 2006c).

Previous reports have also documented upward hydraulic gradients from bedrock to the alluvial aquifer at well locations MW-24BR and PGE-8 (CH2M HILL 2006d). This and data from Table 2-6 indicate that the study area is primarily an area of groundwater discharge, with flow upward and to the east/northeast (as discussed in Section 2.4.1).

2.4.3 Time Variation of Water Levels

Groundwater elevations at the site are strongly affected by Colorado River stage. Figure 2-15 shows the normal variation of groundwater elevations in floodplain well cluster MW-33 over a week during the month of June 2006. As shown on Figure 2-15, Colorado River levels may fluctuate up to 4 feet in one day. Wells from all depth intervals in the floodplain respond almost simultaneously to the corresponding changes in river stage (CH2M HILL 2006c). Hydrographs for selected wells in the IM performance monitoring and IM No. 3 injection areas are included in Appendix C.

The magnitude of well response to river levels becomes less distinct with distance from the river. Figure 2-16 presents hydrographs for three shallow wells located with increasing distance from the river over a 6-month period. It is evident that well MW-28-25 (located closest to the river) is much quicker to respond to changes in river stage than MW-19 (located along Park Moabi Road) and OW-1S located farther west at the IM No. 3 injection area. However, the long-term hydrograph clearly shows the influence of river stage on water levels, even for interior wells located more than 2,000 feet from the river. The majority of wells have their lowest elevations during the months of December and January when river stages tend to be at their lowest.

2.4.4 Groundwater Flow Directions

As noted in Section 2.4.1, horizontal groundwater flow within the Alluvial Aquifer is easterly outside of the floodplain, but is strongly westward towards the pumping wells on the floodplain. In recent 2006 compliance monitoring data, evidence of hydraulic mounding is present in the middle and deep wells around the active injection well IW-2 (CH2M HILL 2006e). Site-wide vertical gradients are predominantly upward, except where pumping is strong enough to change natural gradients to downwards towards the pumping wells. The magnitudes of these gradients are strongly affected by pumping rates and river elevations. Refer to PG&E’s quarterly IM performance monitoring reports (CH2M HILL 2006c) for the evaluation of hydraulic gradients and groundwater flow in the active groundwater extraction area at the Topock site.

2.5 Groundwater Budget

The main source of recharge to the Mohave Valley groundwater basin is from the Colorado River, which acts primarily as a losing stream throughout the northern and central areas of the valley (Anderson and Freethey 1995). In the southern end of the valley where the Topock model domain is situated, the river is a net-gaining stream and, as such, represents a location of groundwater discharge in the basin. This is consistent with published hydrogeologic work in the region (Anderson and Freethey 1992; Metzger and Loeltz 1973), which reports that the vast majority of surface and groundwater in any lower Colorado River basin is associated with the river. Water levels in Topock Marsh are maintained slightly higher than the river at Topock by diverting river water at an upstream location near Needles. The marsh is therefore an indirect source of river recharge to groundwater in the study area. Smaller sources of recharge in Mohave Valley are precipitation recharge in bordering mountains, irrigation return flow, and groundwater underflow from adjacent groundwater basins such as Sacramento Valley (Arizona). Groundwater discharge in Mohave Valley is primarily into the river in the southern area, as described above, but is also in the form of evapotranspiration along the river floodplain and pumping for municipal, industrial, and agricultural use.

Assigned water budget components specific to the model domain are discussed below. Methods used to assign these components to the model are discussed in Section 4.3. The approximate groundwater budget for the model domain is presented in Table 2-7.

2.5.1 Natural Recharge Sources

As discussed above, the vast majority of recharge water for the Mohave Valley groundwater system is from the Colorado River. Most of this recharge occurs in the northern portion of the valley, where the river acts as a losing stream and saturates the alluvial and fluvial material. The boundaries for the groundwater flow model domain, shown on Figure 1-1, are arbitrarily assigned to contain a portion of the southern end of Mohave Valley and the area around the Topock site. The main source of recharge to the model domain is from Topock Marsh. This component was not included in the previous model, as more attention was focused on the Topock site area on the west side of the river. The Havasu National Wildlife Refuge (HNWR) maintains an average water elevation in the marsh of about 455.9 feet msl, and this produces an estimated recharge to groundwater of 6,960 ± 1,650 acre-feet per year (afy) (Guay 2001). Approximately one-half of Topock Marsh lies within the model domain (Figure 1-1), so for the model this figure would drop to 3,500 afy. The majority of this recharge eventually discharges to the river.

The next greatest source of recharge is groundwater underflow into the northern model boundary to the west of Topock Marsh. This represents groundwater originating in northern Mohave Valley that flows into the arbitrarily-assigned model domain boundary. The amount of flux entering the boundary was calculated by assuming hydraulic conductivity to be an average of values assigned in site areas (about 30 feet per day), thickness based upon regional gravity survey (from about 1,100 feet in the west to about 1,400 feet at the marsh boundary), and gradient based on the regional river gradient in the area (1.3×10^{-4}). This corresponds to a total flux of about 400 afy.

A third source of recharge is underflow beneath Sacramento Wash from the east. This wash drains a substantial portion of southeastern Mohave Valley. There are no published estimates of groundwater flow beneath the wash, and the wash itself is not gauged. The previous groundwater model used an estimated 100 afy (Peter Martin, USGS, personal communication, 2005) of groundwater recharge into the model domain from beneath Sacramento Wash on the basis of Technical Workgroup discussions. This will be readjusted for the current model during calibration.

Some precipitation recharge originates in the Chemhuevi Mountains and Sacramento Mountains to the south and southwest of the Topock site, respectively. Precipitation in the highest parts of these mountains is likely no more than 10 inches/year (Metzger and Loeltz 1973). The metamorphic bedrock that makes up these mountains generally has very low fracture permeability. As a result, only a small fraction of rainfall provides recharge to the Alluvial Aquifer, which was estimated to be about 0.1 inch/year. This corresponds to approximately 200 afy over the southwest end of the Mohave Valley. Some of this recharge would be in the form of rainwater flowing downward into the mountain bedrock, traveling northward, and eventually flowing upwards into the overlying alluvium. Vertically-upward gradients between bedrock and alluvium in the MW-24 cluster indicate there is upwelling of water from bedrock into the Alluvial Aquifer. Also, some amount of mountain-front recharge is expected where surface runoff from the mountains recharges into alluvium along the upper margin of the pediment (Metzger and Loeltz 1973).

A small amount (10 afy) of groundwater underflow was assigned to the central-western boundary and northeastern boundary to account for underflow associated with several small drainages entering the model domain in this area. The assigned flux is based on regional model estimates by the USGS (Peter Martin, personal communication 2005).

2.5.2 Discharge

As the Colorado River flows into Topock Canyon at the southern end of Mohave Valley, the Alluvial Aquifer decreases in thickness, forcing groundwater to discharge. Because the river levels are artificially maintained by operations of Davis and Havasu dams, river levels fluctuate daily and seasonally. As a result, there is a net recharge from the river during periods of rising water levels in late winter and spring. During the rest of the year, there may be portions of the day where river levels exceed nearby groundwater levels, but during the majority of the time, the groundwater levels are higher than the river. The net groundwater discharge to the river within the model domain is estimated to be approximately 2,600 afy. This is a larger amount than the previous model, which did not account for the relatively large amount of recharge from Topock Marsh and, therefore, did not project as much discharge from the Arizona side of the river.

Other components of discharge in the southern portion of Mohave Valley are local pumping, evapotranspiration in river floodplain areas, and underflow in the fluvial material beneath the riverbed through Topock Gorge.

The total of groundwater extraction (not including current IM extraction) in and around the model domain is approximately 640 afy. Available records indicate that groundwater extraction occurs within the model domain in two areas. One is the Topock 2/Topock 3 well pair located about 1 mile northeast of the compressor station in Arizona. These wells supply the Topock station with water, along with several other private users in Arizona. In 2004, combined pumping from the wells was about 80 afy. The other pumping location is at Park Moabi to the northwest of the Topock Site. Available records indicate the supply well for this facility extracts approximately 6 afy.

IM extraction was included in the model during calibration of pumping test and monthly time-varying data over the past year (discussed in Section 5.0).

Other pumping centers are not within the model domain but are close enough to the boundaries to be included in the model. The largest of these is the Golden Shores, Arizona community in the northeast corner of the model. Golden Shores consists of two sections (2 square miles) joined at a common corner. Groundwater pumping occurs from various private wells in the community but mostly from four wells owned by the Golden Shores Water Company. The combined total pumping from these wells was about 453 afy in 2003. Although less than one-quarter of the Golden Shores area is contained within the model domain (Figure 1-1), this pumping rate was assigned to the northeast corner of the model domain (Section 4.3).

Another pumping well, the Serrano Well, has been reported as pumping at 220 gpm (Kristie Kilgore, ADEQ, email communication July 18, 2005). The well is located off the eastern edge of the model boundary about halfway between the railroad right-of-way and Golden Shores. The well’s average annual pumping is estimated to be 70 afy.

Two wells operated by El Paso Natural Gas Corporation at their Mohave Transfer Station, MTS-1 and MTS-2, are located off the eastern model boundary, between I-40 and the railroad. These wells together pump about 30 afy.

Evapotranspiration losses occur in the river floodplain areas where vegetation is more prominent and the water table is close to the ground surface. The previously-calibrated model estimate of evapotranspiration in this region was about 140 afy. This assumes that evapotranspiration will only take place when the water table is within 10 feet of land surface and that significant rates only occur where aerial photos indicate dense vegetation.

The remaining discharge is underflow in fluvial materials beneath the river that leaves the model at the southern boundary. Because the aquifer is very narrow at this point, the estimated groundwater discharge is small, about 10 afy.

7.0 References

Note: this section includes references cited in Sections 1, 3 and 4 (initially submitted June 2, 2006) and new Section 2. The report references will be updated as additional sections are submitted.

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Tables

TABLE 2-1
Drilling and Well Information Summary
Groundwater Model Report
PG&E Topock Compressor Station

Well ID	Ground Elevation feet msl	Screened Interval feet bgs	Depth Interval & Monitored Zone	Boring Total Depth feet bgs	Depth to Bedrock feet bgs	Other Testing and Logging
RFI & IM Groundwater Wells						
MW-09	534	77 - 87	UA - alluvial	89	86	
MW-10	529	74 - 94	UA - alluvial	99	--	
MW-11	521	63 - 83	UA - alluvial	87	--	
MW-12	483	28 - 48	UA - alluvial	50	47	
MW-13	487	29 - 49	UA - alluvial	50	--	
MW-14	570	111 - 131	UA - alluvial	135	--	
MW-15	640	181 - 201	UA - alluvial	204	--	
MW-16	655	198 - 218	UA - alluvial	218	--	
MW-17	588	130 - 150	UA - alluvial	151	--	
MW-18	544	85 - 105	UA - alluvial	110	--	
MW-19	499	46 - 66	UA - alluvial	66	--	
MW-20-70	499	50 - 70	UA - alluvial	70	--	
MW-20-100	499	90 - 100	MA - alluvial	100	--	aquifer test
MW-20-130	499	121 - 131	LA - alluvial	132	--	geophysical log & aquifer test
MW-21	506	39 - 59	UA - alluvial	62	--	
MW-22	458	6 - 11	UA - alluvial	12	12	
MW-23	505	60 - 80	Miocene Conglomerate	80	2	slug test
MW-24A	565	104 - 124	UA - alluvial	125	--	aquifer pumping test
MW-24B	563	194 - 214	LA - alluvial	218	--	aquifer pumping test
MW-24BR	563	378 - 438	Pre-Tertiary Bedrock	442	225	geophysical log & slug test
MW-25	541	85 - 105	UA - alluvial	107	--	
MW-26	503	52 - 72	UA - alluvial	74	--	
MW-27	459	7 - 17	UA - alluvial	17	--	
MW-28-25	465	13 - 23	UA - fluvial	23	--	
MW-28-90	465	70 - 90	UA - fluvial	148	141	geophysical log
MW-29	483	30 - 40	UA - fluvial	40	--	
MW-30-30	466	12 - 32	UA - fluvial	32	--	
MW-30-50	466	41 - 51	UA - fluvial	63	--	
MW-31-60	495	42 - 62	UA - alluvial	65	--	
MW-31-135	495	113 - 133	LA - alluvial	168	148	geophysical log
MW-32-20	459	10 - 20	UA - fluvial	20	35	
MW-32-35	459	28 - 35	MA - fluvial	37	--	
MW-33-40	485	30 - 40	UA - fluvial	40	--	
MW-33-90	485	77 - 87	MA - fluvial	130	--	geophysical log
MW-33-150	485	132 - 152	LA - alluvial	158	--	
MW-33-210	485	190 - 210	LA - alluvial	237	222	geophysical log
MW-34-55	459	45 - 55	MA - fluvial	57	--	
MW-34-80	459	73 - 83	LA - fluvial	93	88	geophysical log
MW-34-100	459	90 - 100	LA - fluvial	116	98	geophysical log
MW-35-60	481	37 - 57	UA - alluvial	57	--	
MW-35-135	481	117 - 137	LA - alluvial	168	165	geophysical log

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Well ID	Ground Elevation feet msl	Screened Interval feet bgs	Depth Interval & Monitored Zone	Boring Total Depth feet bgs	Depth to Bedrock feet bgs	Other Testing and Logging
MW-36-20	467	10 - 20	UA - fluvial	70	--	
MW-36-40	467	30 - 40	UA - fluvial	90	--	
MW-36-50	467	46 - 51	MA - fluvial	108	--	
MW-36-70	467	60 - 70	MA - fluvial	70	--	
MW-36-90	467	80 - 90	LA - fluvial	90	--	
MW-36-100	467	88 - 98	LA - fluvial	108	98	geophysical log
MW-37S	484	64 - 84	UA - alluvial	84	--	
MW-37D	484	180 - 200	LA - alluvial	228	200	geophysical log
MW-38S	523	75 - 95	UA - alluvial	85	--	
MW-38D	523	153 - 173	LA - alluvial	195	185	geophysical log
MW-39-40	465	30 - 40	UA - fluvial	70	--	
MW-39-50	465	47 - 52	UA - fluvial	80	--	
MW-39-60	465	49 - 59	UA - fluvial	118	--	
MW-39-70	465	60 - 70	MA - alluvial	70	--	
MW-39-80	465	70 - 80	MA - alluvial	80	--	
MW-39-100	465	80 - 100	LA - alluvial	118	108	geophysical log
MW-40S	566	115 - 135	UA - alluvial	135	--	
MW-40D	567	240 - 260	LA - alluvial	268	265	geophysical log
MW-41S	477	40 - 60	UA - alluvial	60	--	
MW-41M	477	170 - 190	MA - alluvial	190	--	
MW-41D	477	271 - 291	LA - alluvial	320	301	geophysical log
MW-42-30	461	10 - 30	UA - fluvial	30	--	
MW-42-55	461	40 - 50	MA - fluvial	53	--	
MW-42-65	461	55 - 65	MA - fluvial	81	70	geophysical log
MW-43-25	460	15 - 25	UA - fluvial	25	--	
MW-43-75	460	65 - 75	LA - fluvial	75	--	
MW-43-90	460	80 - 90	LA - fluvial	97	89	geophysical log
MW-44-70	471	60 - 70	MA - fluvial	134	124	
MW-44-115	471	105 - 115	LA - alluvial	134	124	
MW-44-125	471	115 - 125	LA - alluvial	134	124	geophysical log
MW-45-95	467	85 - 95	LA - fluvial	97	95	
MW-46-175	481	165 - 175	LA - alluvial	216	211	
MW-46-205	481	195 - 205	LA - alluvial	216	211	geophysical log
MW-47-55	483	45 - 55	MA - alluvial	288	280	
MW-47-115	483	105 - 115	LA - alluvial	288	280	geophysical log
MW-48	484	125 - 135	Miocene Conglomerate	153	50	
MW-49-135	483	125 - 135	LA - alluvial	384	370	
MW-49-275	483	265 - 275	LA - alluvial	384	370	
MW-49-365	483	355 - 365	LA - alluvial	384	370	geophysical log
MW-50-95	495	85 - 95	MA - alluvial	249	227	
MW-50-200	495	190 - 200	LA - alluvial	248	227	geophysical log
MW-51	502	95 - 110	MA - alluvial	114	113	
TW-01	621	169 - 269	Upper, Middle & Lower	312	271	IM test well, aquifer test
TW-2S	497	44 - 94	UA - alluvial	98	--	IM extraction well, aquifer test
TW-2D	497	113 - 153	LA - alluvial	180	150	IM extraction well, aquifer test
TW-3D	497	110 - 155	LA - alluvial	157	157	IM extraction well, aquifer test

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Well ID	Ground Elevation feet msl	Screened Interval feet bgs	Depth Interval & Monitored Zone	Boring Total Depth feet bgs	Depth to Bedrock feet bgs	Other Testing and Logging
TW-04	483	210 - 250	LA - alluvial	288	267	IM test well, aquifer test
TW-05	497	110 - 150	LA - alluvial	150	227	IM test well, aquifer test
PE-01	467	80 - 90	LA - fluvial	180	89	IM extraction well, aquifer test
IW-02	547	170 - 330	LA - alluvial	412	350	IM-3 injection well, aquifer test
IW-03	551	160 - 320	LA - alluvial	411	348	IM-3 injection well, aquifer test
CW-1M	563	140 - 190	MA - alluvial	360	--	IM-3 compliance monitoring well
CW-1D	564	250 - 300	LA - alluvial	360	358	IM-3 compliance monitoring well
CW-2M	547	150 - 200	MA - alluvial	385	--	IM-3 compliance monitoring well
CW-2D	547	285 - 335	LA - alluvial	385	380	IM-3 compliance monitoring well
CW-3M	532	170 - 220	MA - alluvial	360	--	IM-3 compliance monitoring well
CW-3D	532	270 - 320	LA - alluvial	360	360	IM-3 compliance monitoring well
CW-4M	516	120 - 170	MA - alluvial	337	--	IM-3 compliance monitoring well
CW-4D	516	230 - 280	LA - alluvial	337	334	IM-3 compliance monitoring well
OW-1S	548	85 - 115	UA - alluvial	291	--	IM-3 observation well
OW-1M	548	165 - 185	LA - alluvial	291	--	IM-3 observation well
OW-1D	548	255 - 275	LA - alluvial	291	--	IM-3 observation well
OW-2S	546	70 - 100	UA - alluvial	350	--	IM-3 observation well
OW-2M	546	190 - 210	LA - alluvial	350	--	IM-3 observation well
OW-2D	547	310 - 330	LA - alluvial	350	347	IM-3 observation well
OW-3S	550	85 - 115	UA - alluvial	275	--	IM-3 observation well
OW-3M	550	180 - 200	LA - alluvial	275	--	IM-3 observation well
OW-3D	550	245 - 265	LA - alluvial	275	--	IM-3 observation well
OW-5S	549	70 - 110	UA - alluvial	350	--	IM-3 observation well
OW-5M	549	210 - 250	LA - alluvial	350	--	IM-3 observation well
OW-5D	550	300 - 320	LA - alluvial	350	346	IM-3 observation well
Other Wells in Project Site						
PGE-06	562	110 -153	UA - alluvial	180	--	inactive supply well
PGE-07	563	195 - 330	Basal alluvial & Bedrock	330	180	inactive supply well
PGE-08	595	405 - 554	Pre-Tertiary Bedrock	562	85	former injection well
PGE-9N	460	26 - 95	Fluvial	95	94	inactive supply well
PGE-9S	459	30 - 100	Fluvial	105	104	inactive supply well
Park Moabi	517	80 - 200	LA - alluvial	250	--	active production well
MW-01	660	201 - 211	UA - alluvial	212	--	New Pond site compliance well
MW-03	649	189 - 207	UA - alluvial	207	--	New Pond site compliance well
MW-04	624	165 - 175	UA - alluvial	180	--	New Pond site compliance well
MW-05	635	176 - 185	UA - alluvial	188	--	New Pond site compliance well
MW-06	642	185 - 194	UA - alluvial	194	--	New Pond site compliance well
MW-07	630	173 - 182	UA - alluvial	188	--	New Pond site compliance well
MW-08	627	169 - 178	UA - alluvial	179	--	New Pond site compliance well
P-2	624	239 - 249	UA - alluvial	249	--	New Pond site piezometer
PT-1	622	220 - 260	UA - alluvial	280	--	New Pond site aquifer test well
MWP-08	677	181 - 211	UA - alluvial	211	--	Old Pond site monitoring well
MWP-10	675	194 - 234	UA - alluvial	235	230	Old Pond site monitoring well
MWP-12	662	96 - 136	UA - alluvial	217	130	Old Pond site monitoring well

TABLE 2-1
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Well ID	Ground Elevation feet msl	Screened Interval feet bgs	Depth Interval & Monitored Zone	Boring Total Depth feet bgs	Depth to Bedrock feet bgs	Other Testing and Logging
Investigation Borings in Project Site						
IW-B1	548	--	--	411	340	IM-3 exploration boring
B-25	673	--	--	210	198	RFI exploration boring
XMW-9	538	--	--	78	63	RFI exploration boring
CB-08	460	--	--	40	34	I-40 Bridge boring
CB-10	461	--	--	114	--	I-40 Bridge boring
CB-12	458	--	--	123	72	I-40 Bridge boring
CB-14	458	--	--	108	80	I-40 Bridge boring

Notes:

1. Ground surface elevations in feet above mean sea level (msl); rounded to whole-foot values.
2. Well screen depths in feet below ground surface (bgs); rounded to whole-foot values.
4. Aquifer intervals: UA = screen elevations between 455 and 425' msl, MA = between 425 and 395' msl, LA = below 395' msl. Monitored zone refers to the general hydrostratigraphic units (alluvial, fluvial, bedrock).

TABLE 2-2
Site Hydrostratigraphic Units, June 2006 Update
Groundwater Model Report
PG&E Topock Compressor Station

Stratigraphic Age	Site Hydrostratigraphic Units: Alluvial Deposits		Characteristics	Fluvial Deposits		Characteristics
Holocene	**Younger Alluvium**	**Qya**	unconsolidated sandy gravel & silty/clayey gravel (youngest alluvial deposits and surficial deposits, undifferentiated)	**Upper Fluvial Sand & Silt** (Floodplain Area)	**Qr3**	unconsolidated sand & silty sand (no gravel), massive-bedded, very well-sorted; contains fine-gr. organic matter
				Middle Fluvial Deposits (Floodplain Area)	**Qr2**	unconsolidated sand, clay & minor gravelly sand, interbedded; clay/silt lenses exhibit both brown and gray (reduced) appearance
				Lower Fluvial Deposits (Floodplain Area)	**Qr1**	unconsolidated sandy gravel & gravelly sand, minor silty gravel (gravel content >15%); subrounded to very well-rounded pebbles & cobbles from distant sources & fluvial transport
				Colorado River Channel Fill fluvial deposits in paleo-channel	**Qr0**	fluvial channel-fill sediments that occur below elevation 360' MSL (deepest river deposits encountered in floodplain borings). Per Caltrans I-40 bridge borings includes moderately consolidated to dense, fine to coarse sand & sandy gravel
Pleistocene	**Older Quaternary Alluvium**	**Qoa**	unconsolidated sandy gravel & silty/clayey gravel (alluvial fan deposits). Comprises moderately-dissected alluvial terraces; terrace/wash slopes are moderate-angle (i.e., 45 degrees)	**Older Fluvial Sediments** (surface outcrop)	**Qrs**	pinkish to tan, weakly to moderately consolidated fine sand, silt/clay, with minor pebble gravel; contains root casts (paleosol); outcrops occur as remnants on alluvial terraces as high as elevation 670' MSL (Old Ponds site)
				Older River Gravels (surface outcrop)	**Qrg**	moderately consolidated to cemented, sandy pebble to boulder gravel; subrounded to very well-rounded clasts from distant sources & fluvial transport (unit outcrops west of MW-20 bench)
Pliocene	**Bouse Formation**	**(Tb)**	pre-Colorado River lacustrine & deltaic deposits: well-bedded, moderately indurated, green clay, siliceous claystone, sandstone & basal marl			
Pliocene to Late Miocene	**Tertiary Alluvium - Upper**	**Toa2**	Moderately consolidated sandy gravel, gravelly sand & silty/clayey gravel (oldest alluvial fan deposits). Comprises deeply-dissected alluvial terraces; terrace canyon walls are vertical/steep	= Tertiary Fanglomerate of Metzger & Loeltz, 1973		Note: Toa1 and Toa2 are subdivisions based on contrasts in hydraulic permeability observed in the Tertiary Alluvium sequence in TW-1, TW-2D, and IW-2 well-flow spinner logs.
	Tertiary Alluvium - Lower	**Toa1**				
Late Miocene	**Basal Alluvium**	**Toa0**	Moderately consolidated silty sand, clayey/silty gravel & minor gravelly sand. Consists of 100% reddish detritus of Miocene conglomerate unit (reworked Tmc deposits) in floodplain area. In other site areas, Toa0 is well-consolidated alluvium, lacks reddish color, and exhibits high-induction geophyiscal log response			
angular unconformity (post-extension erosion)						
Middle Miocene	**Miocene Conglomerate**	**Tmc**	consolidated conglomerate & sandstone containing rock fragments & megabreccia derived from Chemehuevi Mtns. bedrock			
unconformity & detachment faulting						
Pre-Tertiary	**Metamorphic / Igneous Bedrock**	**pTbr**	metadiorite, gneiss & granitic bedrock exposed in Chemehuevi Mountains & underlies the groundwater basin			

Notes:
1. Hydrostratigraphic units that comprise the Alluvial Aquifer in groundwater model area are shaded yellow
2. Bedrock formations, grey shaded, are essentially impermeable but locally yield water where fractured
3. Within groundwater model area, Younger Alluvium and Older Fluvial and River Deposits occur above the water table
4. Stratigraphic age assignments from published geologic reports and are generalized for units in study area

