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July 29, 2005

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Subject: Groundwater Model Update Report
Pacific Gas and Electric Company, Topock Compressor Station

Dear Mr. Shopay:

This letter transmits the *Groundwater Model Update Report* for the Pacific Gas and Electric Company (PG&E) Topock site. This report is provided in conformance with the Department of Toxic Substances Control (DTSC) request to document the objectives, configuration, and calibration procedures for the Topock groundwater model.

If you have any questions, please do not hesitate to contact me. I can be reached at 805/546-5243.

Sincerely,

Julie Eakins for Yvonne Meeks

Cc: Kate Burger
Richard Coffman

Groundwater Model Update Report

Topock Compressor Station Needles, California

Prepared for

Pacific Gas and Electric Company

July 2005

CH2MHILL
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Oakland, CA 94612

Contents

Acronyms and Abbreviations .... **iii**

1.0 Introduction **1-1**

2.0 Model Configuration **2-1**
2.1 Hydrogeology and Hydrostratigraphy 2-1
2.1.1 Hydrogeologic Setting 2-1
2.1.2 Hydrostratigraphy 2-2
2.2 Model Domain and Structure 2-4
2.3 HSU Hydraulic Property Distribution 2-5
2.4 Groundwater Elevations and Gradients 2-6
2.5 Water Budget 2-6
2.5.1 Recharge 2-7
2.5.2 Discharge 2-8

3.0 Model Calibration **3-1**
3.1 Calibration Targets 3-1
3.2 Calibration Procedure 3-1
3.2.1 Stage 1: 1951 – 1960 3-3
3.2.2 Stage 2: 1960 – 1970 3-3
3.2.3 Stage 3: 1970 – 1999 3-4
3.3 Calibration Results 3-4

4.0 Conclusions **4-1**

5.0 References **5-1**

Tables

2-1 Site Hydrostratigraphic Units
2-2 Summary of Well and Aquifer Tests and Estimated Hydraulic Properties
2-3 Vertical Gradient Summary

Figures

1-1 Regional Surface Features Map
1-2 Site Well Map
2-1 Regional Hydrogeologic Cross Section
2-2 Regional Isopach Map of Saturated Unconsolidated Deposits
2-3 Geologic Map of Study Area
2-4 Schematic Stratigraphic Section
2-5 Hydrogeologic Section A
2-6 Hydrogeologic Cross Section B-B′
2-7 Isopach Map of Alluvial Deposits

2-8 Isopach Map of Fluvial Deposits
2-9 Model Grid
2-10 Model Layers
2-11 Hydraulic Testing Locations
2-12 River and Groundwater Elevations
2-13 Average Shallow Groundwater Elevations 2001 – 2003 (Quarterly Monitoring Data)
2-14 Map of Model Boundaries and Top System
3-1 Simulated versus Observed Responses to TW-2D Shutdown, November 2004
3-2 Simulated versus Observed Water Levels, November 2004
3-3 Map of Modeled Hydraulic Conductivity Distribution for Qr1 and Toa1
3-4 Modeled Hydraulic Conductivity Distribution – Model Layer
3-5 Simulated Flowpaths from Disposal Area

Appendices

A Bedrock Elevation and HSU Isopach Maps
B Model Hydraulic Parameter Distributions

Acronyms and Abbreviations

af/yr	acre-feet per year
DTSC	Department of Toxic Substances Control
ET	evapotranspiration
gpm	gallons per minute