TABLE 2-3

Summary of Well and Aquifer Tests and Estimated Hydraulic Properties

Groundwater Model Report

PG&E Topock Compressor Station, Needles, California

Well ID	HSU[1]	Date	Type of Hydraulic Test [2]	Pumping Rate (gpm)	Duration of Pumping (minutes)	Specific Capacity (gpm/ft)	Estimated Transmissivity (ft^2/day)	Estimated Saturated Thickness (at well, feet)	Estimated Hydraulic Conductivity (ft/day)	Reference
Fluvial HSUs										
MW-27	Qrd	Jan-02	Slug	--	--	--	500	30	15	E&E 2002
MW-28-25	Qr3	Jan-02	Slug	--	--	--	300	30	10	E&E 2002
MW-28-90	Qr1, Qr2	Apr & Jun-04	Devel./Purge	1.2 - 2	50 - 248	2 - 6.3	1,100	50	20	
MW-30-30	Qr3	Jan-02	Slug	--	--	--	100	30	3	E&E 2002
MW-30-30	Qr3	Feb-04	Purge[3]	1.5	--	1.4	400	33	10	
MW-30-50	Qr2	Feb-04	Purge[3]	1.5		5	1,300	21	60	
MW-32-35	Qr2	Feb-04	Purge[3]	1.4		0.6	200	16	10	
MW-34-55	Qr2	Feb-04	Purge[3]	3.5 - 6.3		12 - 16	4,000	35	110	
MW-34-80	Qr1	Feb & Jun-04	Purge[3]	1.4 - 3		1.1 - 1.3	300	16	20	
Alluvial HSUs										
MW-20-100	Toa	Jan-02	Pumping	3.1	525	0.1	100 - 600	86	1-7	E&E 2002
MW-20-130	Toa0	Jan-02	Pumping	6.9	600	0.4	1,200 - 3,400	86	14 - 40	E&E 2002
MW-24B	Toa0	Jan-02	Pumping	6.3	215	0.4	200	115	2	E&E 2002
MW-31-135	Toa	Apr & Jun-04	Devel./Purge	3	21 - 187	1.3 - 1.5	400	21	20	
MW-33-90	Qoa	Feb & Jun-04	Purge[3]	1.5 - 3		4.3 - 6.4	1,400	63	20	
MW-35-60	Qoa	May & Jun-04	Purge	2 - 3.5	18 - 77	2.5 - 3.4	800	32	20	
MW-35-135	Toa	Apr & Jun-04	Devel./Purge	3 - 3.5	31 - 81	2.1 - 2.3	600	20	30	
MW-36-100	Qoa	May & Jun-04	Purge	2	24 - 29	0.7	200	11	20	
MW-37S	Qoa	May & Jun-04	Devel./Purge	2 - 3	18 - 76	5.8 - 10	2,100	56	40	
MW-37D	Toa	Apr & Jun-04	Devel./Purge	3	37 - 99	5.1 - 5.6	1,400	20	70	
MW-38S	Qoa	May & Jun-04	Devel./Purge	2 - 5	24 - 30	1 - 1.1	300	28	10	
MW-38D	Toa0	Apr & Jun-04	Devel./Purge	3	23 - 136	2.1 - 6.8	1,200	32	40	
MW-39-100	Toa	Apr & Jun-04	Devel./Purge	1.5 - 2	23 - 157	2.6 - 6.8	1,300	27	50	
MW-40D	Toa0	May-04	Develop	4.5	55					
TW-1	Toa0	Dec-03	Step	22 - 88	120	11-16	2,200 - 3,300	100	20 - 90	CH2M 2003
TW-2S	Qoa	Apr-04	Pumping	85	825	4 - 5		55		CH2M 2004
TW-2D	Toa, Toa0	May-04	Pumping	98	480	1 - 2		40		CH2M 2004
TW-2S & 2D	Qoa, Toa, Tsu	May-04	Pumping	150	300	1 - 2	3,000	100	300	CH2M 2004

TABLE 2-3

Summary of Well and Aquifer Tests and Estimated Hydraulic Properties

Groundwater Model Report

PG&E Topock Compressor Station, Needles, California

Well ID	**HSU**[1]	**Date**	**Type of Hydraulic Test** [2]	**Pumping Rate** (gpm)	**Duration of Pumping** (minutes)	**Specific Capacity** (gpm/ft)	**Estimated Transmissivity** (ft^2/day)	**Estimated Saturated Thickness** (at well, feet)	**Estimated Hydraulic Conductivity** (ft/day)	**Reference**
Bedrock / Miocene Conglomerate										
MW-23	Tmc	Jan-02	Slug	--	--	--	0.1	27	0.004	E&E 2002
MW-24BR	Tmc	Jan-02	Slug	--	--	--	0.2	60	0.003	E&E 2002
Injection Wells										
IW-2	Toa	Dec-04	Pumping/MLU	140	350	--	2,000 - 11,000[4]	260	7 - 40[4]	CH2M 2005
IW-3	Toa	Dec-04	Pumping/MLU	251	290	--				CH2M 2005
IW-2	Toa	Dec-04	Step	72-185	146	31-34	8,200 - 9,000	267	30	CH2M 2005
IW-3	Toa	Dec-04	Step	80-195	155	41-48	11,000-13,000	255	40 - 50	CH2M 2005

Notes:

1 See Table 2-1 for description and explanation of hydrostratigraphic units (HSU).

2 Slug - slug injection or removal test; Devel. - testing during development; Purge - testing during purging/sampling; Step - variable rate step test; Pumping - constant rate pumping/aquifer test; MLU - (Multi Layer Unsteady state) is a program for drawdown calculations and inverse modeling (pumping tests and recovery tests) of transient well flow in layered aquifer systems. MLU computes the set of aquifer parameters that achieves the best match to observed drawup in all monitoring wells and the pumping well.

3 For well purging data, aquifer properties determined from calculated specific capacity.

4 The MLU analyses here were conducted iteratively using test data from the injection of water at IW-2 and IW-3.
Analyses of the injection test data using the Cooper-Jacob method yielded similar results (T: 2,000 - 14,500 ft2/d, pumping wells only), also reported in CH2M, 2005.

Abbreviations: gallons per minute (gpm), feet per day (ft/day), transmissivity (T)

TABLE 2-4
Ratios of Horizontal to Vertical Hydraulic Conductivity (K_h/K_v) used in the Groundwater Model
Groundwater Model Report
PG&E Topock Compressor Station, Needles, California

Hydrostratigraphic Unit[1]	**Qoa**	**Qr3**	**Qr2**	**Qr1**	**Tb**[2]	**Toa2**	**Toa1**	**Toa0**
Median	10.7	6.1	159.0	9.8	50.0	9.7	118.1	43.6
Average	10.7	6.3	173.7	9.8	50.0	11.9	120.5	56.5
Standard Deviation	3.8	1.5	106.5	0.6	N/A	8.4	19.4	42.0
Minimum	1.2	1.1	13.8	7.7	50.0	4.0	7.3	10.2
Maximum	123.2	9.9	850.5	13.1	50.0	51.0	254.4	140.0
Range	122.0	8.8	836.7	5.4	0.0	47.0	247.1	129.8
Default Value[3]	10	10	10	10	50	10	110	10

Notes:
1. See Table 2-1 for description and explanation of hydrostratigraphic units.
2. The K_h/K_v ratio for the Bouse formation (Tb) was 50 at all model nodes.
3. Default values were excluded from calculations, and are values used in areas of the model where there were no aquifer testing data.

TABLE 2-5

Storativity Values Determined from the Simulation of Three Events[1]

Groundwater Model Report

PG&E Topock Compressor Station, Needles, California

Event & Duration:	Injection Tests at IW-2 & IW-3: hours	Response to pumping well shut off: hours	Aquifer response to monthly changes in river stage: months
Average value[2] of storativity in each model layer			
Model Layer			
1	6.0E-03	6.8E-03	7.5E-02
2	1.4E-04	5.2E-05	5.2E-05
3	1.4E-04	7.7E-05	1.4E-05
4	1.4E-04	9.3E-05	2.3E-05
5	2.2E-04	1.7E-04	2.2E-04
Average	1.3E-03	1.4E-03	1.5E-02
Variability: standard deviation of storativity in each layer			
Model Layer			
1	uniform	uniform	uniform
2	uniform	3.5E-03	3.5E-03
3	uniform	1.6E-04	1.2E-03
4	uniform	1.2E-03	3.0E-04
5	1.1E-03	8.3E-04	1.1E-03
Average value of storativity in each HSU[3]			
HSU			
Qr3	5.2E-03	5.9E-03	6.5E-02
Qr2	1.7E-03	1.8E-03	1.9E-02
Qr1	1.2E-03	1.3E-03	1.4E-02
Qoa	4.1E-03	4.6E-03	5.1E-02
Tb	4.8E-03	5.4E-03	6.0E-02
Toa2	1.6E-03	1.7E-03	1.9E-02
Toa1	1.5E-04	1.1E-04	8.1E-05
Toa0	1.5E-04	1.1E-04	2.8E-05
Tmc	2.2E-04	1.7E-04	2.2E-04
Average	2.1E-03	2.3E-03	2.5E-02

Notes:

a Values were assigned and calibrated according to model layer, not HSU.

b Average values are calculated on a nodal basis, and are not necessarily representative of spatial distribution.

c Values for HSU were determined by weighting the percentage of each HSU in each layer for each model node.

TABLE 2-6
Vertical Hydraulic Gradients in Monitoring Well Clusters
Revised Topock Groundwater Model Report
PG&E Topock Compressor Station

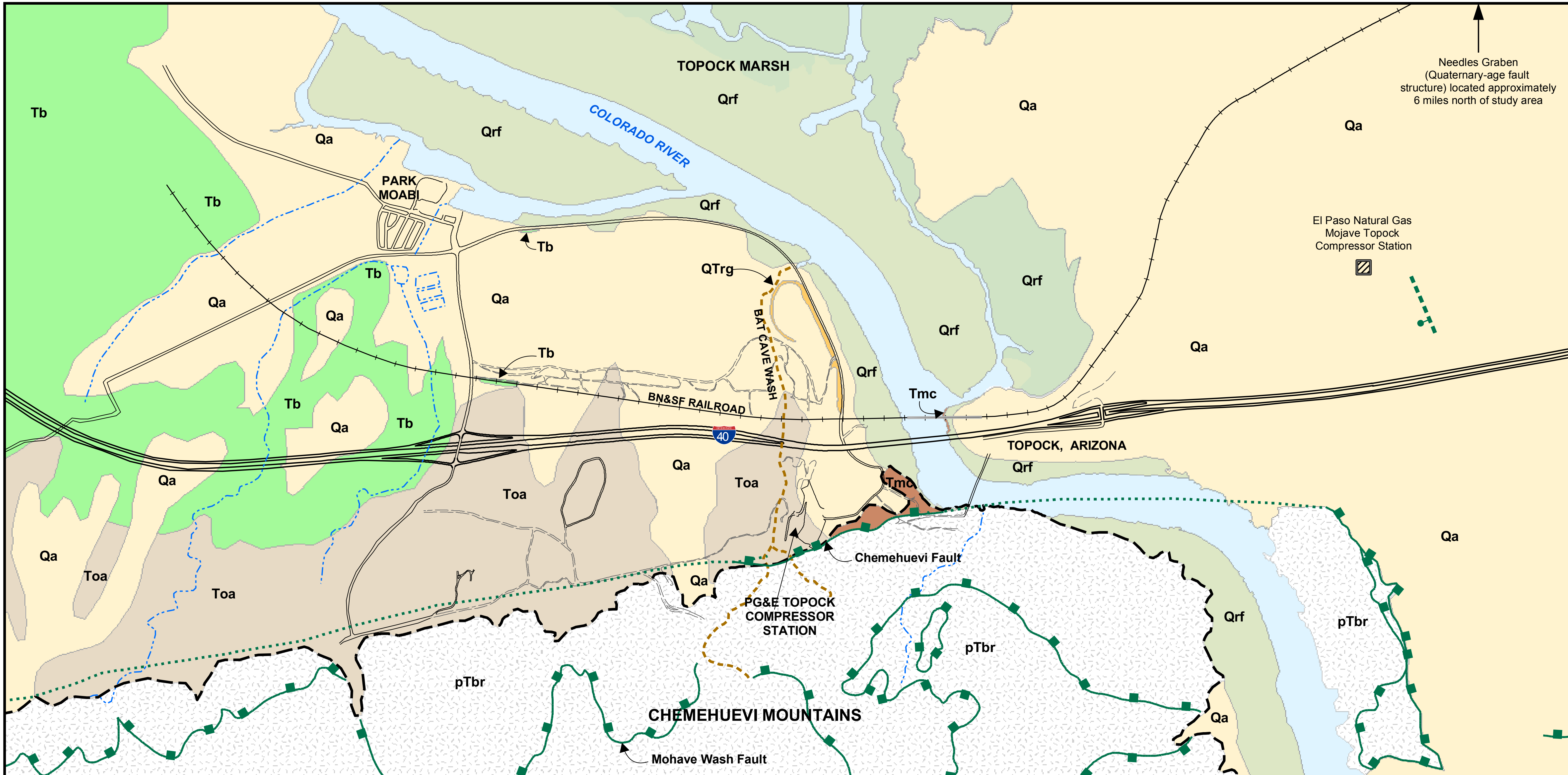
Shallower Well	Deeper Well	Aquifer Depth Interval	Vertical Distance between Screens (feet)	Start Date	End Date	Average Vertical Hydraulic Gradient (feet/foot)	Standard Deviation	Minimum	Maximum
Well Clusters in Bat Cave Wash Area									
MW-24A	MW-24B	UA-LA	89	Jan-04	Feb-04	0.001	1.6E-04	9.0E-04	1.1E-03
MW-24B	MW-24BR	LA-bedrock	205	Aug-01	May-05	0.004	8.8E-04	2.5E-03	6.0E-03
MW-24A	MW-24BR	LA-bedrock	294	Aug-01	May-05	0.003	6.5E-04	2.0E-03	4.4E-03
Well Clusters in Floodplain									
MW-34-055	MW-34-080	UA-MA	28	Jan-04	Feb-04	0.015	6.3E-03	1.9E-03	3.1E-02
MW-43-025	MW-43-075	UA-MA	50	Jun-05	Jun-06	0.004	1.1E-03	3.8E-04	7.1E-03
MW-43-075	MW-43-090	MA-LA	15	Jun-05	Jun-06	0.010	3.8E-03	8.7E-04	1.7E-02
MW-43-025	MW-43-090	UA-LA	65	Jun-05	Jun-06	0.005	1.2E-03	1.2E-03	8.8E-03
Well Clusters along Park Moabi Road									
MW-35-060	MW-35-135	UA-LA	75	Apr-04	Jun-06	-0.002	3.2E-03	-1.1E-02	6.1E-03
MW-47-055	MW-47-115	UA-LA	60	Apr-06	Jun-06	0.001	9.5E-04	-4.2E-03	2.9E-03
MW-26	MW-51	UA-MA	43	May-06	Jun-06	0.001	6.0E-04	-2.1E-04	2.9E-03
MW-19	MW-50-095	UA-MA	34	May-06	Jun-06	-0.001	3.2E-03	-1.2E-02	7.8E-03
MW-50-095	MW-50-200	MA-LA	105	May-06	Jun-06	0.002	4.3E-04	7.5E-04	3.4E-03
MW-19	MW-50-200	UA-LA	139	May-06	Jun-06	0.002	1.5E-03	-2.1E-03	6.9E-03
Well Clusters in the East Mesa									
CW-02M	CW-02D	(LA-1)-(LA-3)	130	Nov-04	Jun-05	0.004	2.3E-04	3.3E-03	4.5E-03
CW-03M	CW-03D	(LA-2)-(LA-3)	98	Nov-04	Jun-05	0.007	3.3E-04	5.9E-03	7.6E-03
CW-04M	CW-04D	(LA-1)-(LA-3)	114	May-05	Jun-05	0.003	1.8E-04	2.5E-03	3.2E-03

Notes:
1. All groundwater elevations measured in wells have been normalized to freshwater head by adjusting for salinity and temperature.
2. The distance between mid-points of well screens is used to calculate vertical gradients at well pairs.
3. Positive vertical gradients denote upward flow, and negative vertical gradients denote downward flow.
Gradients < |0.001| are neutral and considered negligible vertical flow component.
3. Values for MW-24A, MW24B and MW-24BR were calculated from hand measured data, not transducers
4. Alluvial Aquifer depth intervals:
UA = Upper Interval, elevations between 455 and 425' MSL
MA = Middle Interval, elevations between 425 and 395' MSL
LA-1 = Lower Interval, elevations between 395 and 370' MSL
LA-2 = Lower Interval, elevations between 370 and 330' MSL
LA-3 = Lower Interval, elevations between 330 and 250' MSL

TABLE 2-7
Groundwater Budget Components for Model Domain
Groundwater Model Report
PG&E Topock Compressor Station

Recharge Components	Approximate Flux (acre-ft/year)	Totals
Topock Marsh Influx	2,700	
Underflow from North	400	
Underflow from Sacramento Wash	100	
Underflow from Washes to West	10	
Underflow from Washes to East (north of Sacramento Wash)	10	
Precipitation Recharge in South	200	**Total Recharge = 3,420**
Discharge Components		
Extraction from Wells	640	
Evapotranspiration	140	
Underflow to South	10	
Discharge to River	2,630	**Total Discharge = 3,420**

Figures



LEGEND

- Qrf = Quaternary Colorado River and recent Floodplain Deposits
- QTrg = Quaternary-Tertiary River Gravels
- Qa = Quaternary Alluvium and surficial deposits, undifferentiated
- Tb = Bouse Formation
- Toa = Tertiary Alluvium (Fanglomerate of Motzger & Loeltz)
- Tmc = Miocene conglomerate (Bedrock)
- pTbr = Pre-Tertiary Bedrock (Metadiorite, Gneiss, Granitic Rocks)

Normal Fault ball on downthrown side

Detachment Fault barbs on downthrown side

Detachment Fault concealed

NOTE:
Generalized surface geologic map compiled from Metzger and Loeltz (1973), John (1987), Howard and others (1997) and PG&E technical reports.

N

0 1,500 3,000 Feet

FIGURE 2-1
GEOLOGIC MAP OF STUDY AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

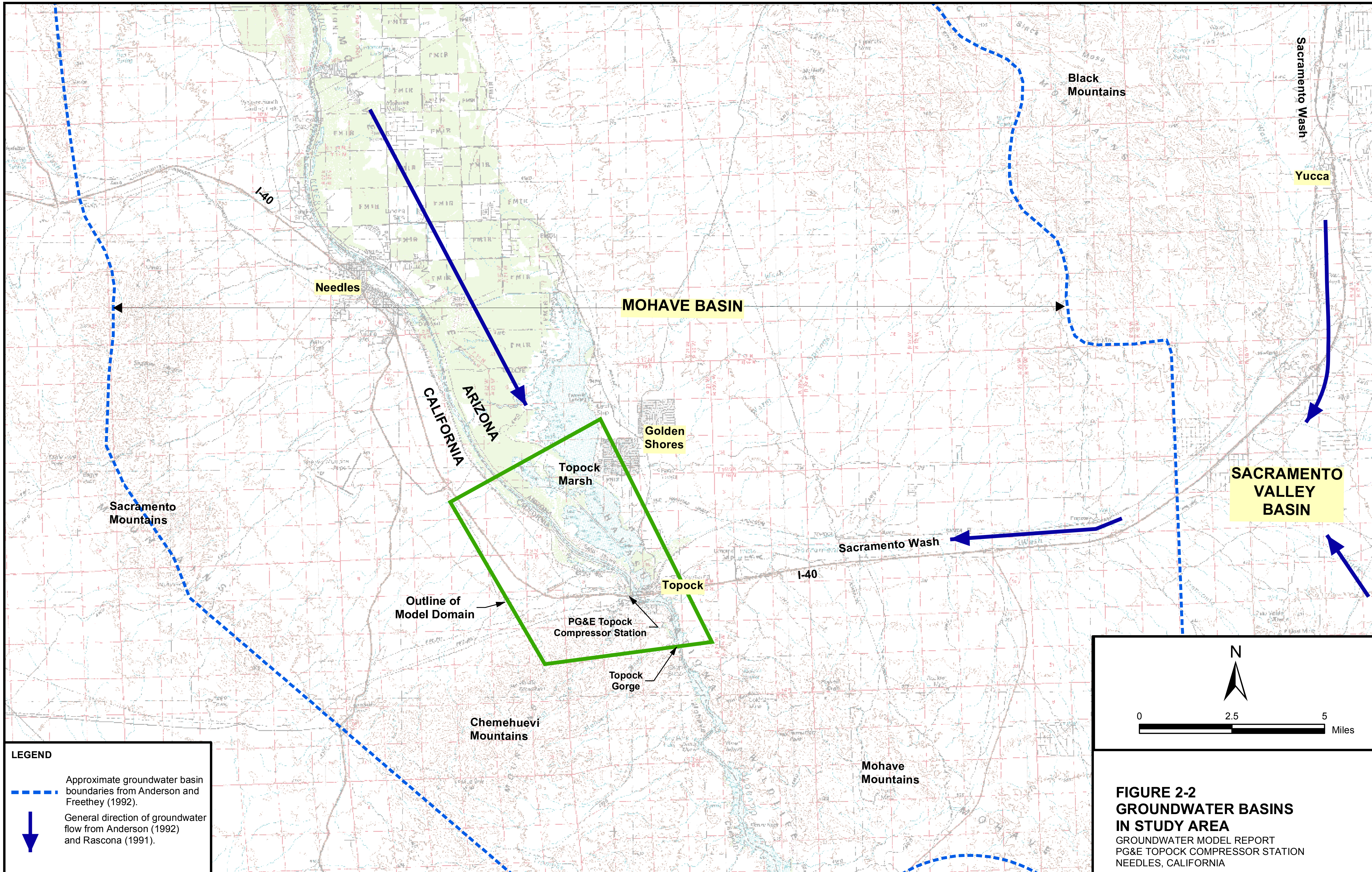


FIGURE 2-2
GROUNDWATER BASINS
IN STUDY AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

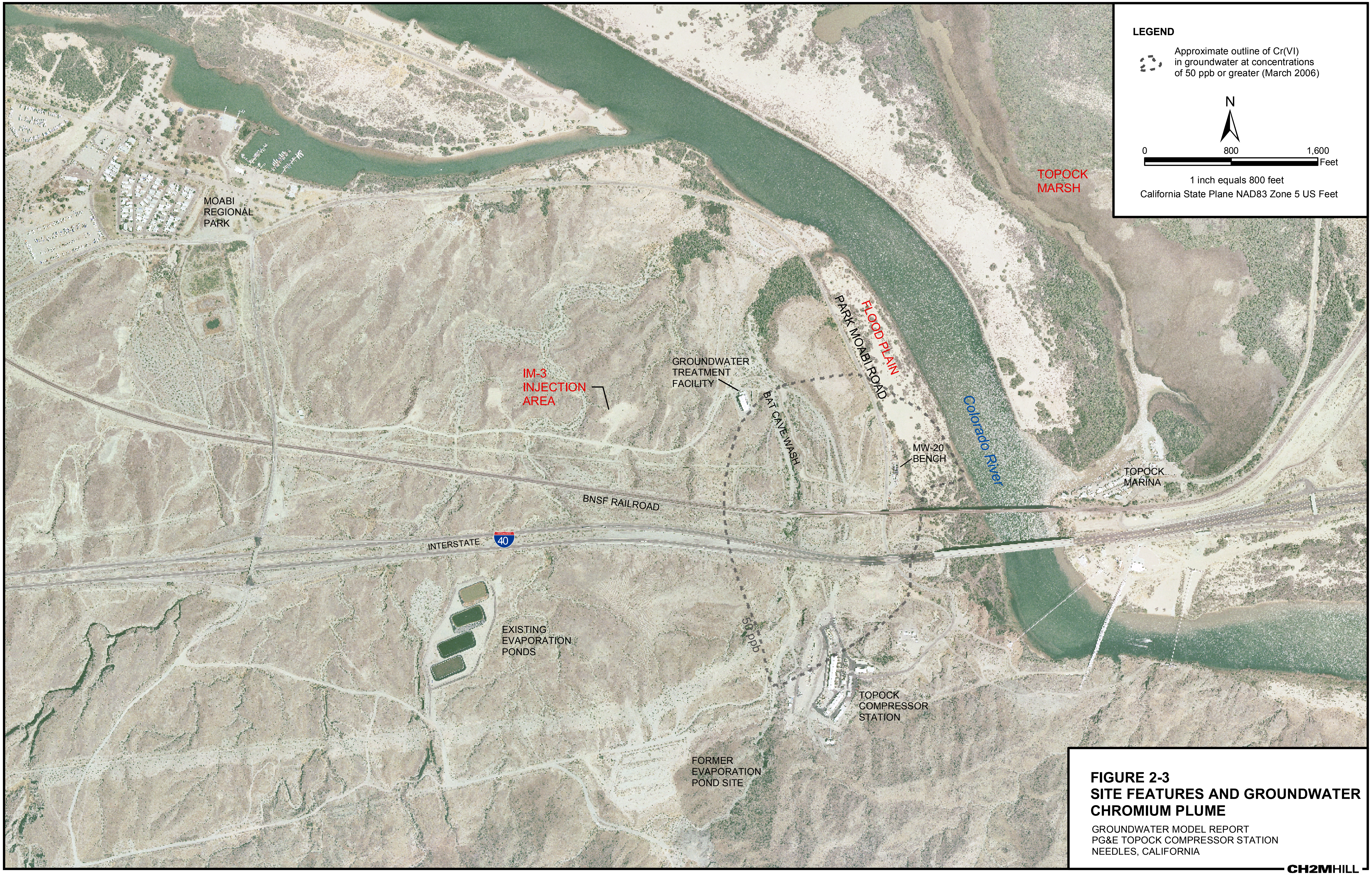


FIGURE 2-3
SITE FEATURES AND GROUNDWATER CHROMIUM PLUME

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

Source: Topographic data from E & E, Inc., 1994, with additional aerial topographic mapping flown April, 2004 (CH2M HILL)

California State Plane, NAD 83, Zone 5, US Feet
Contour interval is 10 feet, with indices at 50 feet.

N

0 350 700 1,400 Feet

1 inch equals 700 feet

FIGURE 2-4
SITE TOPOGRAPHY

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

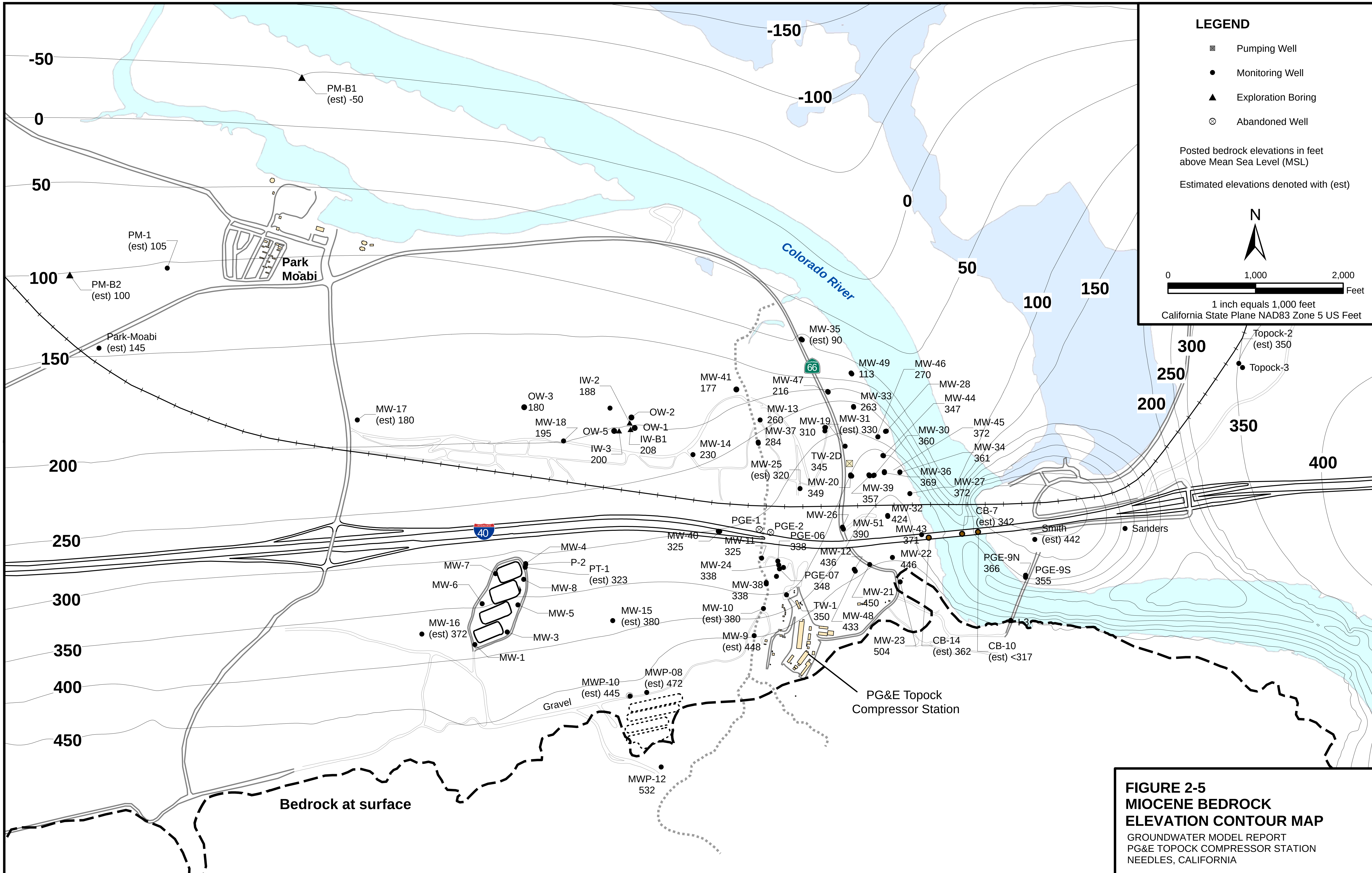


FIGURE 2-5
MIOCENE BEDROCK ELEVATION CONTOUR MAP
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

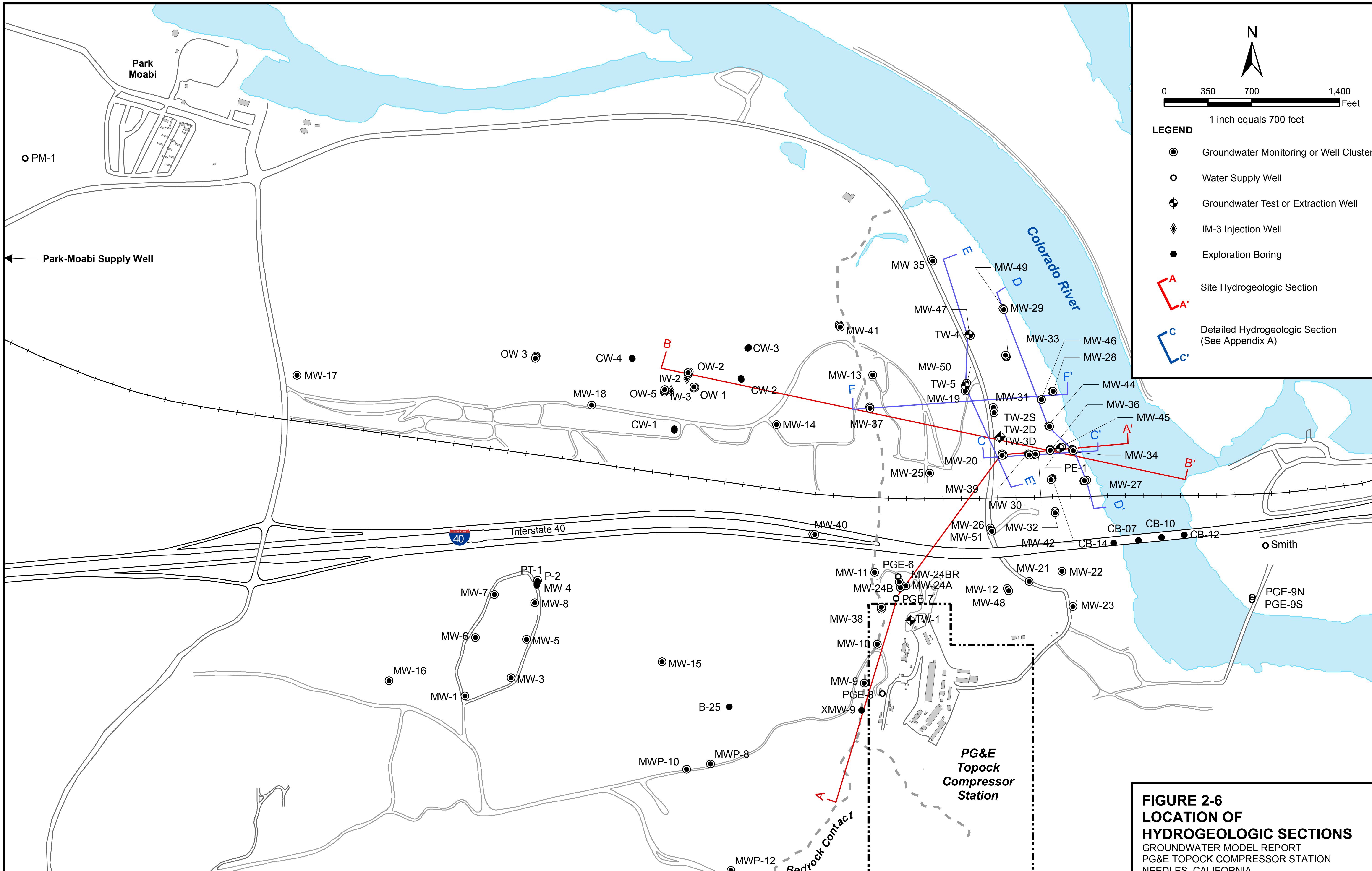


FIGURE 2-6
LOCATION OF HYDROGEOLOGIC SECTIONS
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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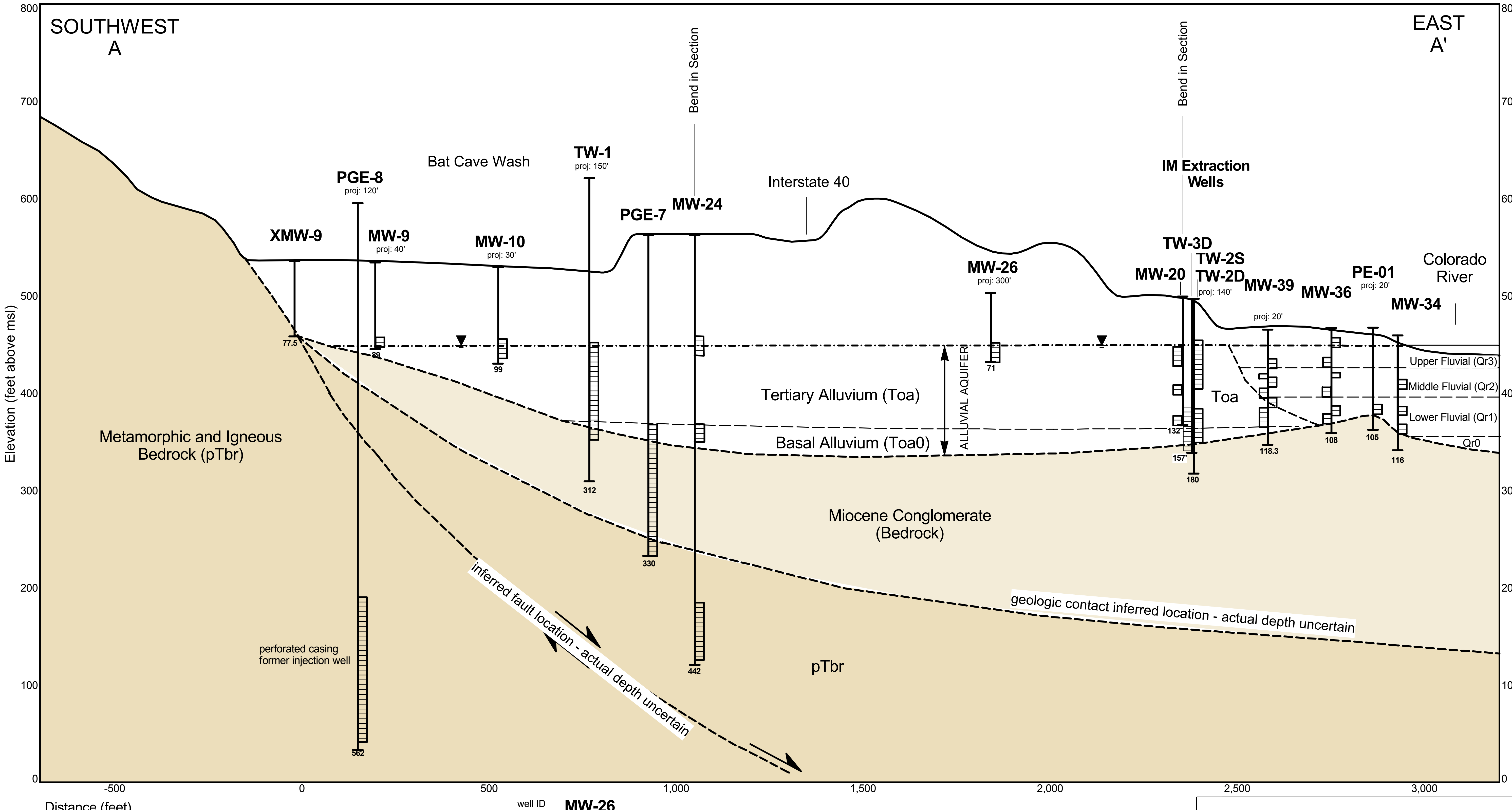
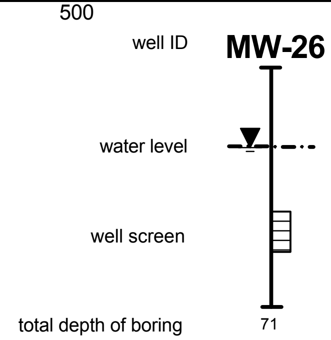




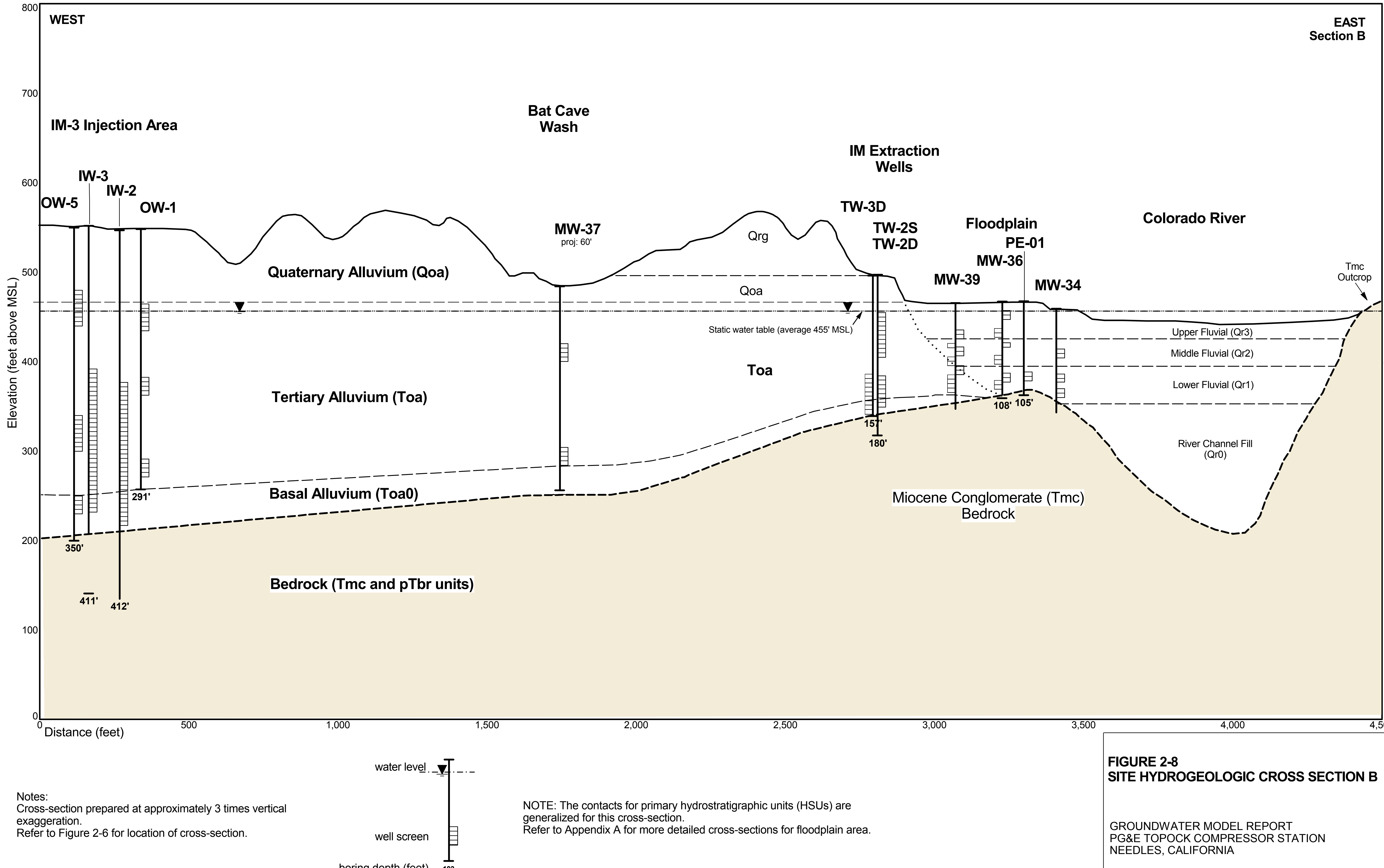
NOTE:
Cross section prepared at approximate 3 times vertical exaggeration.
Refer to Figure 2-6 for location of cross-section.

NOTE: The contacts for primary hydrostratigraphic units (HSUs) are generalized for this cross-section.
Refer to Appendix A for more detailed cross-sections for floodplain area.

FIGURE 2-7
SITE HYDROGEOLOGIC CROSS SECTION A

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL



Notes:
Cross-section prepared at approximately 3 times vertical exaggeration.
Refer to Figure 2-6 for location of cross-section.

NOTE: The contacts for primary hydrostratigraphic units (HSUs) are generalized for this cross-section.
Refer to Appendix A for more detailed cross-sections for floodplain area.

FIGURE 2-8
SITE HYDROGEOLOGIC CROSS SECTION B

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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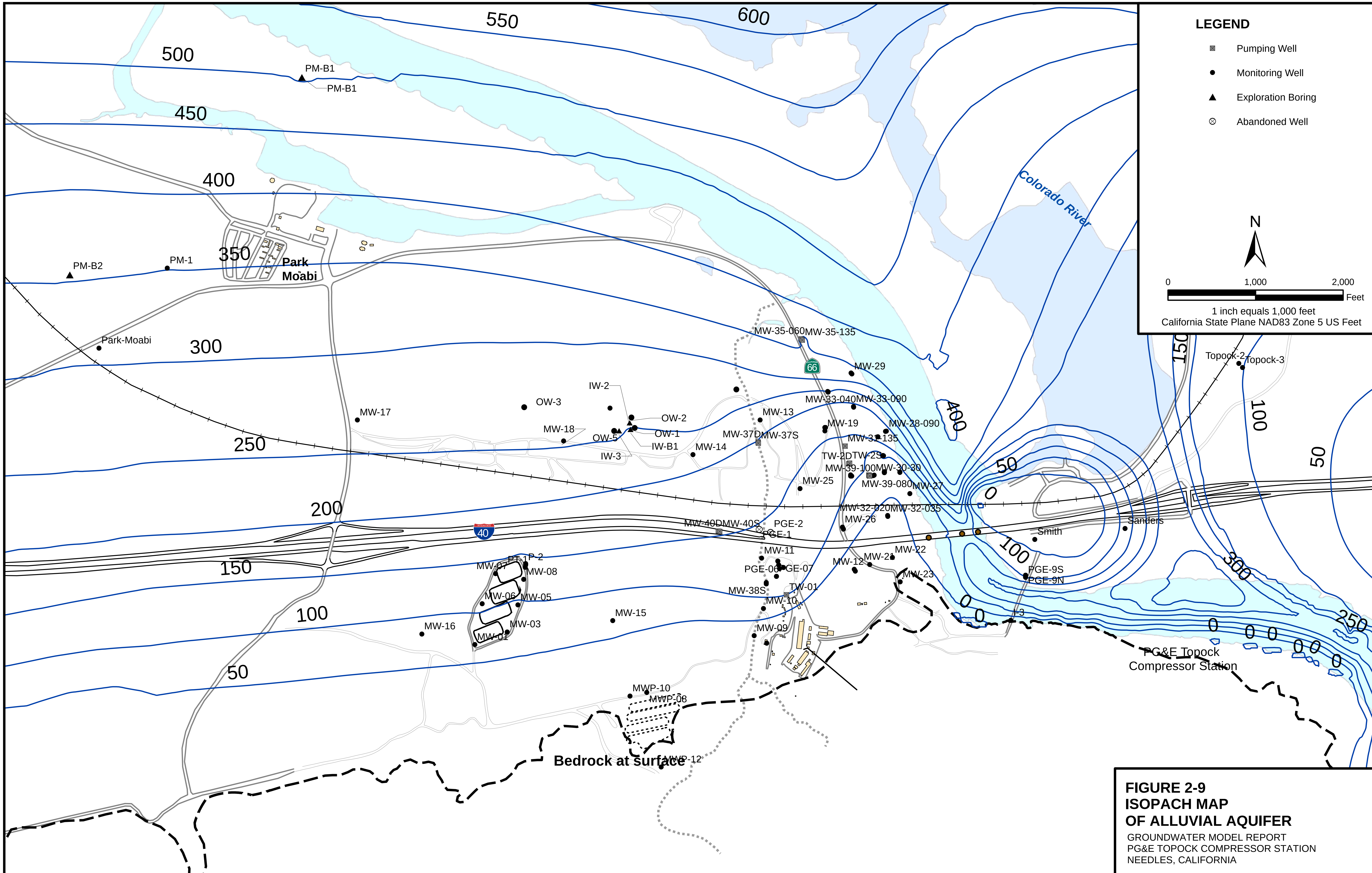

FIGURE 2-9
ISOPACH MAP
OF ALLUVIAL AQUIFER
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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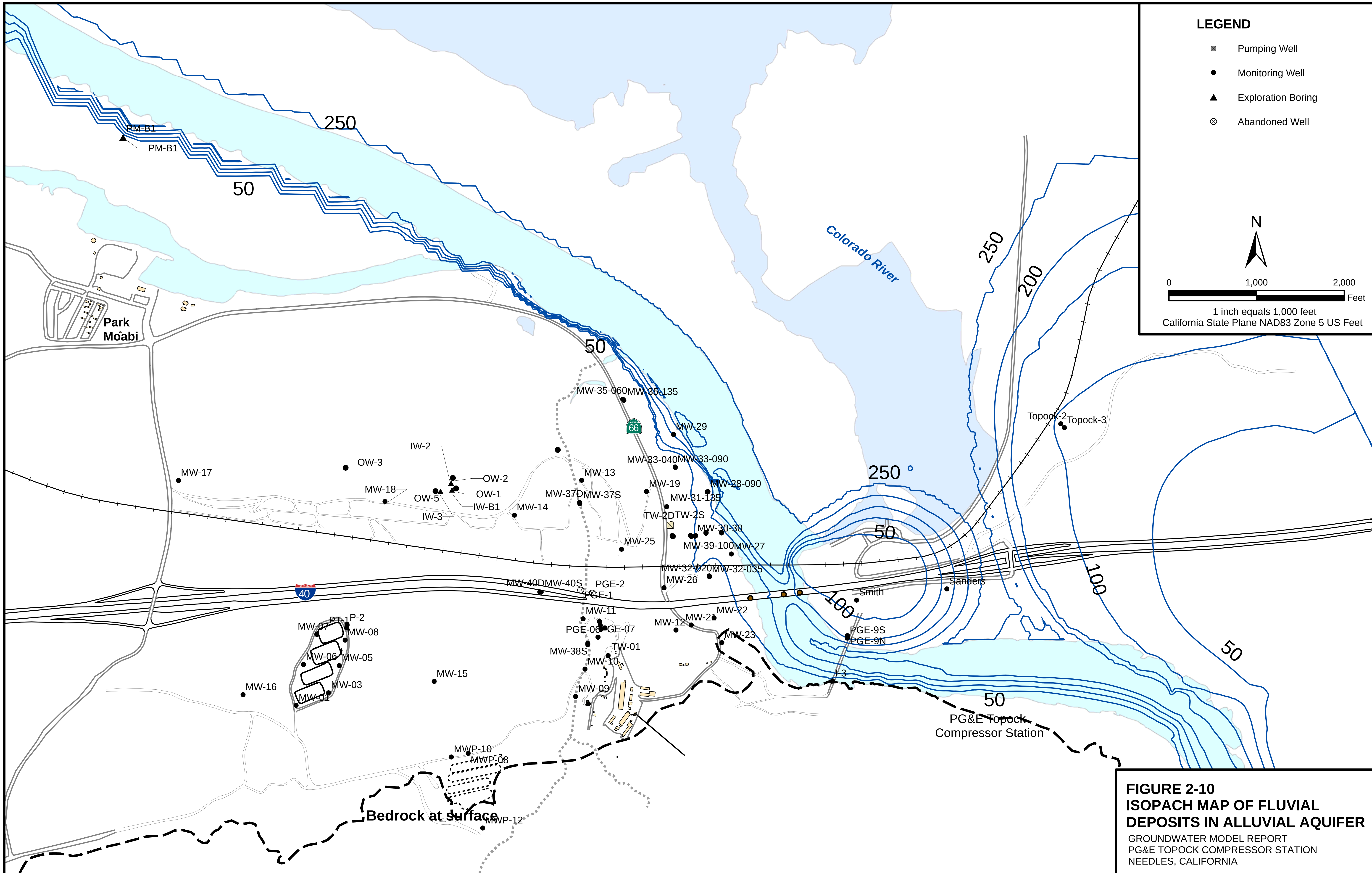

FIGURE 2-10
ISOPACH MAP OF FLUVIAL DEPOSITS IN ALLUVIAL AQUIFER
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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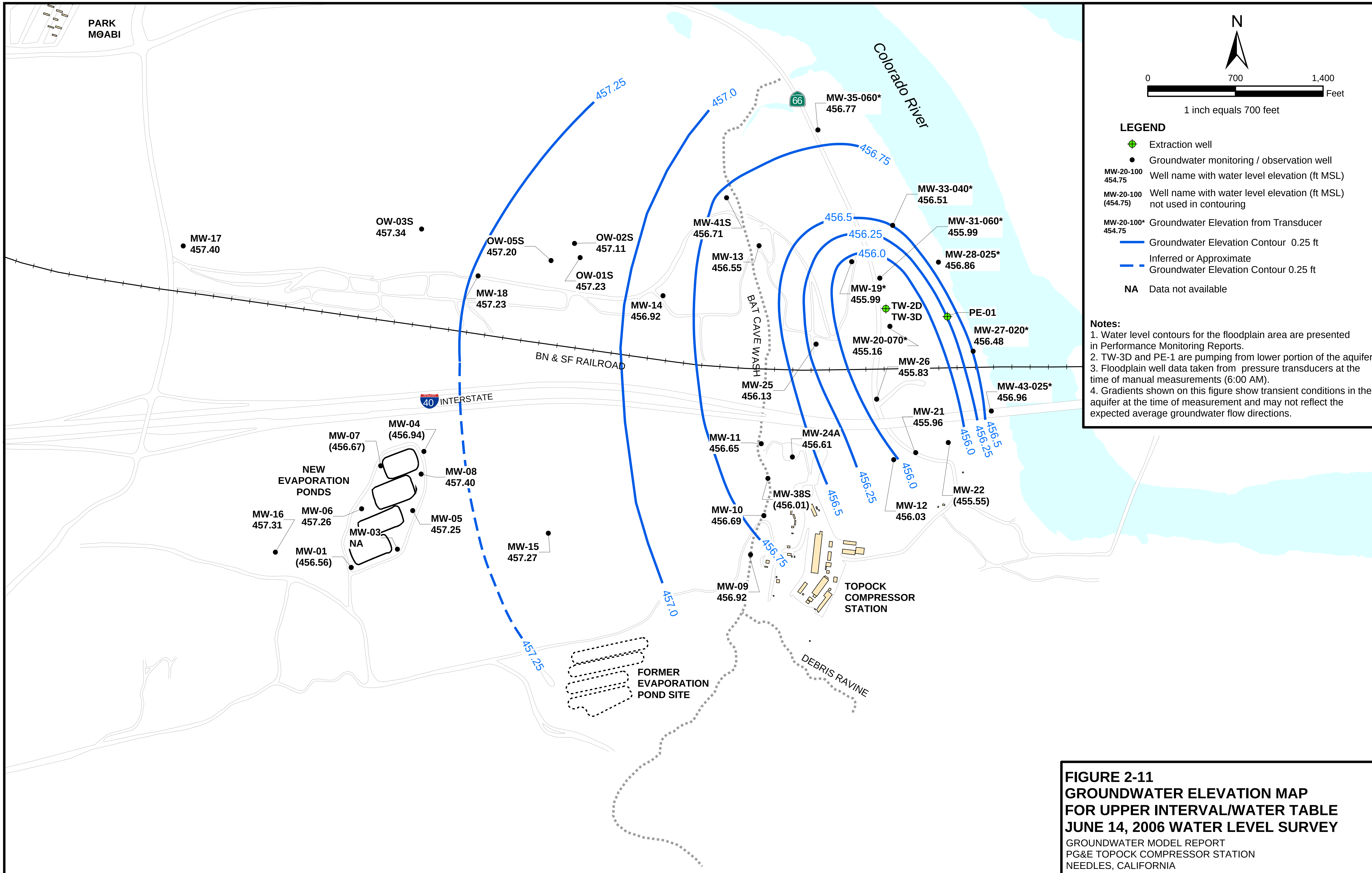

FIGURE 2-11
GROUNDWATER ELEVATION MAP FOR UPPER INTERVAL/WATER TABLE JUNE 14, 2006 WATER LEVEL SURVEY
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

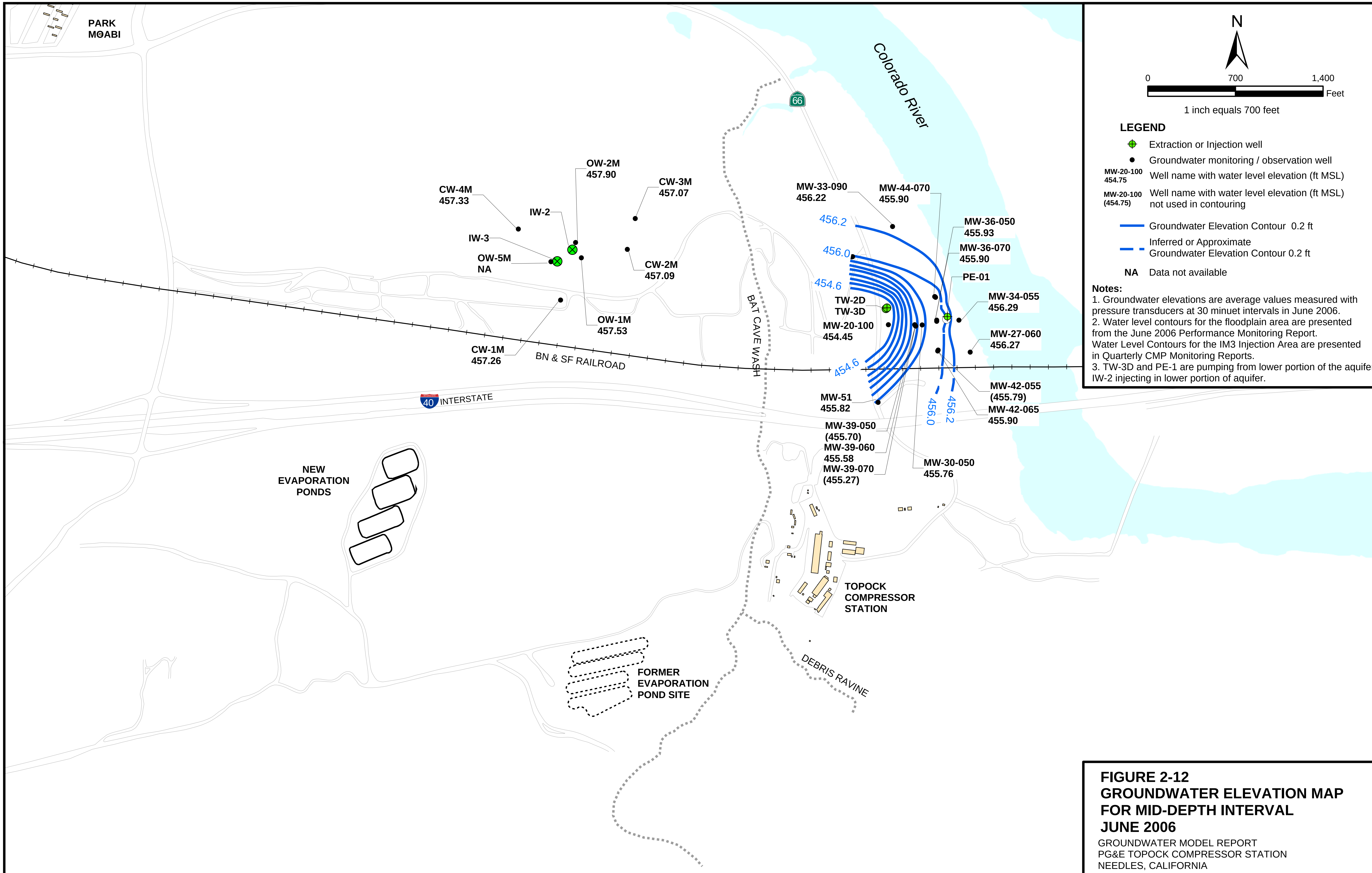

FIGURE 2-12
GROUNDWATER ELEVATION MAP FOR MID-DEPTH INTERVAL JUNE 2006

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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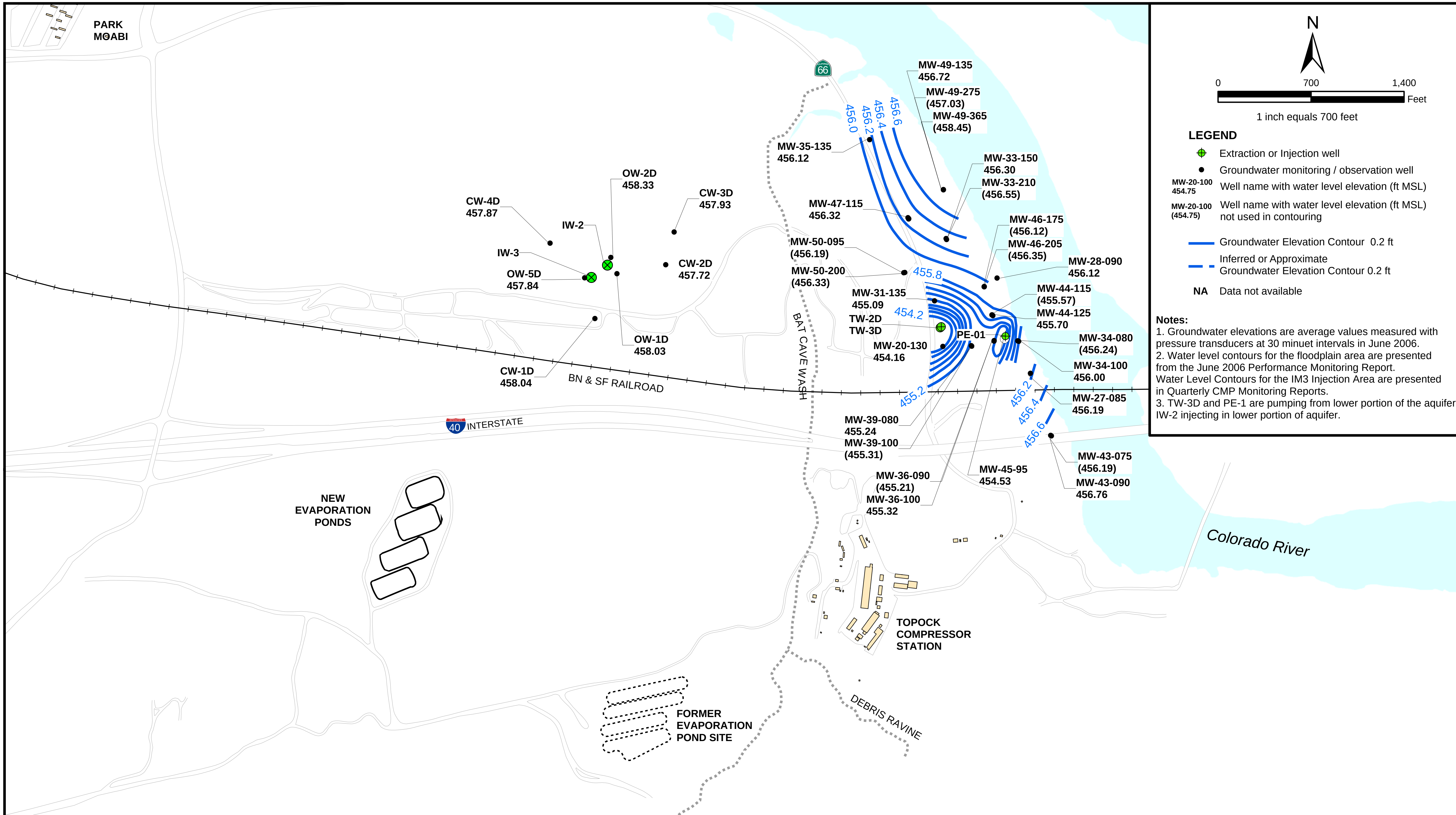

FIGURE 2-13
GROUNDWATER ELEVATION MAP FOR DEEP INTERVAL JUNE 2006
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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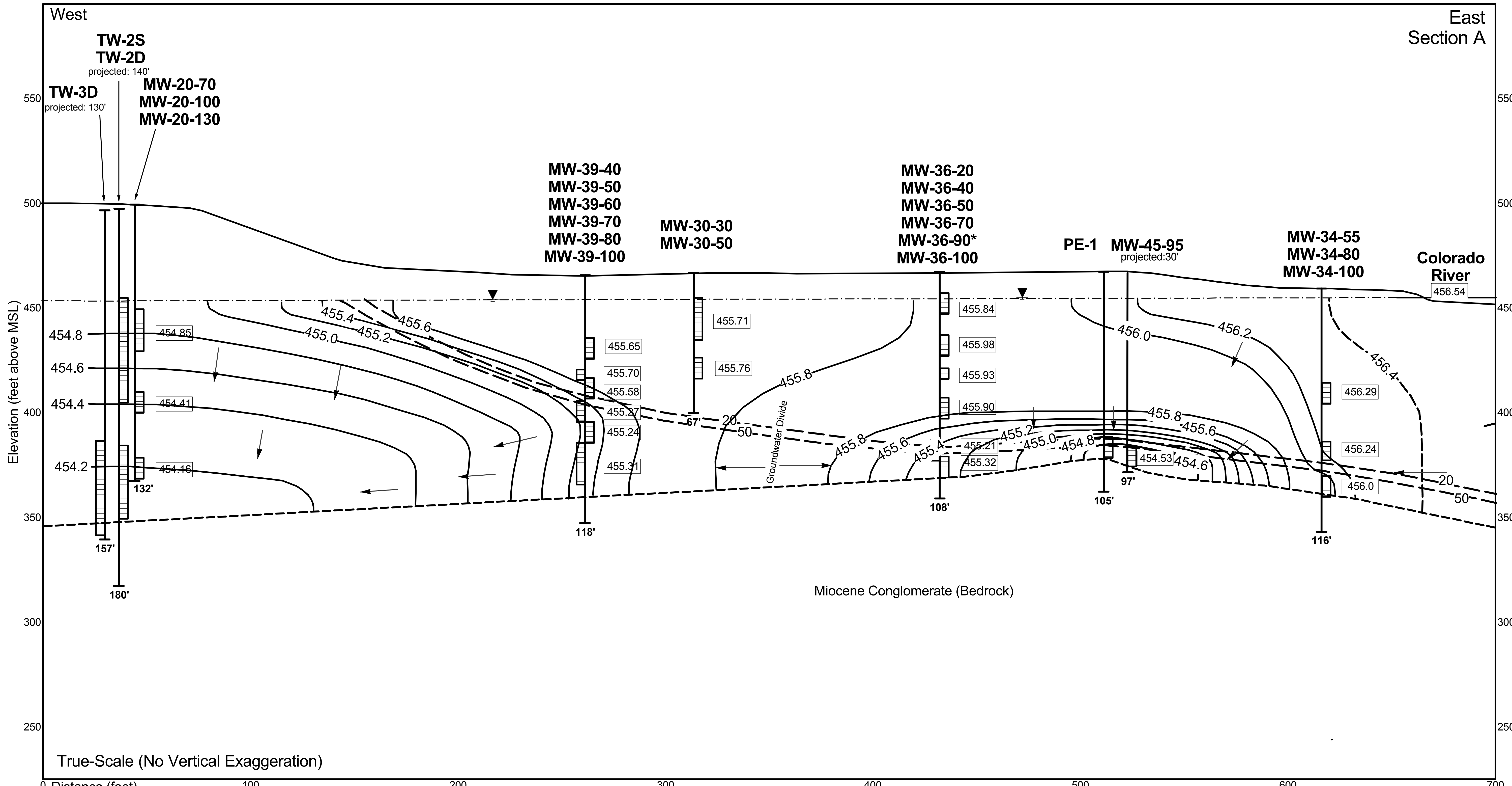

Notes:
Results show average groundwater elevations for June 1-28, 2006 measured with transducers at 30 minute intervals.
Groundwater elevations adjusted for salinity and temperature.

Well MW-36-90* excluded from contouring.

PE-1 pumping began on 1/26/06.
River elevation (R-20) is the calculated average river level based upon the river gradient between RRB and I-3.
Data subject to review.

Legend:

MW-30-50
Inferred water table
well screen 453.66 Annual average groundwater head (ft MSL)
103 boring depth (feet)

— — 20 — — Inferred hexavalent chromium contour (ppb) June, 2006

—— 453.5 —— Groundwater head contour

— — — 453.5 — — — Inferred groundwater head contour

← Interpreted groundwater flow direction

FIGURE 2-14
AVERAGE GROUNDWATER ELEVATIONS FOR WELLS ON FLOODPLAIN CROSS-SECTION A JUNE 2006
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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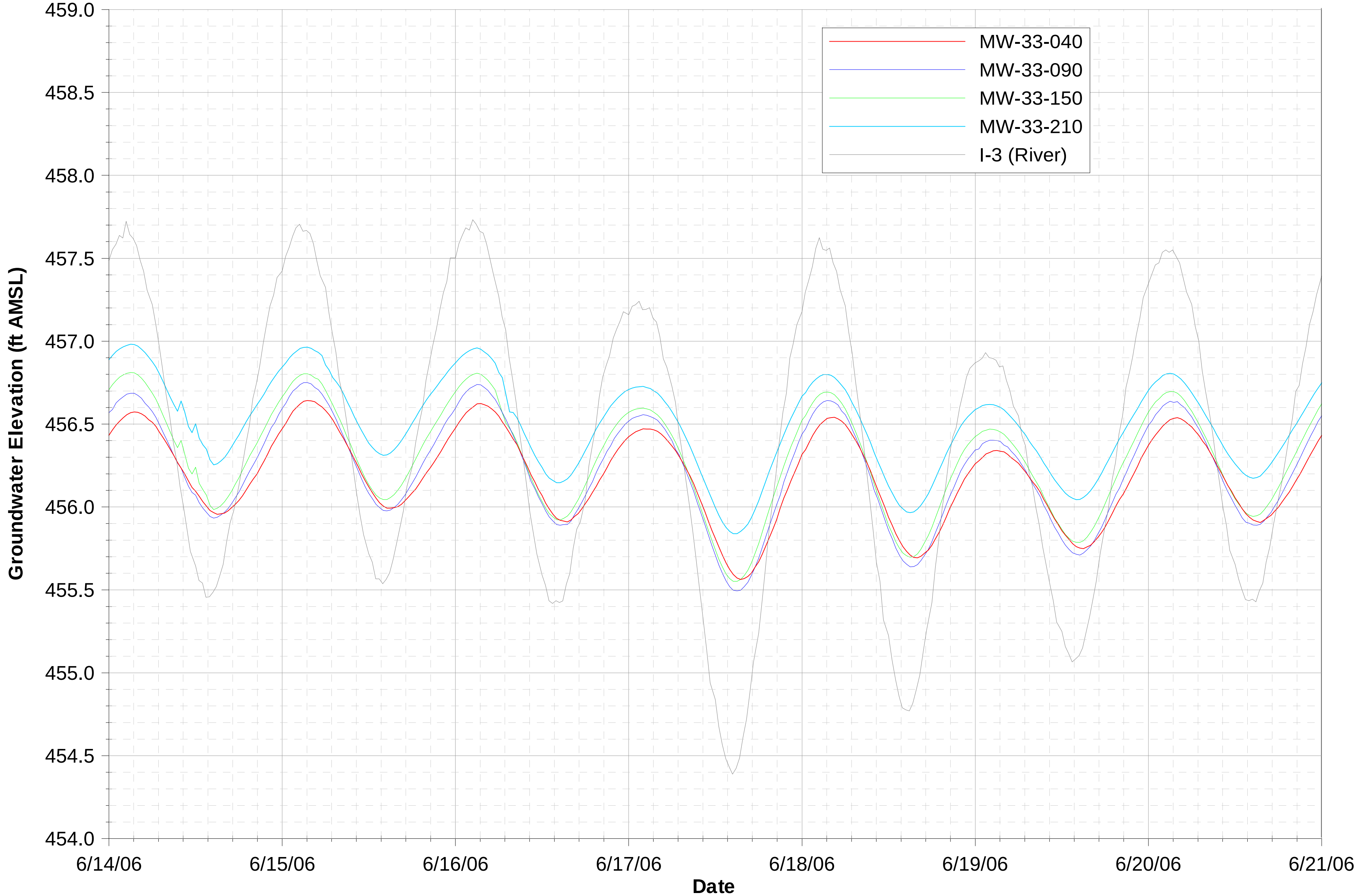

Note: Data subject to review.

FIGURE 2-15
WEEKLY HYDROGRAPH OF RIVER
AND FLOODPLAIN WELL CLUSTER MW-33
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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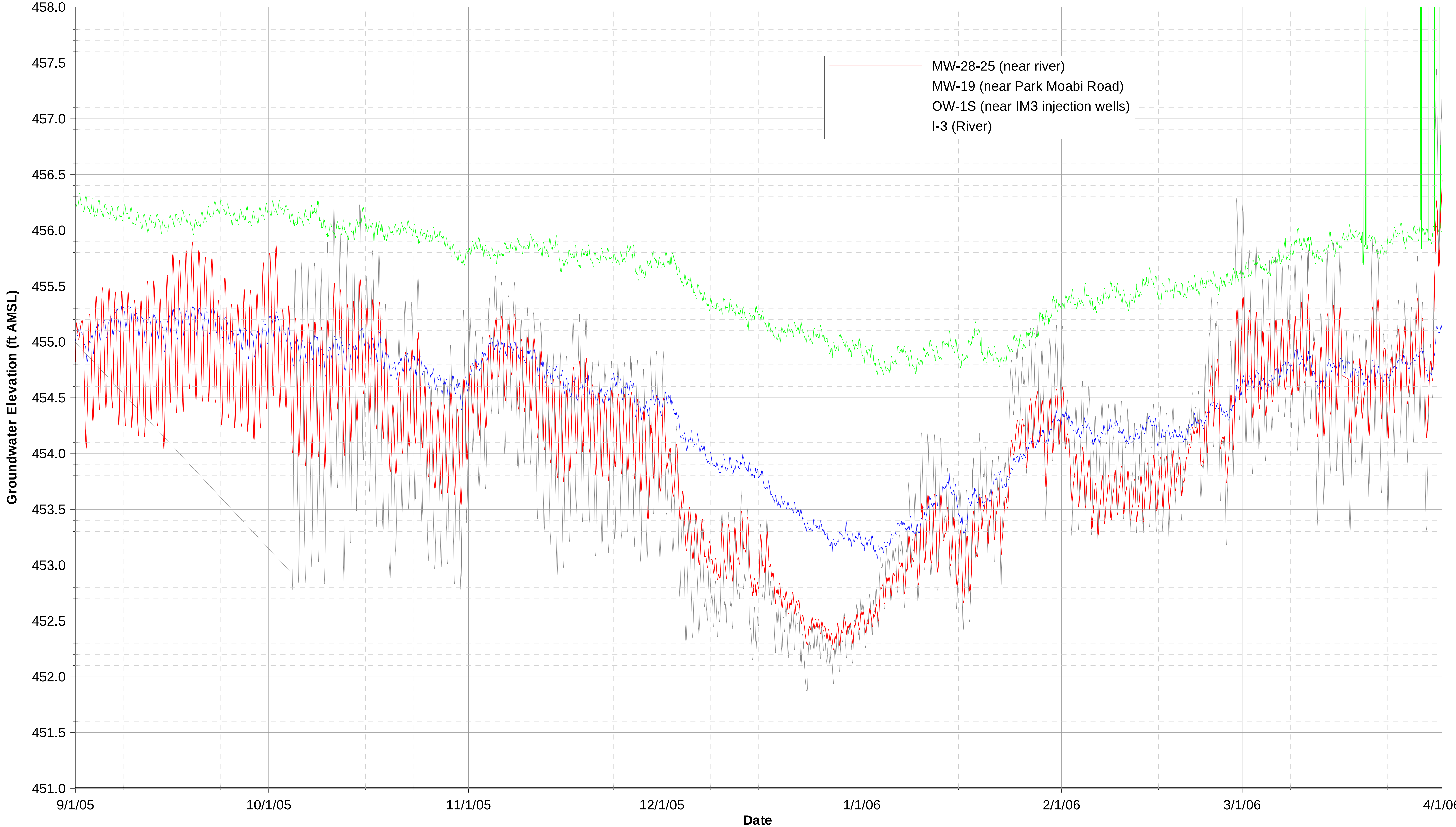

Note: I-3 River data unvailable in September 2005.

FIGURE 2-16
HYDROGRAPHS OF SELECTED SHALLOW WELLS
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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Appendix A
Hydrogeologic Cross Sections for IM Performance Monitoring Area

TABLE A-1
Site Hydrostratigraphic Units, June 2006 Update
Groundwater Model Report
PG&E Topock Compressor Station

Stratigraphic Age	Site Hydrostratigraphic Units					
	Alluvial Deposits		Characteristics	Fluvial Deposits		Characteristics
Holocene	**Younger Alluvium**	**Qya**	unconsolidated sandy gravel & silty/clayey gravel (youngest alluvial deposits and surficial deposits, undifferentiated)	**Upper Fluvial Sand & Silt** (Floodplain Area)	**Qr3**	unconsolidated sand & silty sand (no gravel), massive-bedded, very well-sorted; contains fine-gr. organic matter
				Middle Fluvial Deposits (Floodplain Area)	**Qr2**	unconsolidated sand, clay & minor gravelly sand, interbedded; clay/silt lenses exhibit both brown and gray (reduced) appearance
				Lower Fluvial Deposits (Floodplain Area)	**Qr1**	unconsolidated sandy gravel & gravelly sand, minor silty gravel (gravel content >15%); subrounded to very well-rounded pebbles & cobbles from distant sources & fluvial transport
				Colorado River Channel Fill fluvial deposits in paleo-channel	**Qr0**	fluvial channel-fill sediments that occur below elevation 360' MSL (deepest river deposits encountered in floodplain borings). Per Caltrans I-40 bridge borings includes moderately consolidated to dense, fine to coarse sand & sandy gravel
Pleistocene	**Older Quaternary Alluvium**	**Qoa**	unconsolidated sandy gravel & silty/clayey gravel (alluvial fan deposits). Comprises moderately-dissected alluvial terraces; terrace/wash slopes are moderate-angle (i.e., 45 degrees)	**Older Fluvial Sediments** (surface outcrop)	**Qrs**	pinkish to tan, weakly to moderately consolidated fine sand, silt/clay, with minor pebble gravel; contains root casts (paleosol); outcrops occur as remnants on alluvial terraces as high as elevation 670' MSL (Old Ponds site)
				Older River Gravels (surface outcrop)	**Qrg**	moderately consolidated to cemented, sandy pebble to boulder gravel; subrounded to very well-rounded clasts from distant sources & fluvial transport (unit outcrops west of MW-20 bench)
Pliocene	**Bouse Formation**	**(Tb)**	pre-Colorado River lacustrine & deltaic deposits: well-bedded, moderately indurated, green clay, siliceous claystone, sandstone & basal marl			
Pliocene to Late Miocene	**Tertiary Alluvium - Upper**	**Toa2**	Moderately consolidated sandy gravel, gravelly sand & silty/clayey gravel (oldest alluvial fan deposits). Comprises deeply-dissected alluvial terraces; terrace canyon walls are vertical/steep	= Tertiary Fanglomerate of Metzger & Loeltz, 1973	Note: Toa1 and Toa2 are subdivisions based on contrasts in hydraulic permeability observed in the Tertiary Alluvium sequence in TW-1, TW-2D, and IW-2 well-flow spinner logs.	
	Tertiary Alluvium - Lower	**Toa1**				
Late Miocene	**Basal Alluvium**	**Toa0**	Moderately consolidated silty sand, clayey/silty gravel & minor gravelly sand. Consists of 100% reddish detritus of Miocene conglomerate unit (reworked Tmc deposits) in floodplain area. In other site areas, Toa0 is well-consolidated alluvium, lacks reddish color, and exhibits high-induction geophyiscal log response			
angular unconformity (post-extension erosion)						
Middle Miocene	**Miocene Conglomerate**	**Tmc**	consolidated conglomerate & sandstone containing rock fragments & megabreccia derived from Chemehuevi Mtns. bedrock			
unconformity & detachment faulting						
Pre-Tertiary	**Metamorphic / Igneous Bedrock**	**pTbr**	metadiorite, gneiss & granitic bedrock exposed in Chemehuevi Mountains & underlies the groundwater basin			

Notes:
1. Hydrostratigraphic units that comprise the Alluvial Aquifer in groundwater model area are shaded yellow
2. Bedrock formations, grey shaded, are essentially impermeable but locally yield water where fractured
3. Within groundwater model area, Younger Alluvium and Older Fluvial and River Deposits occur above the water table
4. Stratigraphic age assignments from published geologic reports and are generalized for units in study area

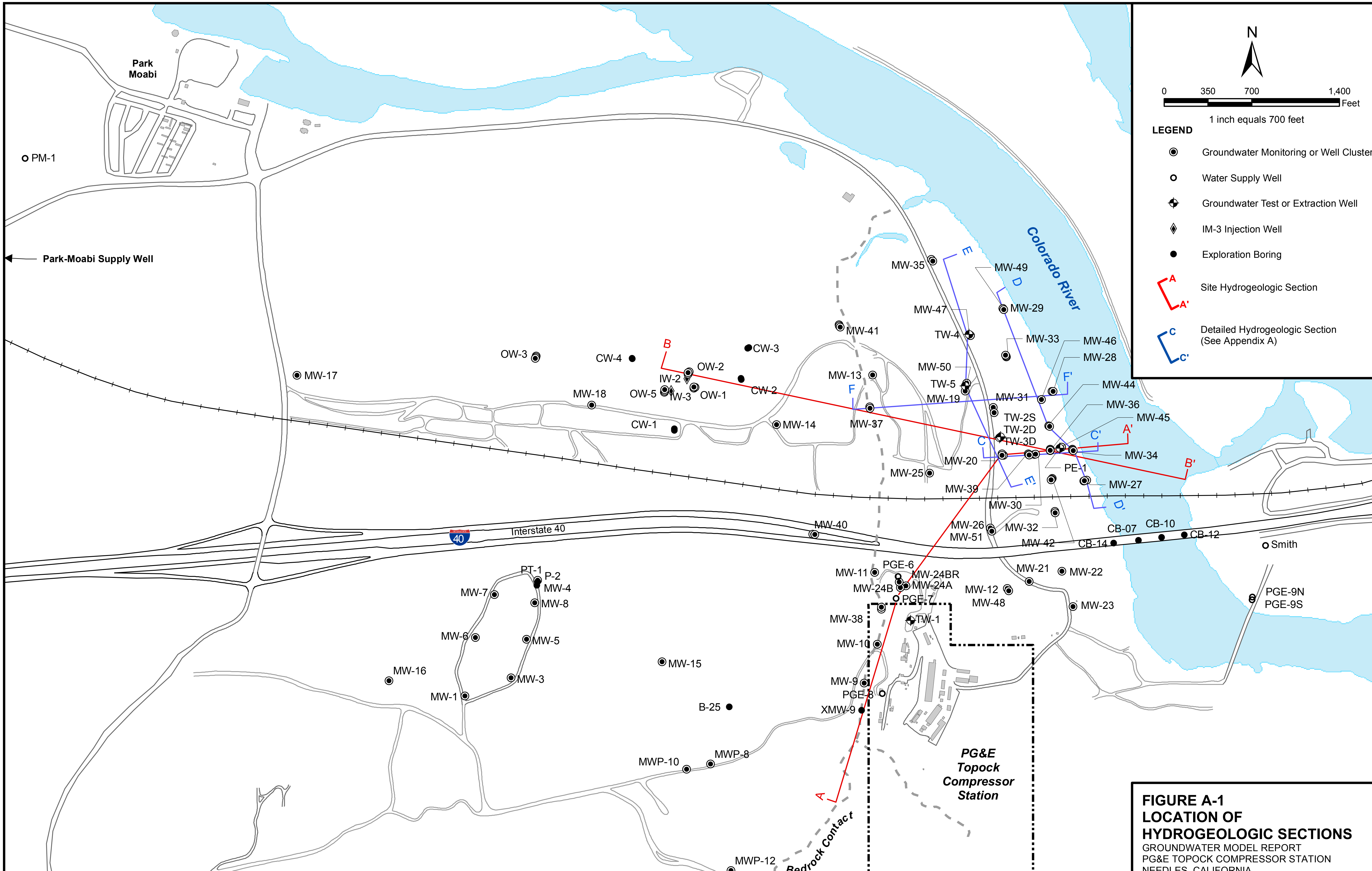

FIGURE A-1
LOCATION OF HYDROGEOLOGIC SECTIONS
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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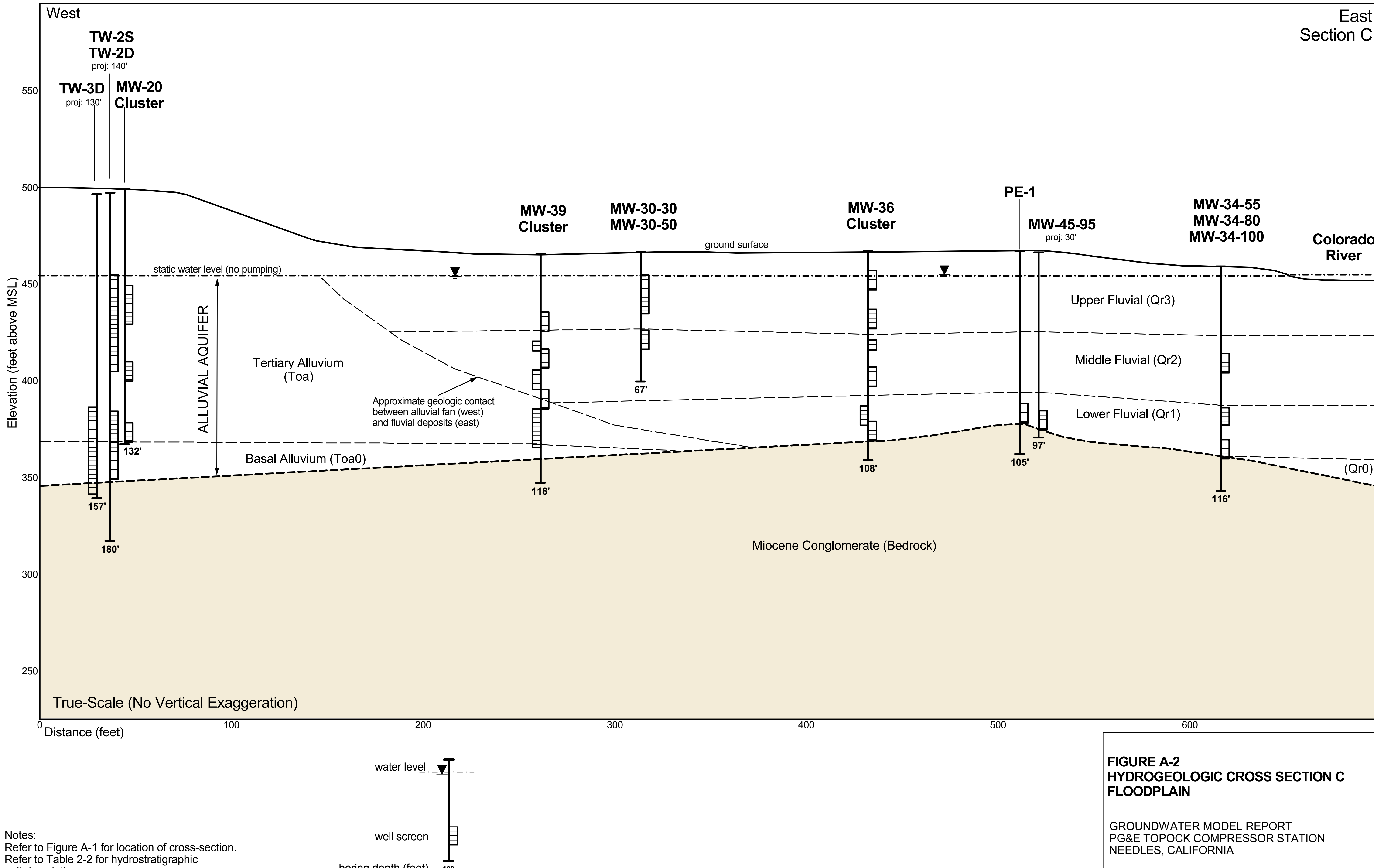

Notes:
Refer to Figure A-1 for location of cross-section.
Refer to Table 2-2 for hydrostratigraphic unit descriptions.

FIGURE A-2
HYDROGEOLOGIC CROSS SECTION C
FLOODPLAIN

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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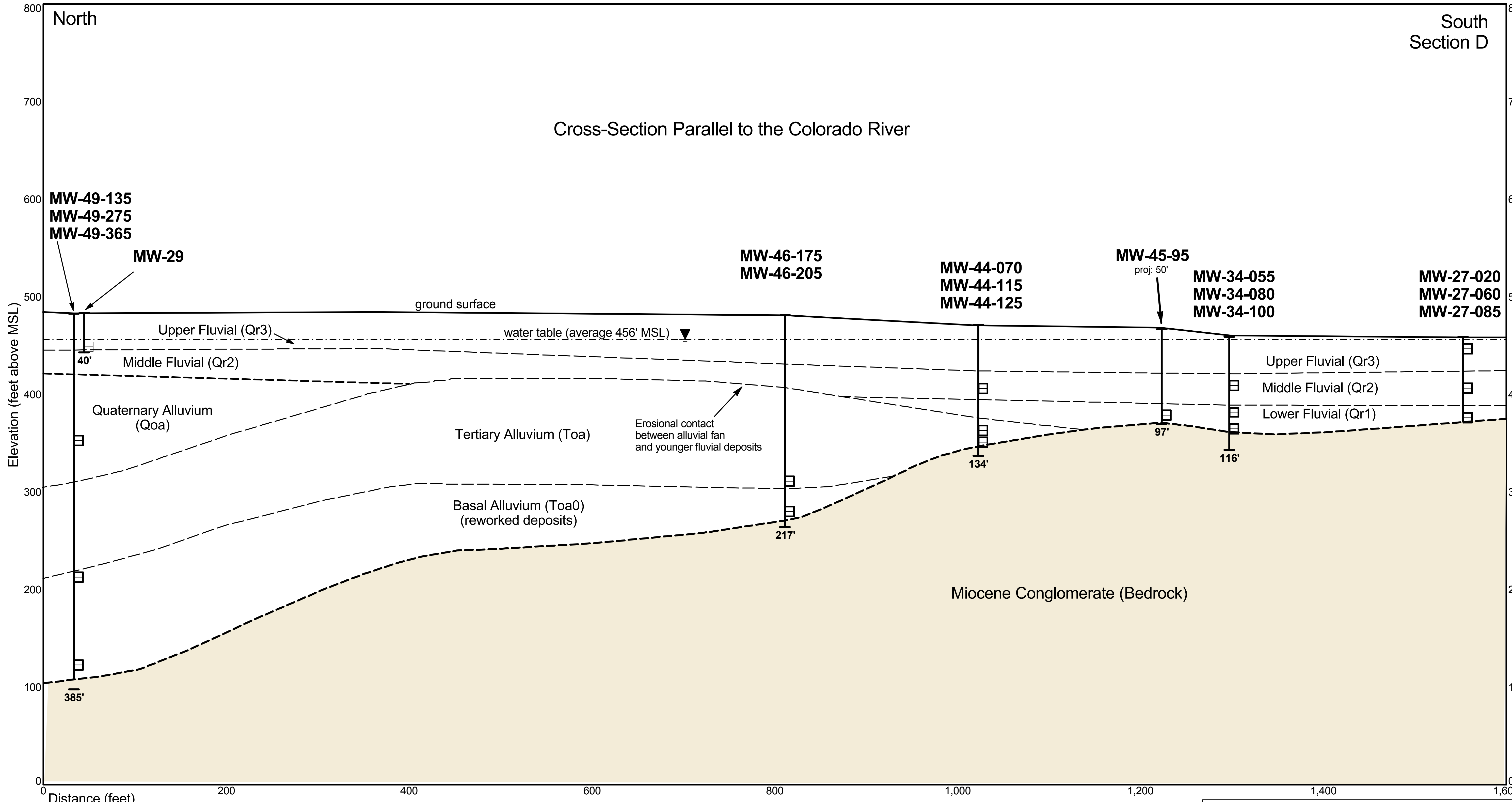

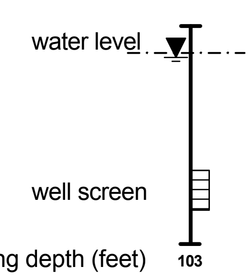

Notes:
Refer to Figure A-1 for location of cross-section.
Refer to Table 2-2 for hydrostratigraphic unit descriptions.

FIGURE A-3
HYDROGEOLOGIC CROSS SECTION D
FLOODPLAIN

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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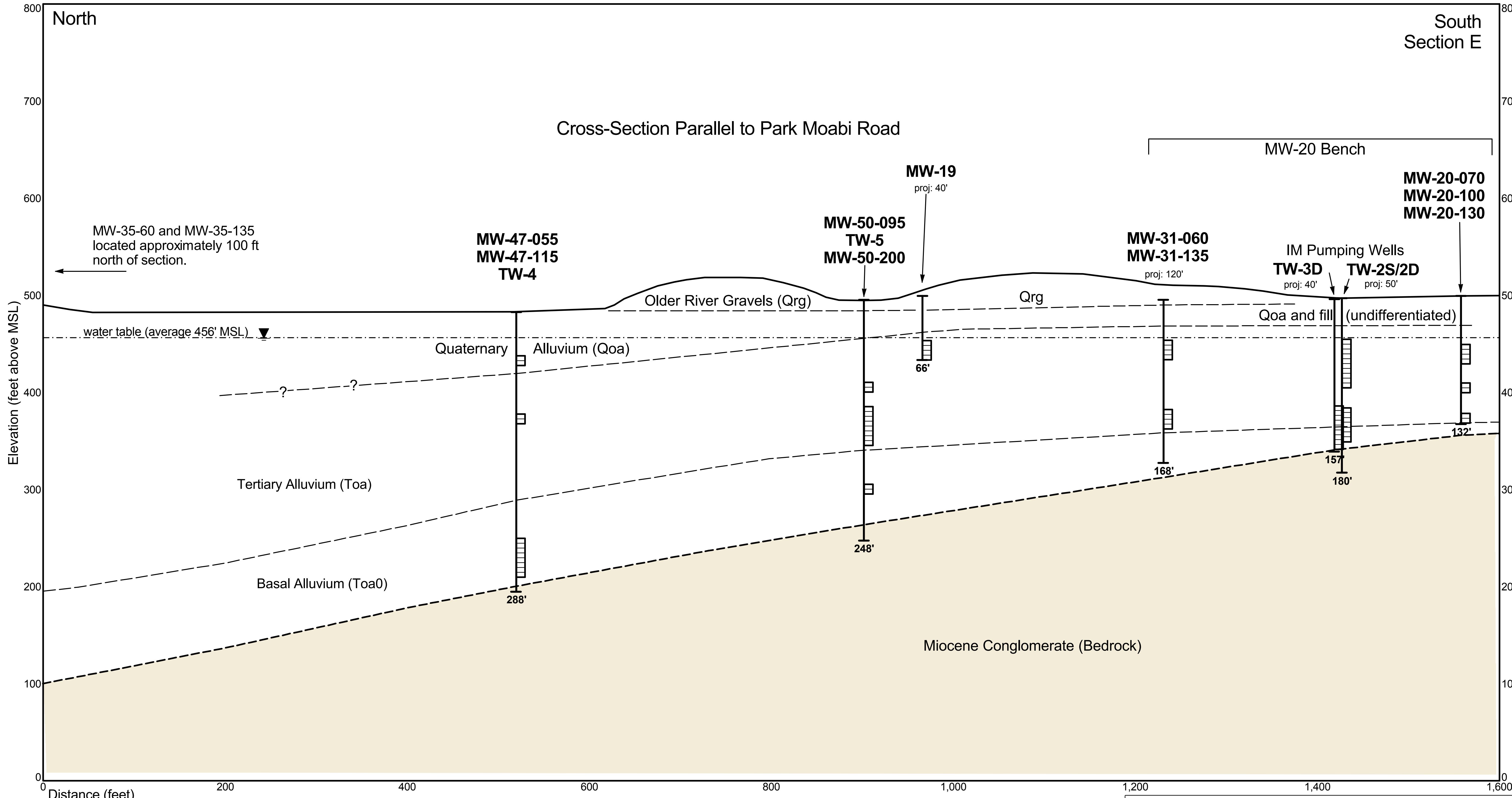

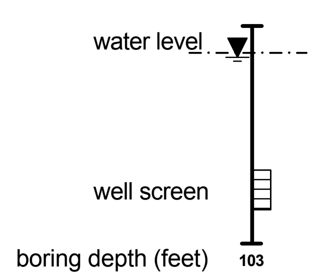

Notes:
Refer to Figure A-1 for location of cross-section.
Refer to Table 2-2 for hydrostratigraphic unit descriptions.

FIGURE A-4
HYDROGEOLOGIC CROSS SECTION E
PARK MOABI ROAD AND MW-20 BENCH

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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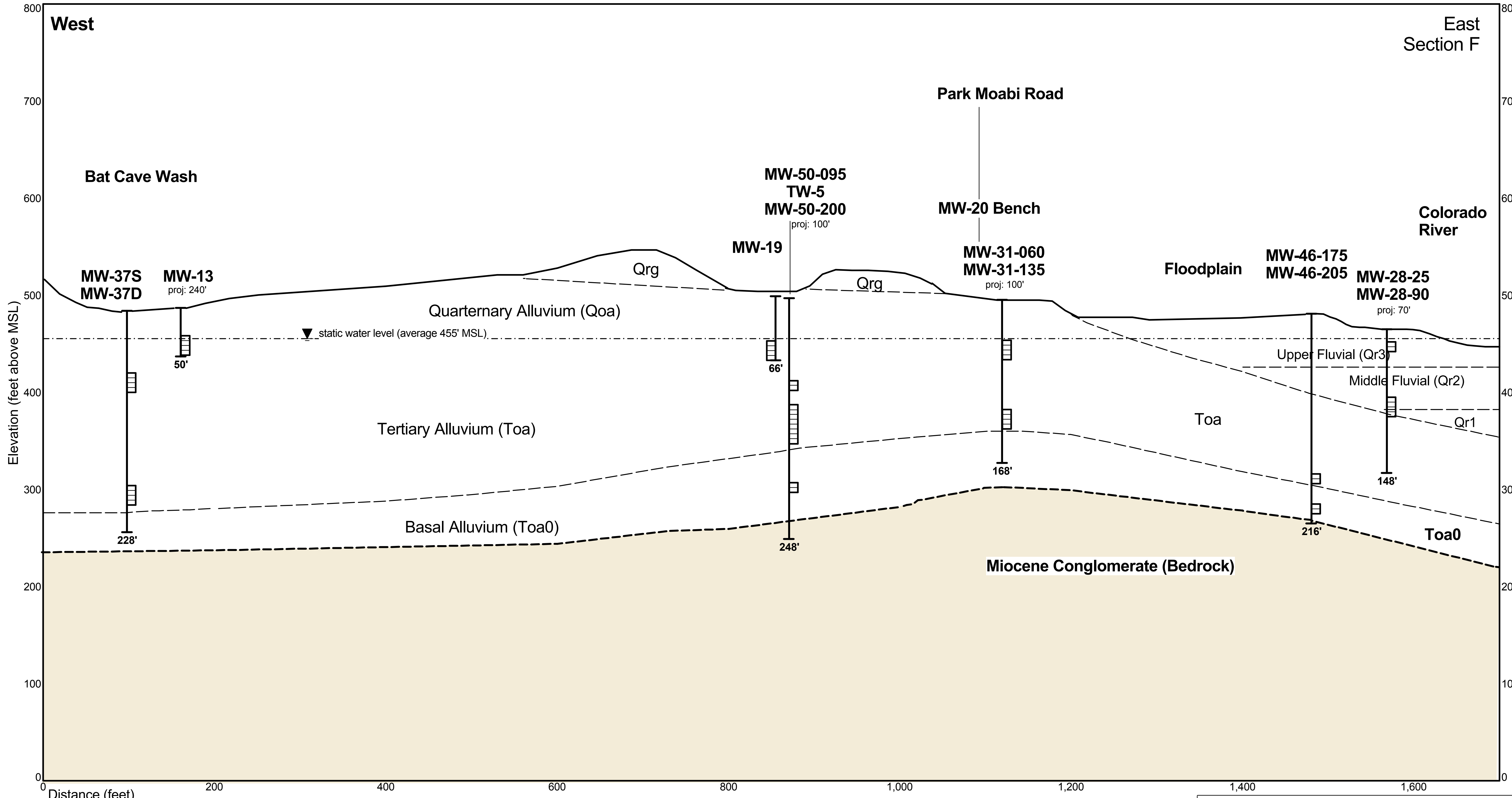

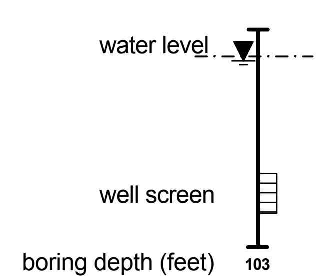

Notes:
Refer to Figure A-1 for location of cross-section.
Refer to Table 2-2 for hydrostratigraphic unit descriptions.

FIGURE A-5
HYDROGEOLOGIC CROSS SECTION F
BAT CAVE WASH TO FLOODPLAIN

GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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Appendix B
Isopach Maps for Hydrostratigraphic Units

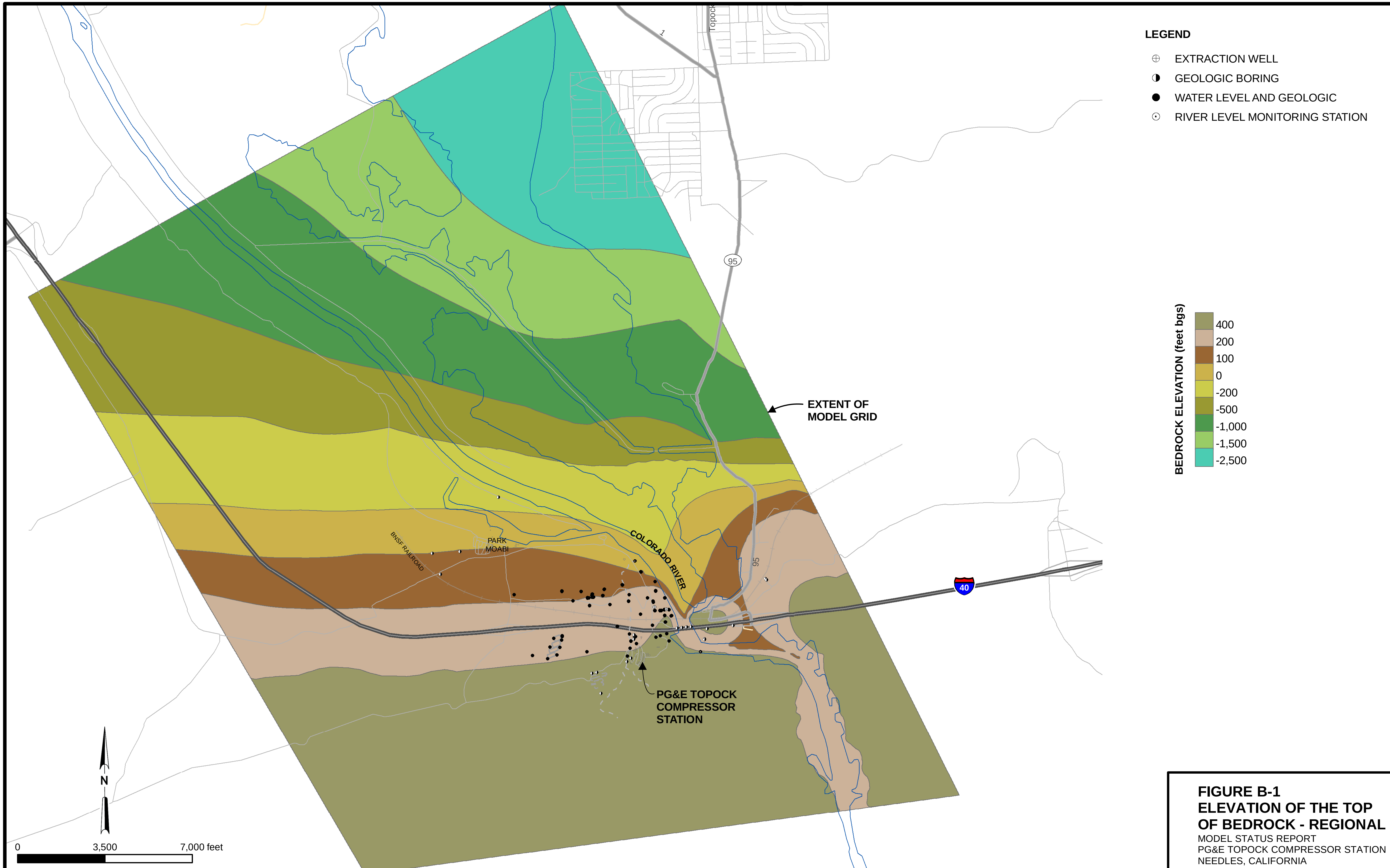

FIGURE B-1
ELEVATION OF THE TOP OF BEDROCK - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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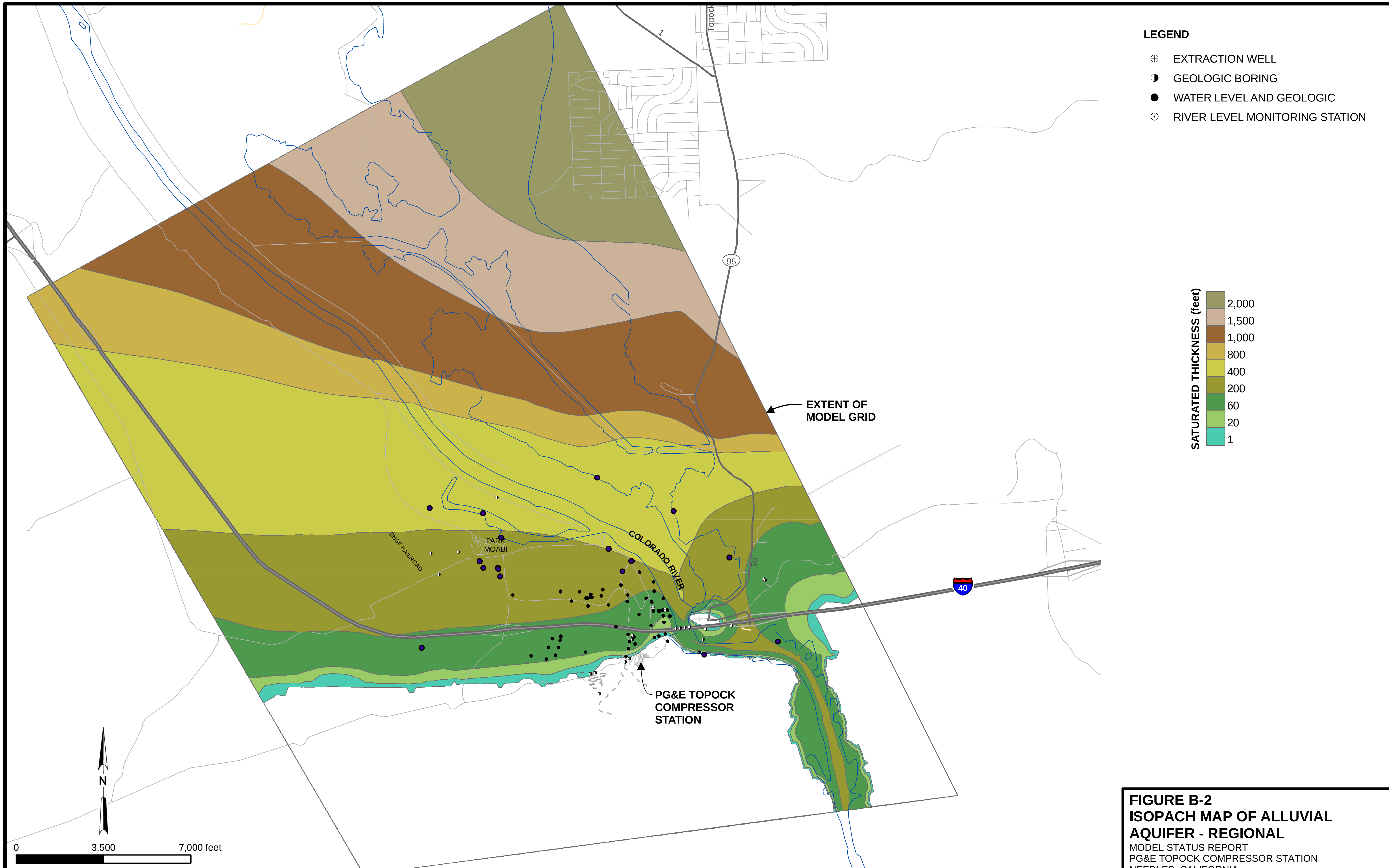

FIGURE B-2
ISOPACH MAP OF ALLUVIAL AQUIFER - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
CH2MHILL

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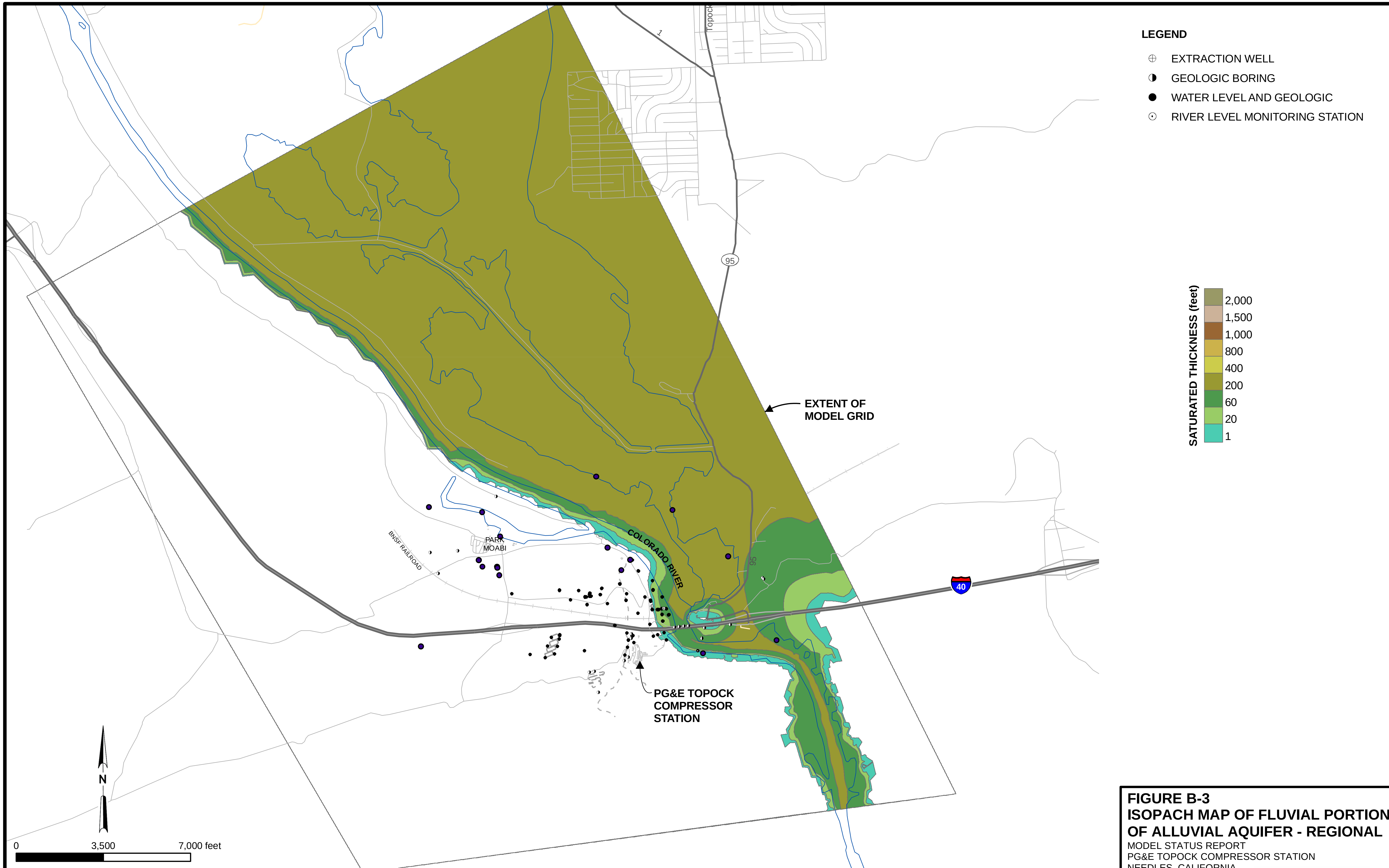

FIGURE B-3
ISOPACH MAP OF FLUVIAL PORTION OF ALLUVIAL AQUIFER - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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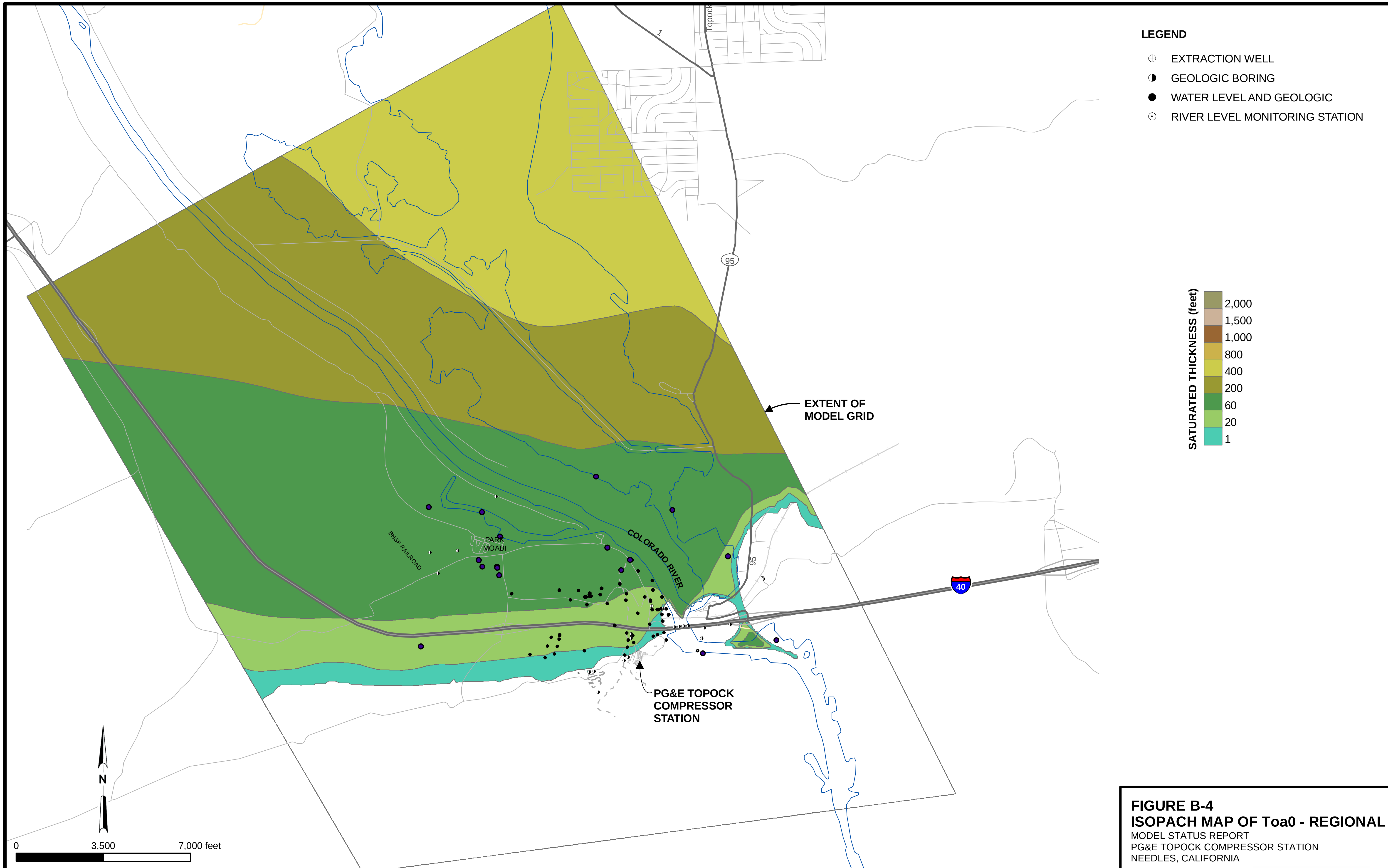

FIGURE B-4
ISOPACH MAP OF Toa0 - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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FIGURE B-5
ISOPACH MAP OF Toa0 - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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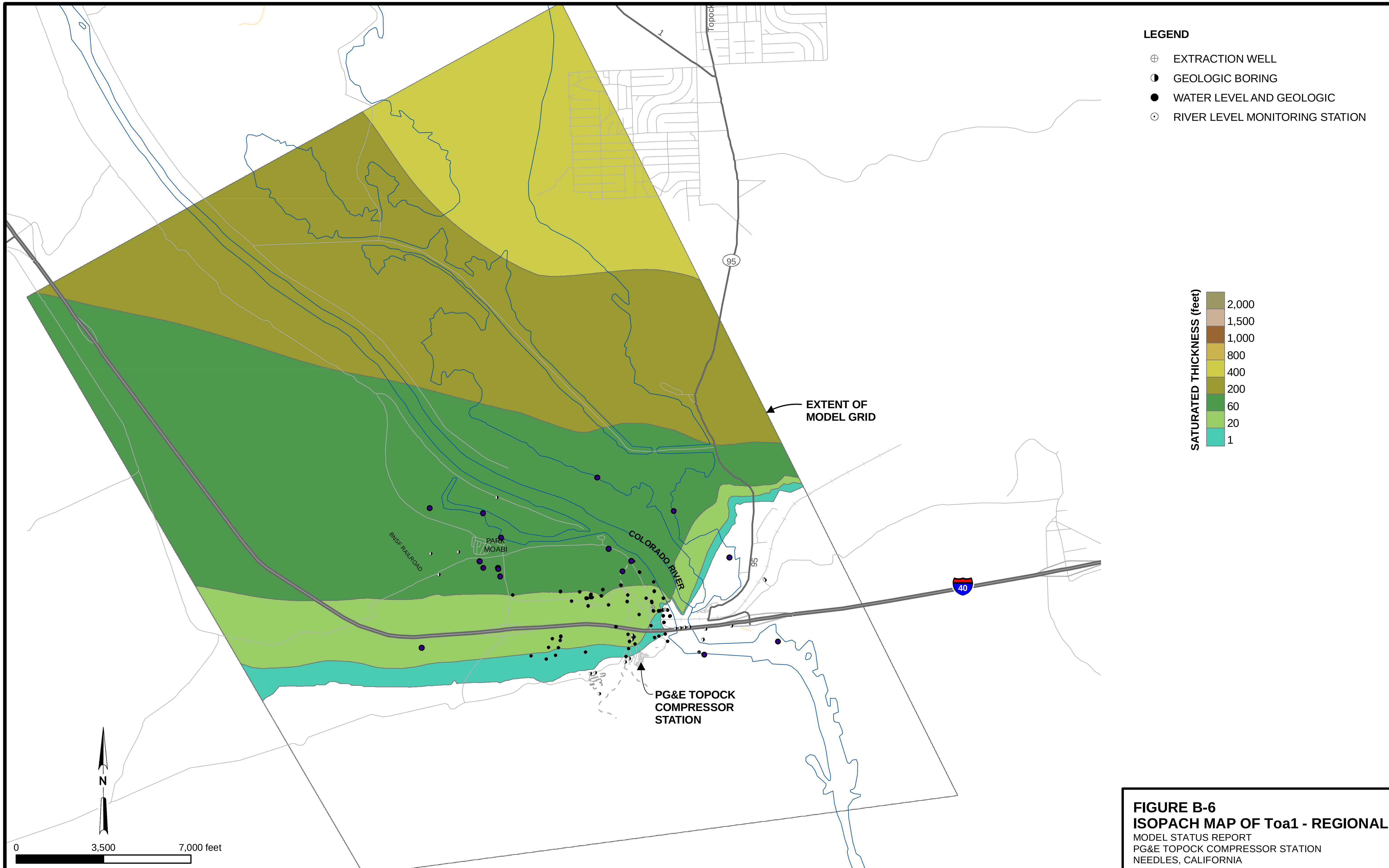

FIGURE B-6
ISOPACH MAP OF Toa1 - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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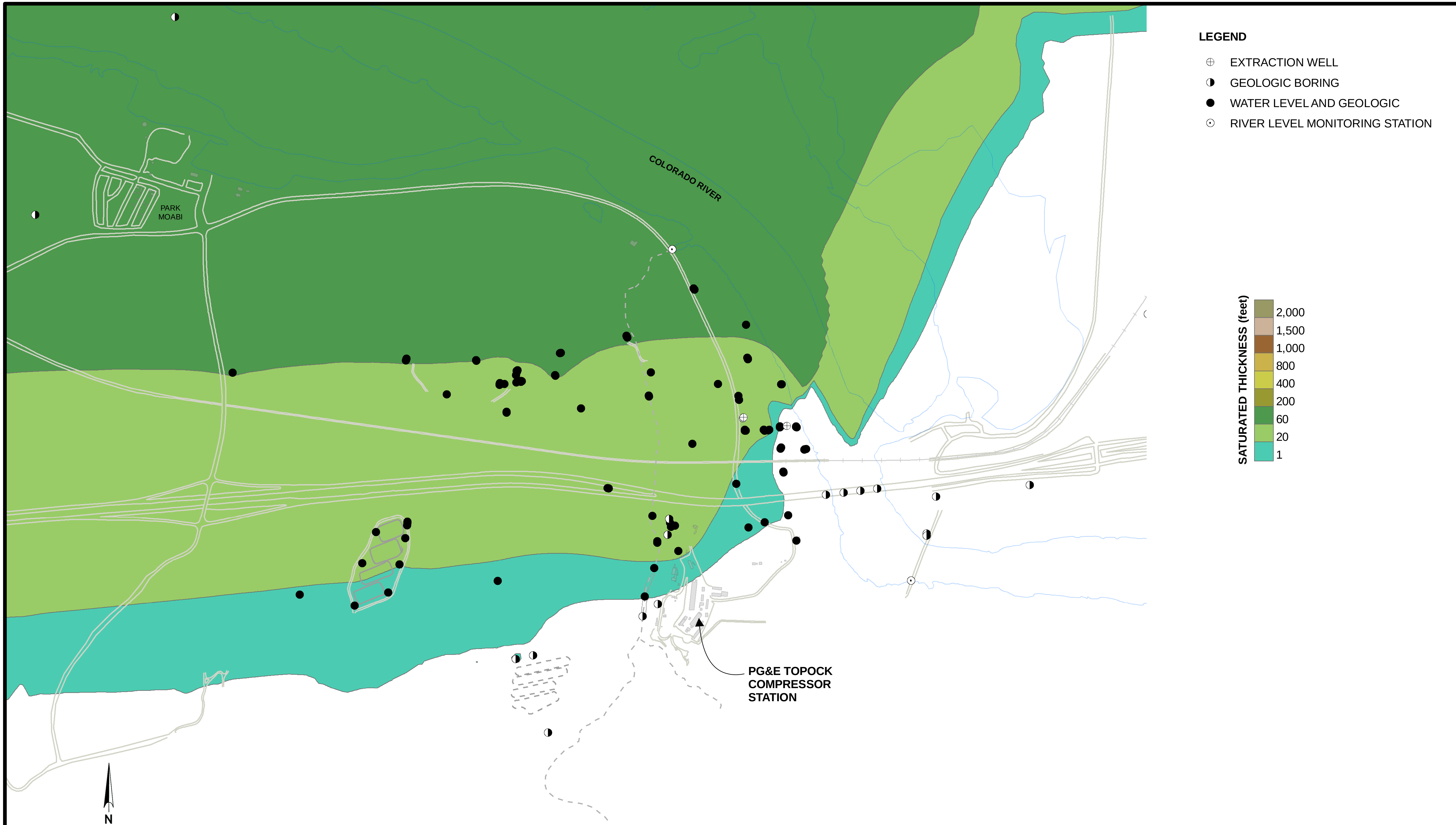

FIGURE B-7
ISOPACH MAP OF Toa1 - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
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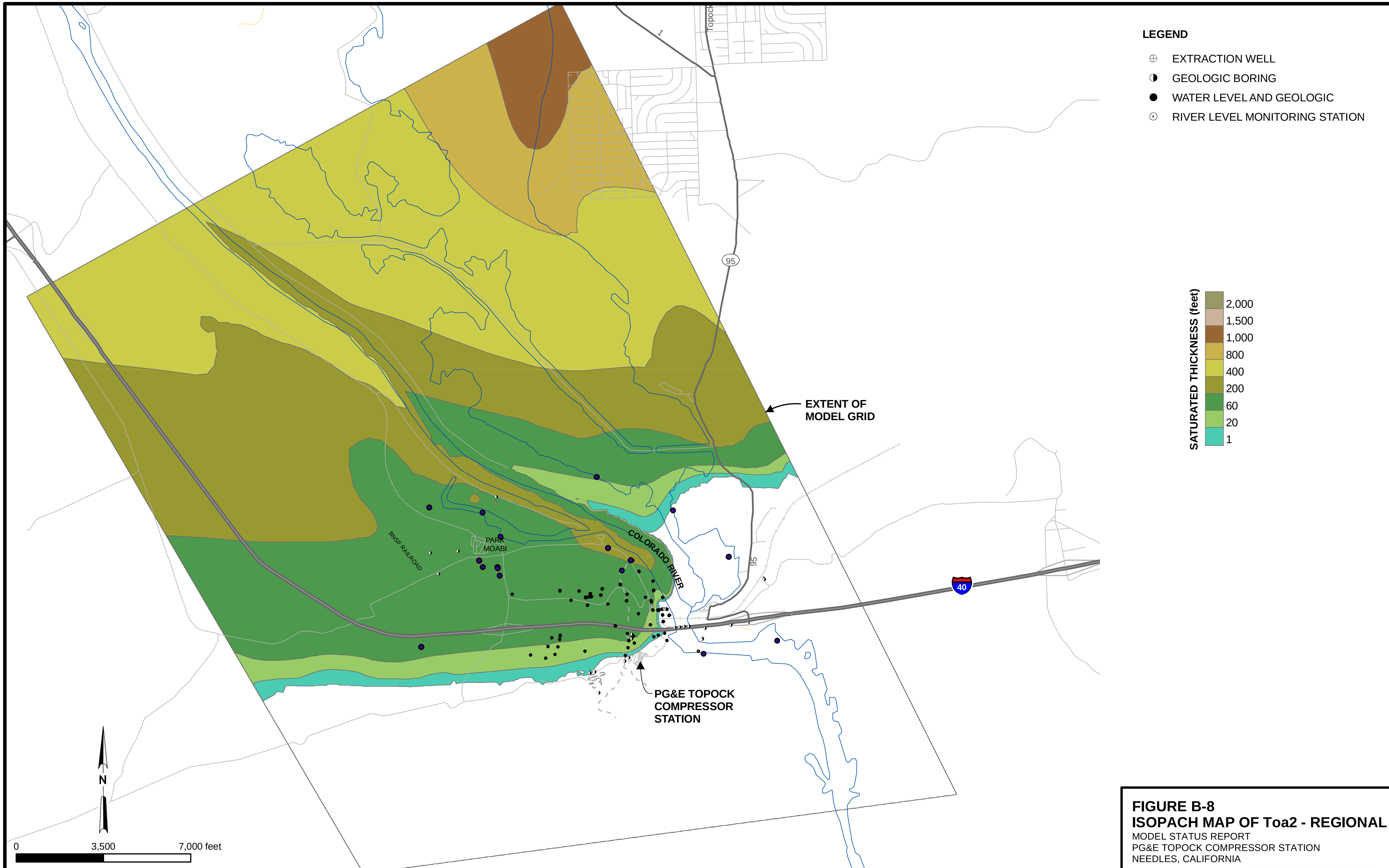

FIGURE B-8
ISOPACH MAP OF Toa2 - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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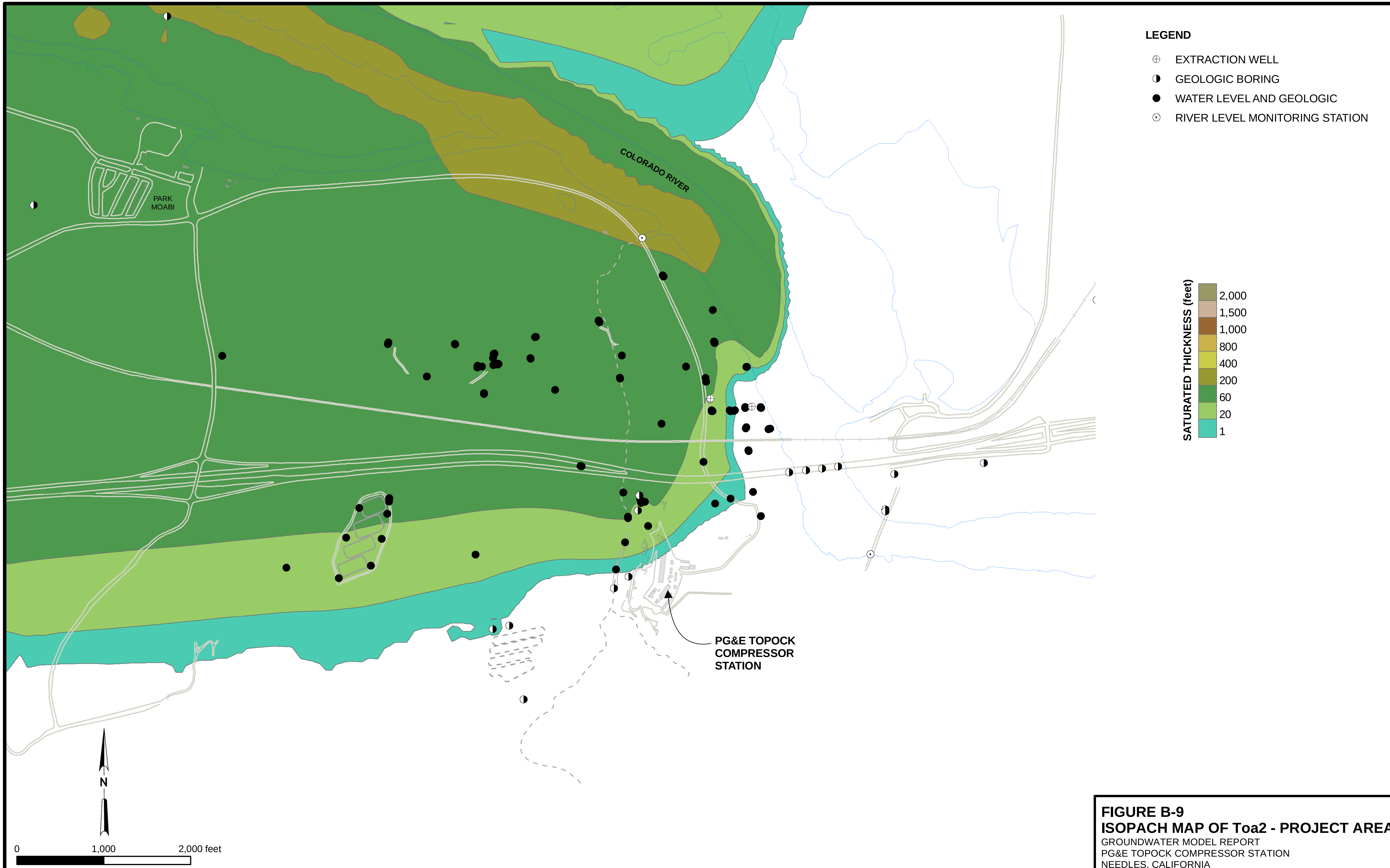

FIGURE B-9
ISOPACH MAP OF Toa2 - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

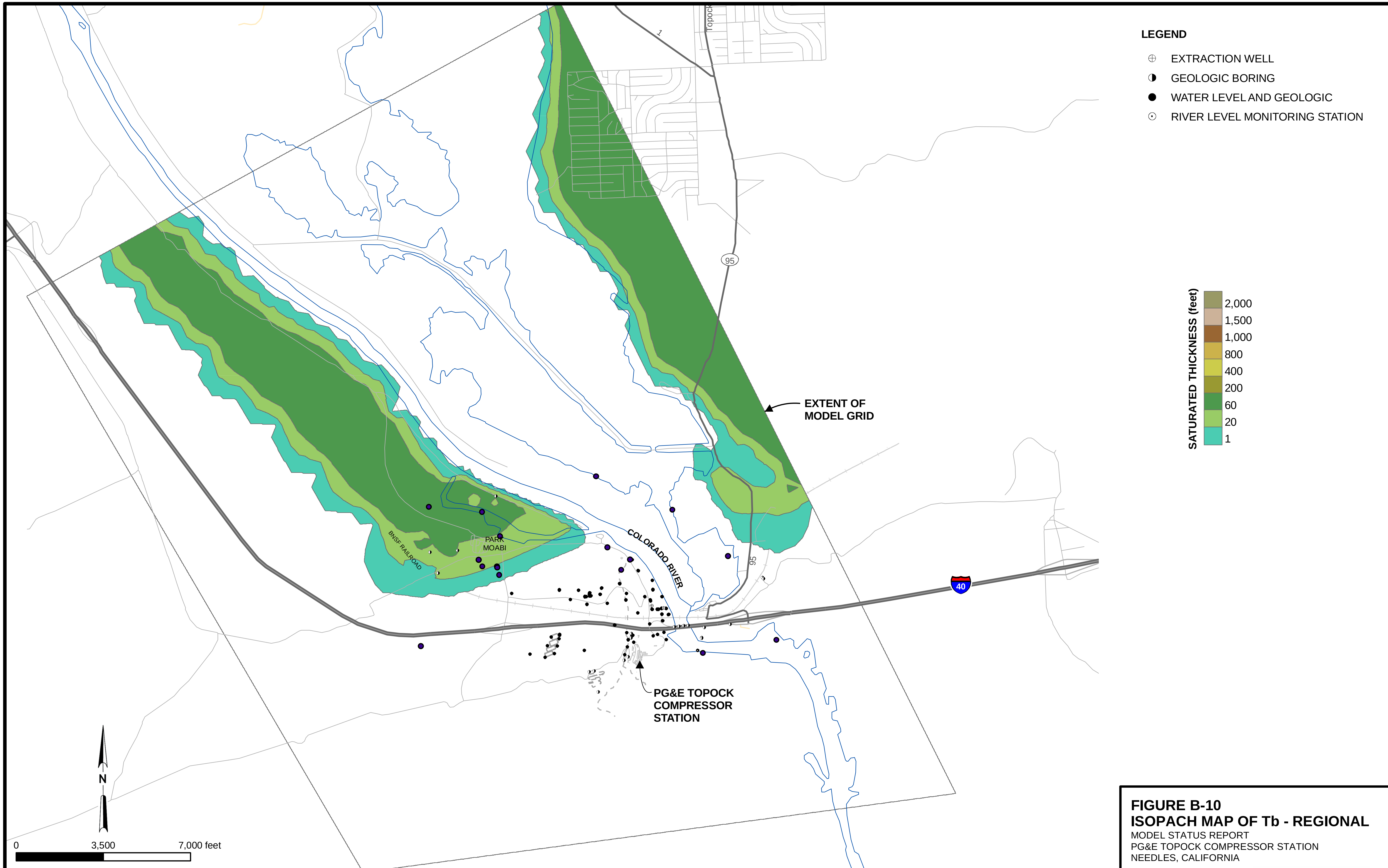

FIGURE B-10
ISOPACH MAP OF Tb - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

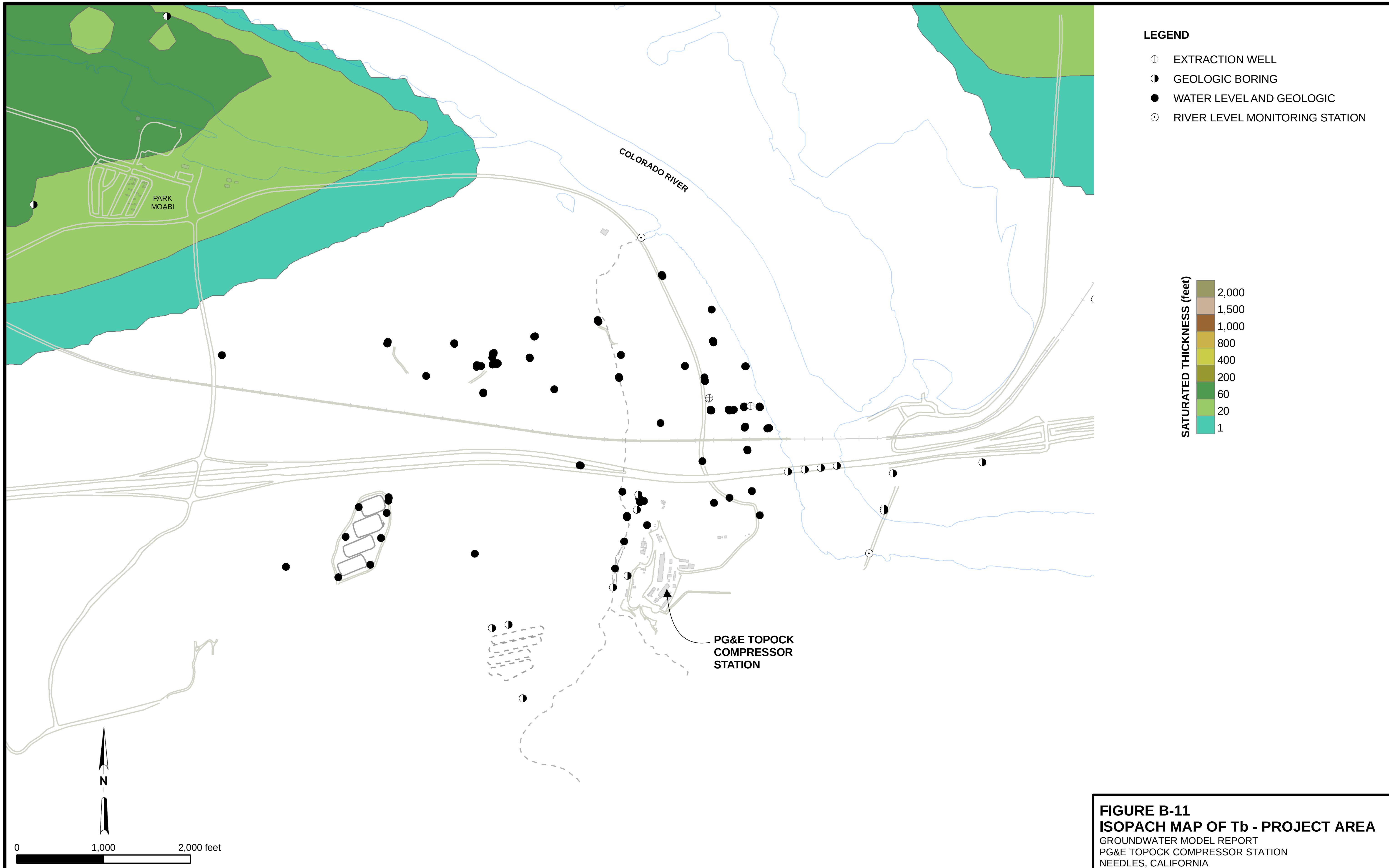

FIGURE B-11
ISOPACH MAP OF Tb - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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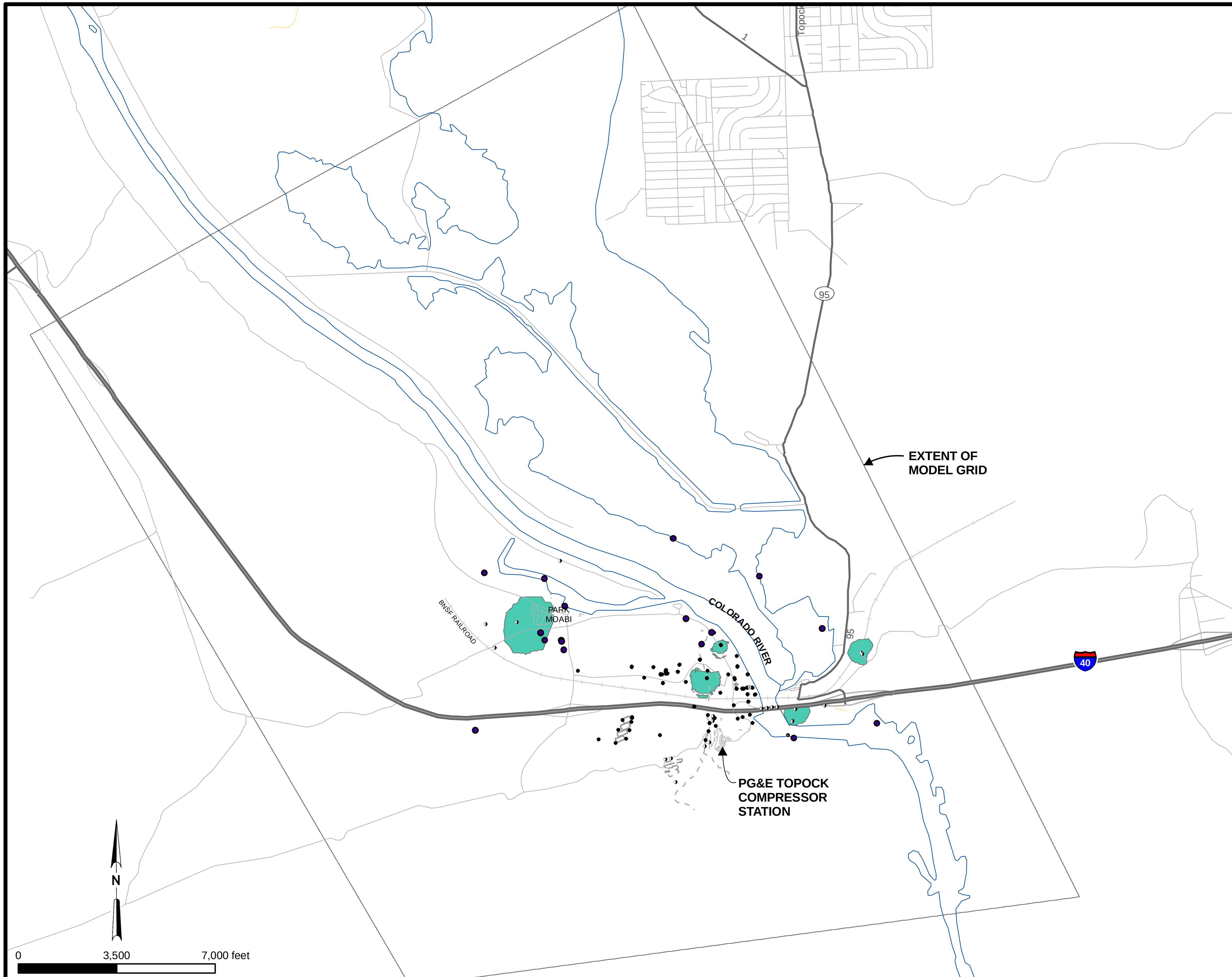

FIGURE B-12
ISOPACH MAP OF Qoa - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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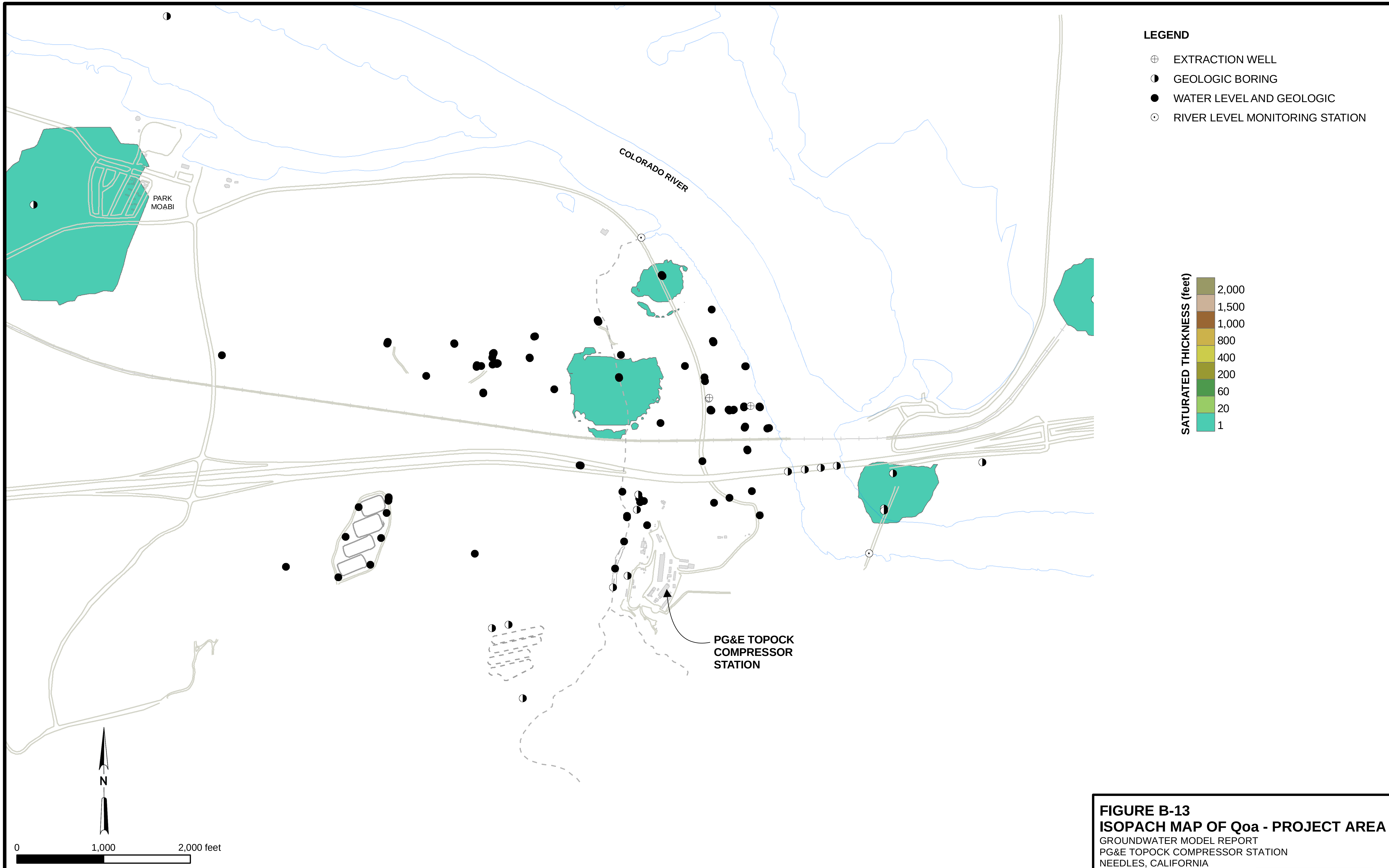

FIGURE B-13
ISOPACH MAP OF Qoa - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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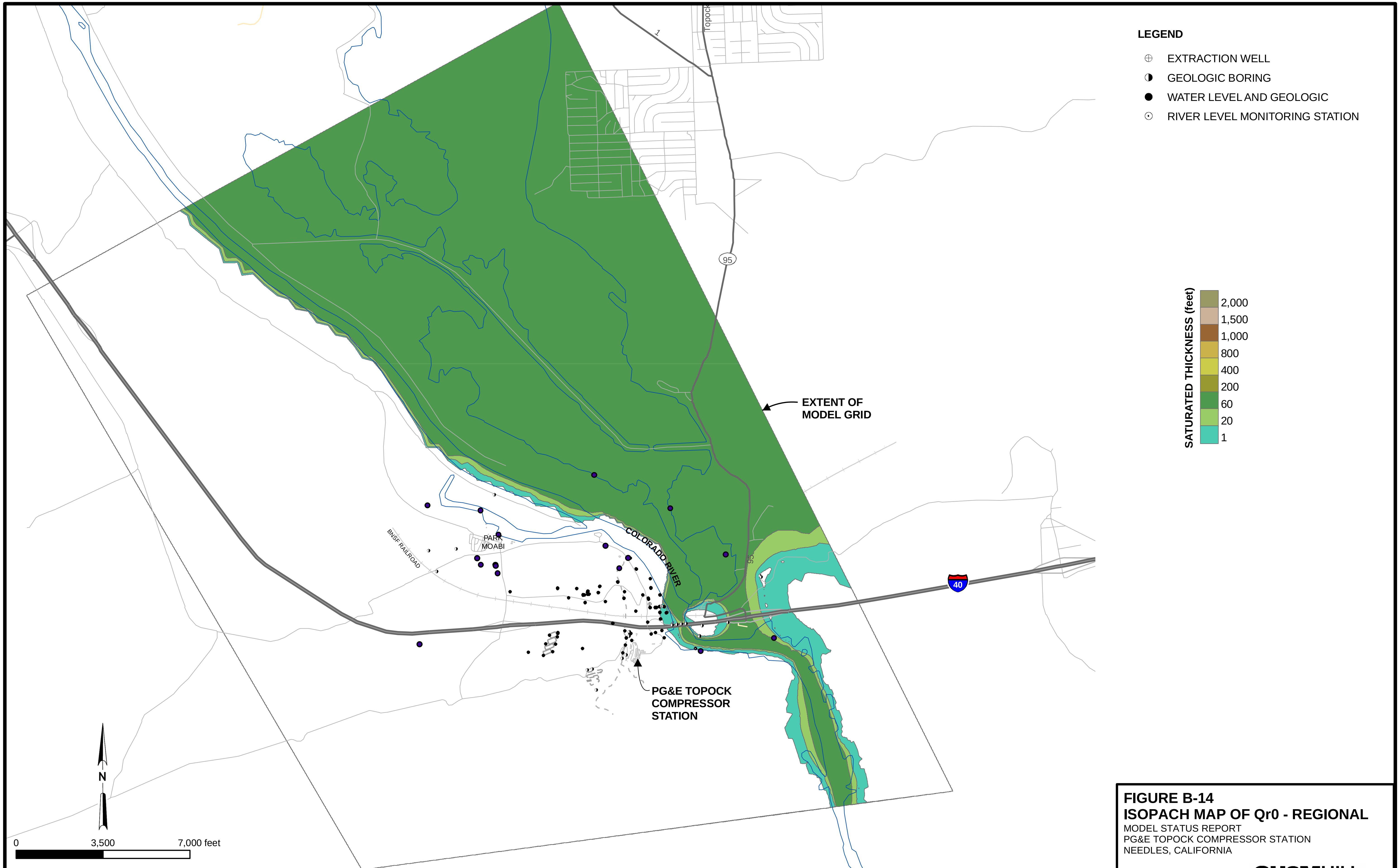

FIGURE B-14
ISOPACH MAP OF Qr0 - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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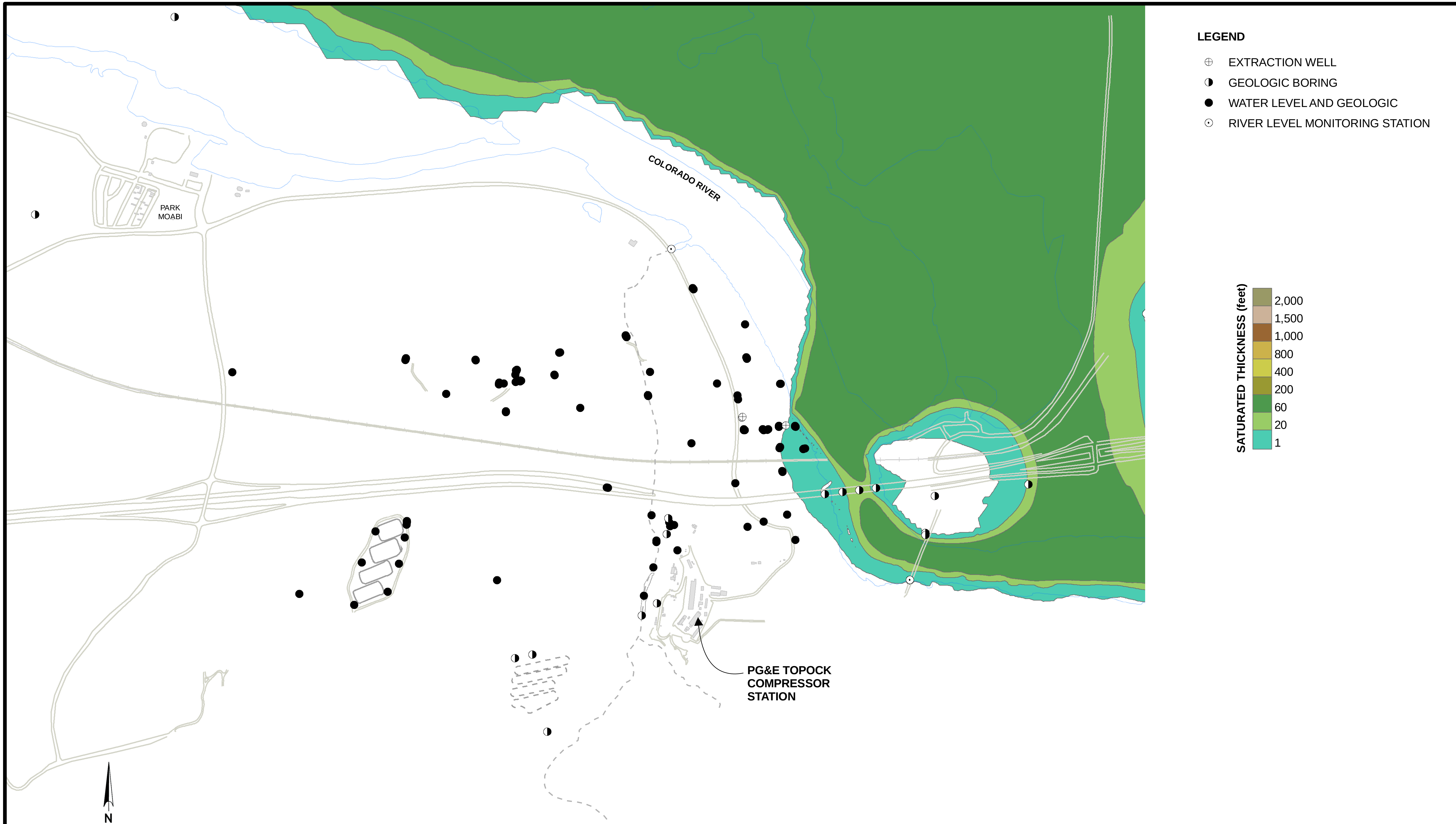

FIGURE B-15
ISOPACH MAP OF Qr0 - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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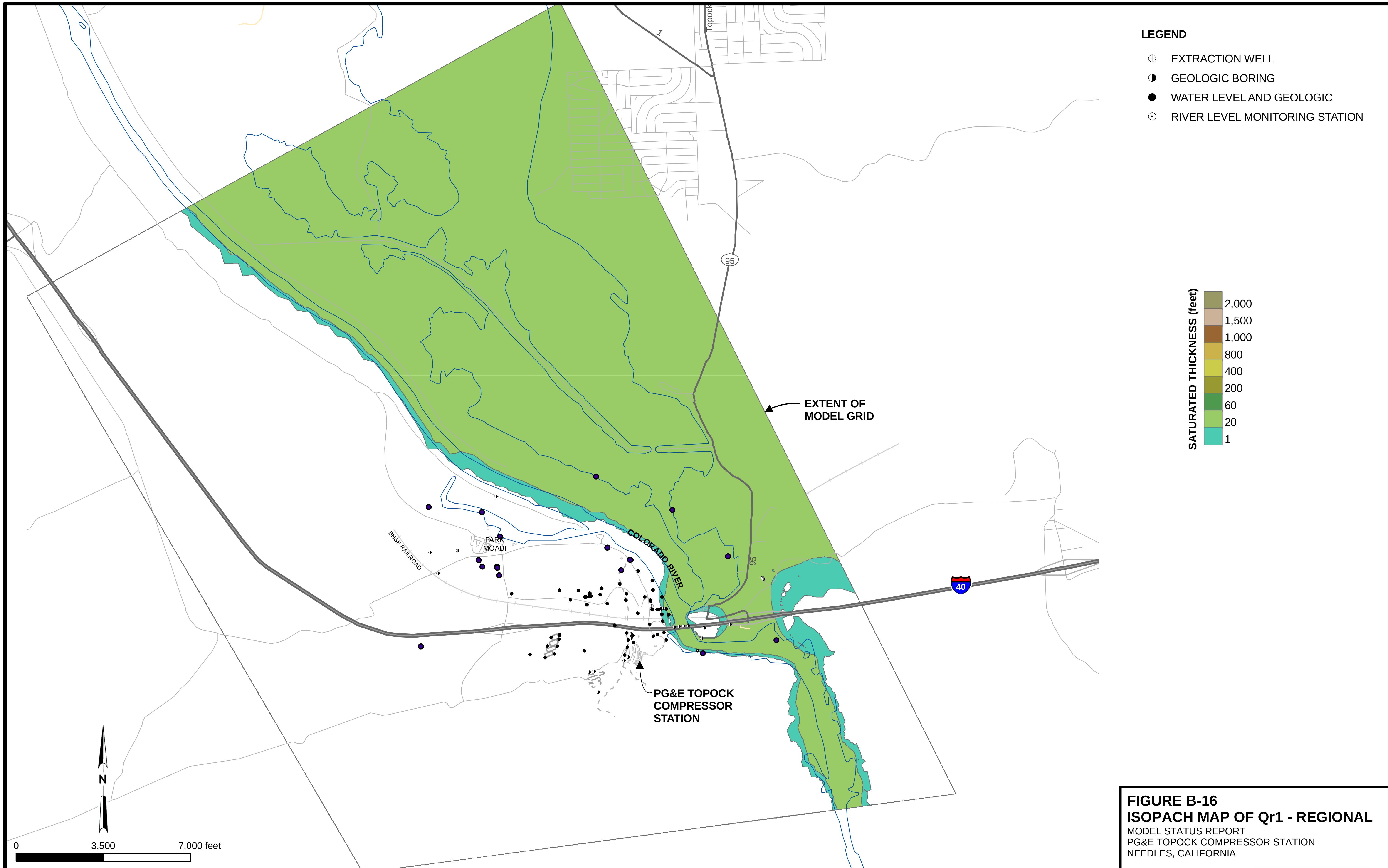

FIGURE B-16
ISOPACH MAP OF Qr1 - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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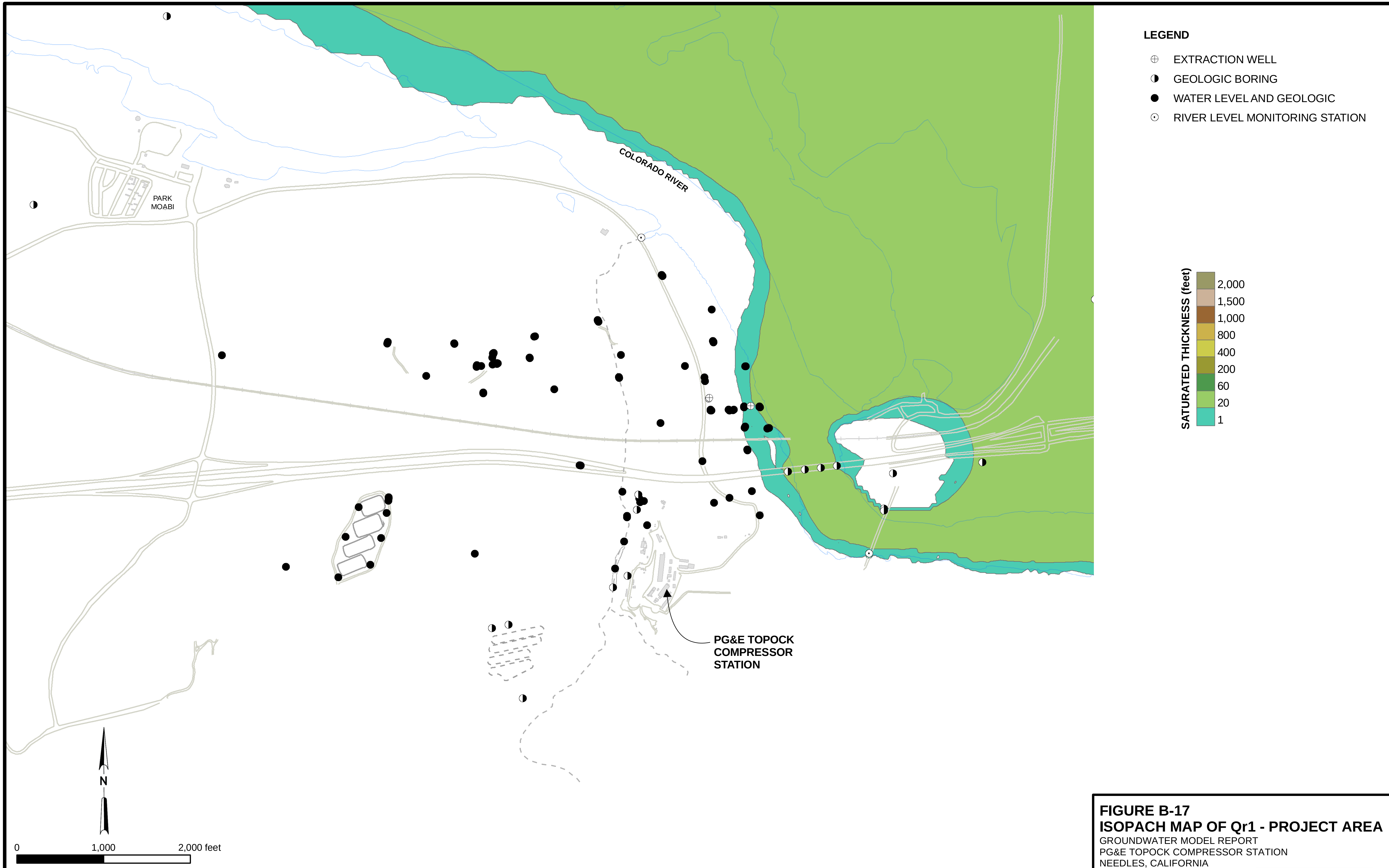

FIGURE B-17
ISOPACH MAP OF Qr1 - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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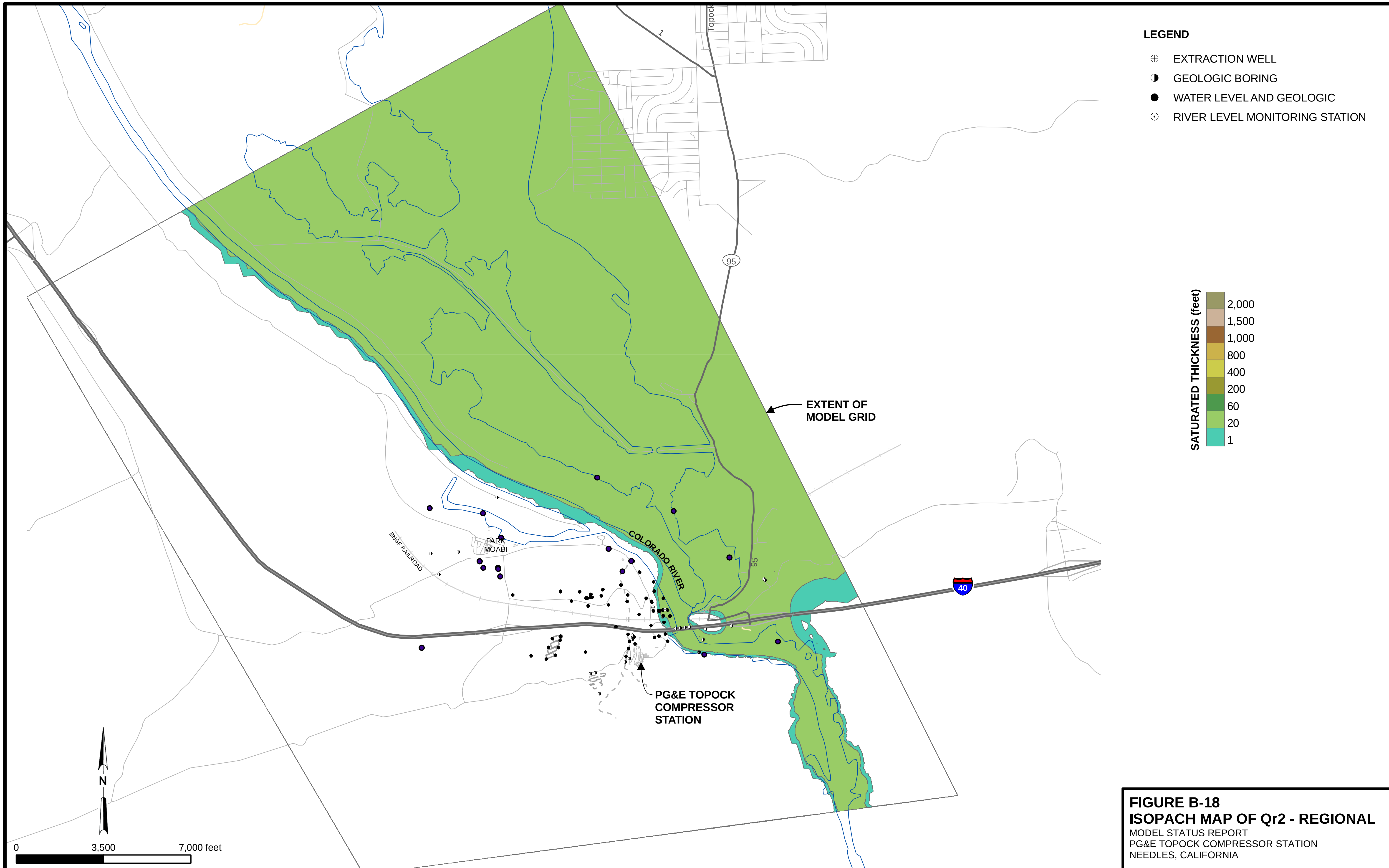

FIGURE B-18
ISOPACH MAP OF Qr2 - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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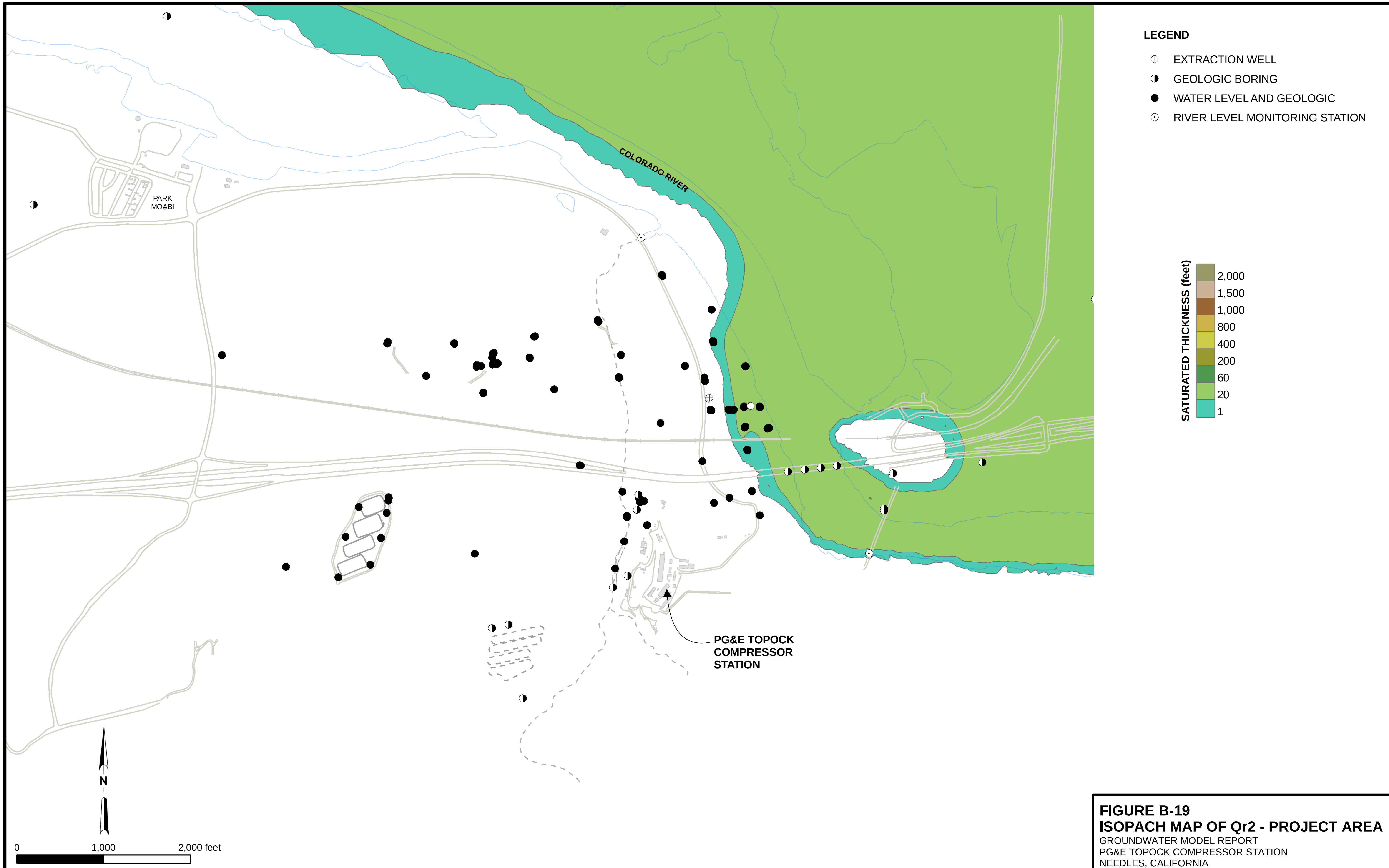

FIGURE B-19
ISOPACH MAP OF Qr2 - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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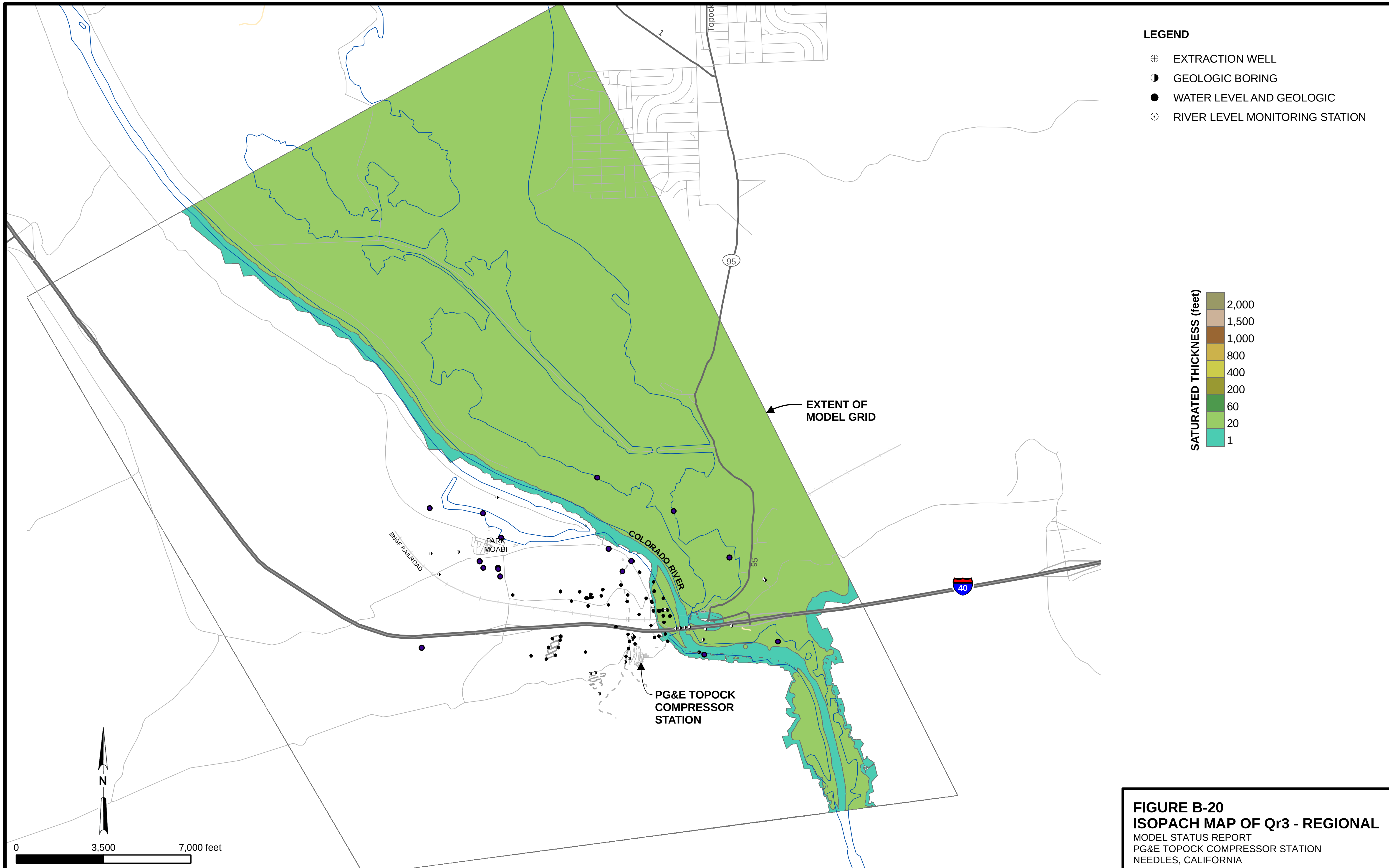

FIGURE B-20
ISOPACH MAP OF Qr3 - REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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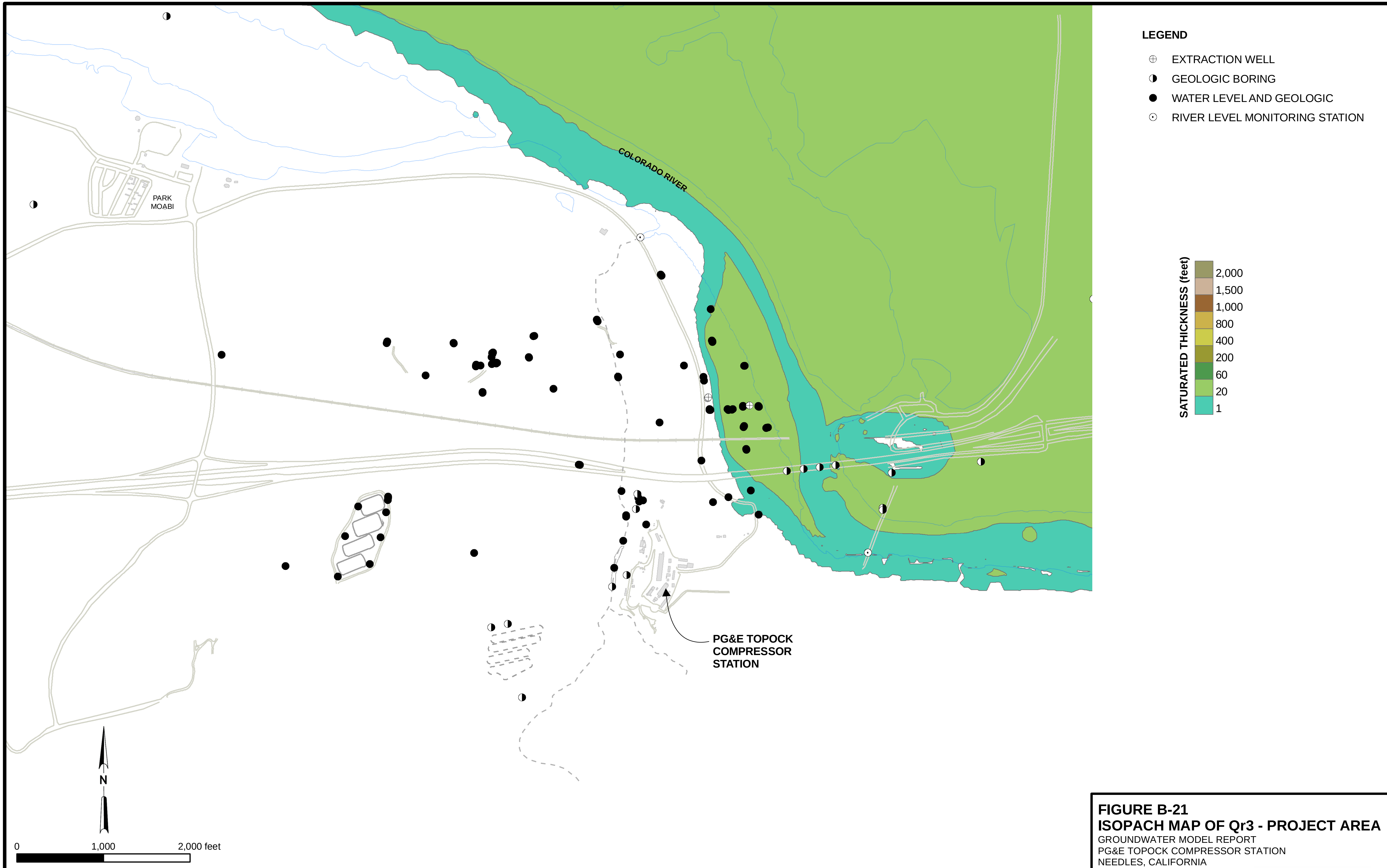

FIGURE B-21
ISOPACH MAP OF Qr3 - PROJECT AREA
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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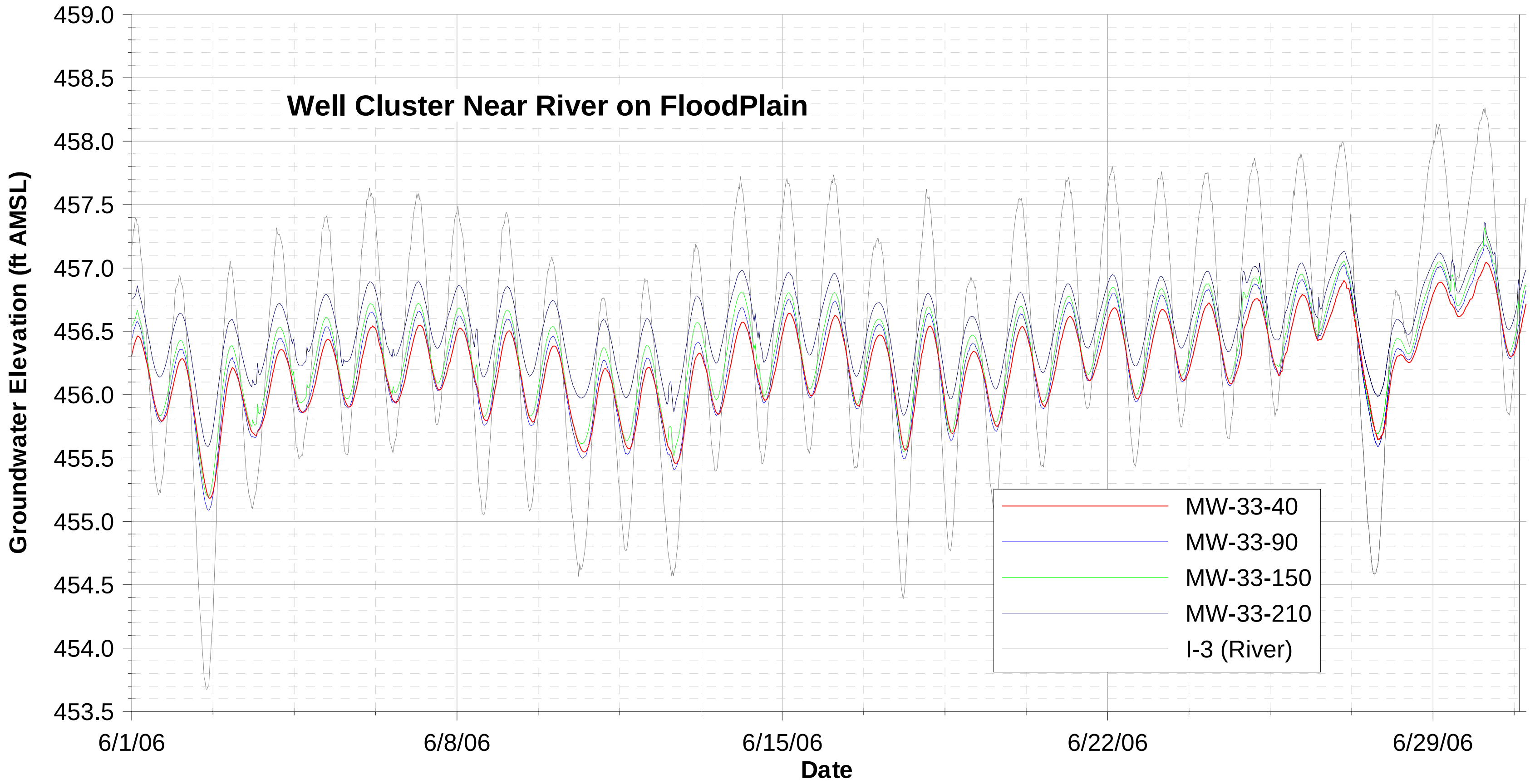
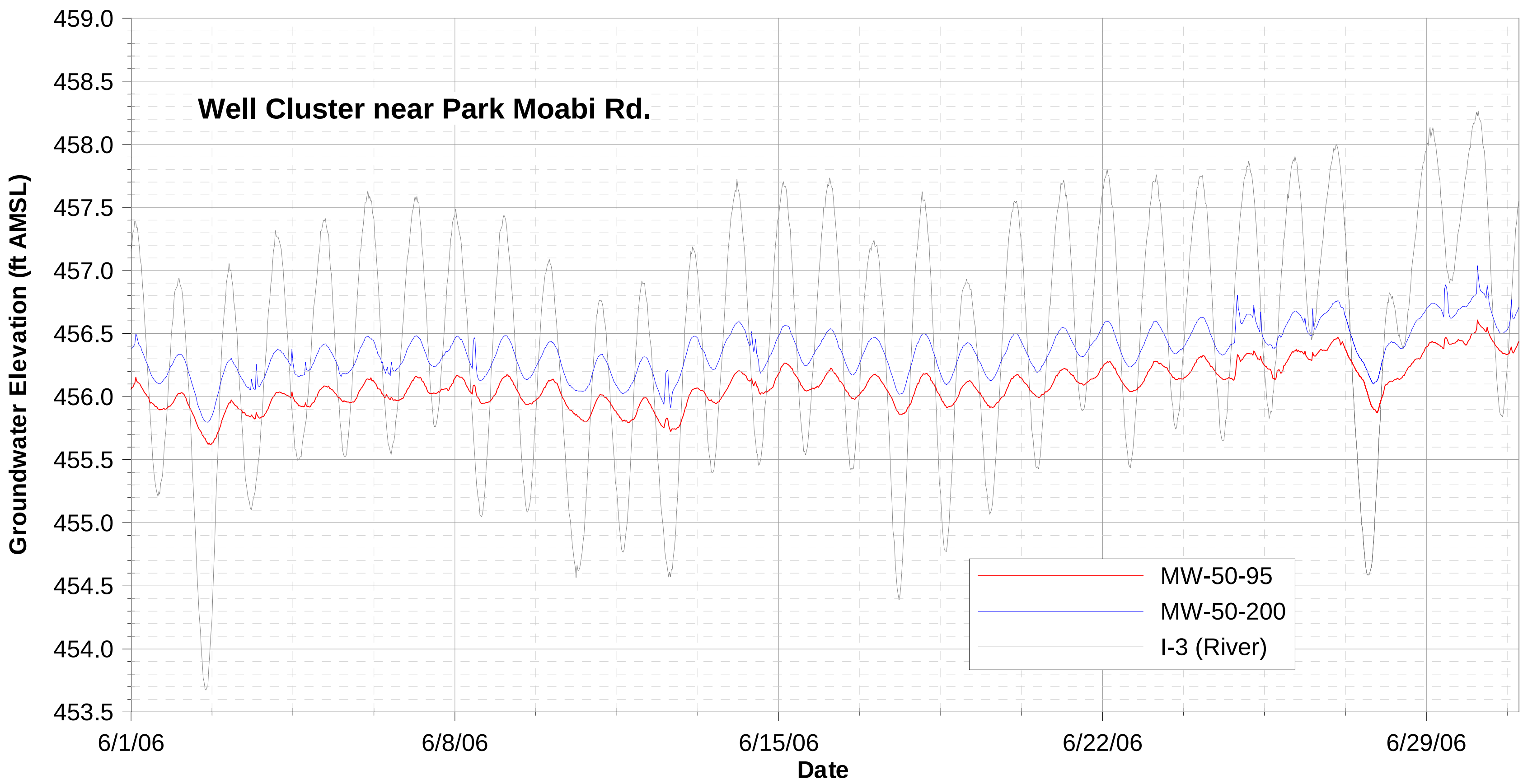
Appendix C
Hydrographs for Selected Wells in IM Performance Monitoring and IM No. 3 Injection Area





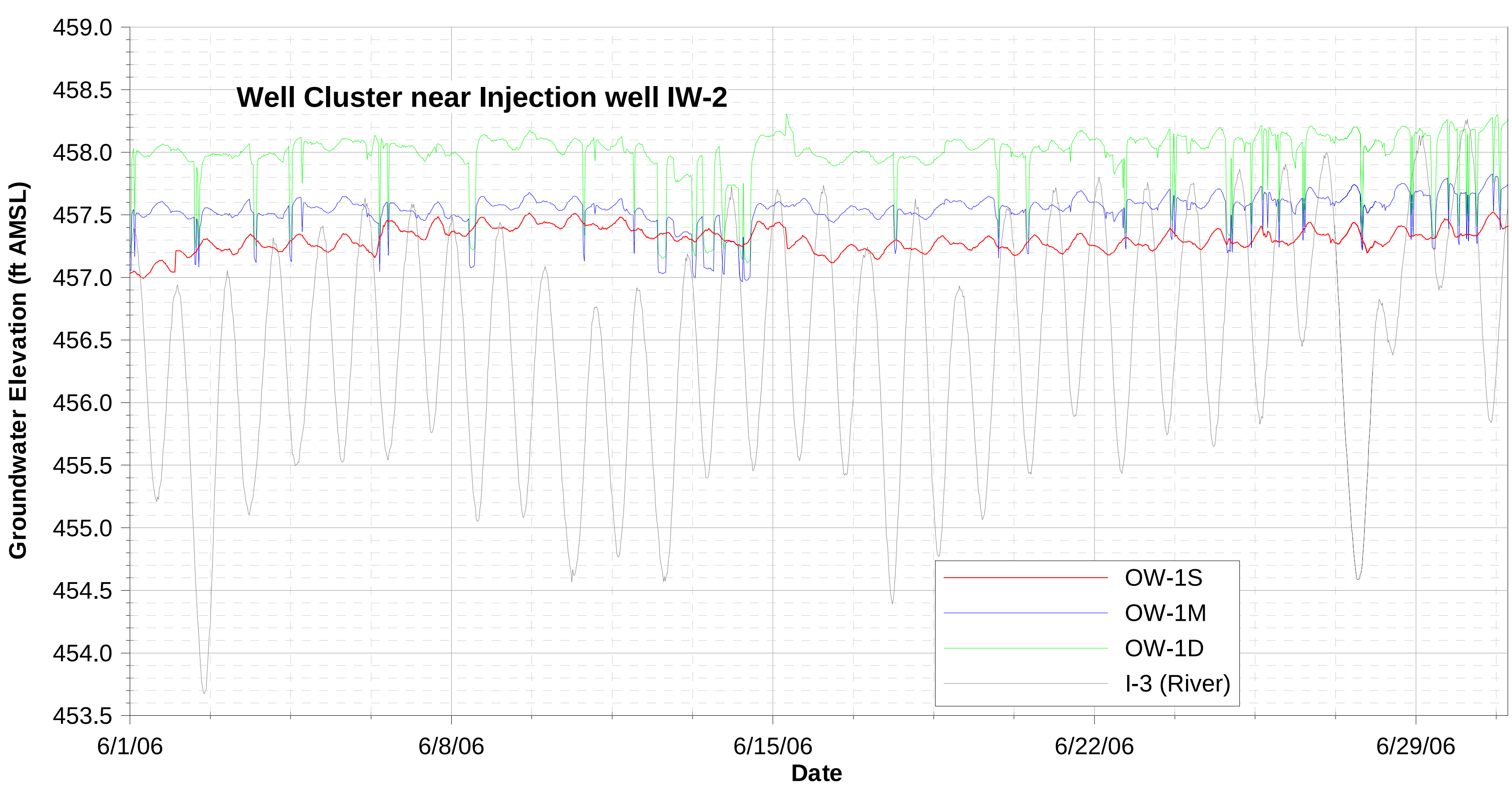


FIGURE C-1
HYDROGRAPHS OF SELECTED WELL CLUSTERS EAST TO WEST
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

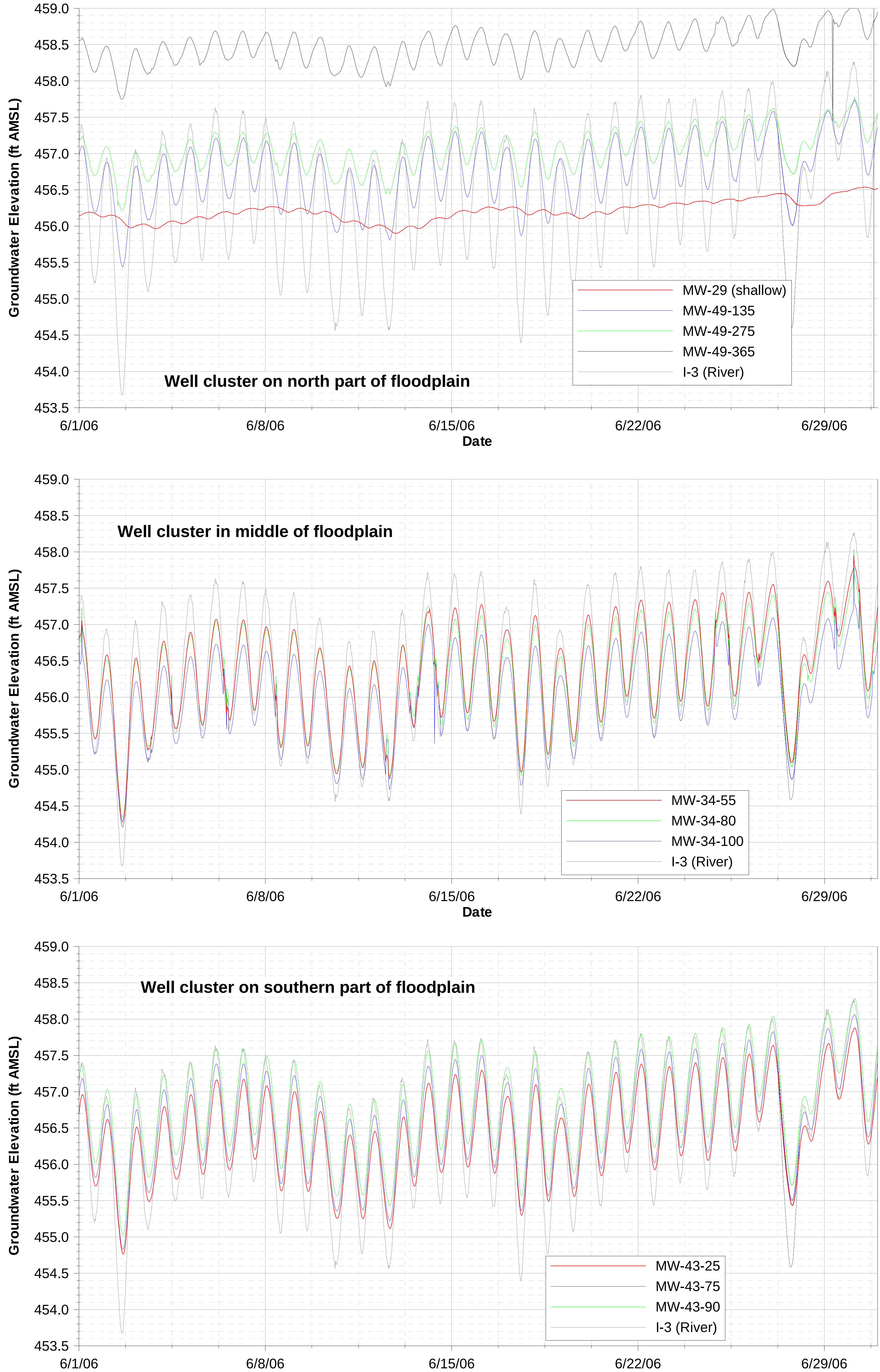


FIGURE C-2
HYDROGRAPHS OF SELECTED WELL CLUSTERS NORTH TO SOUTH
GROUNDWATER MODEL REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
CH2MHILL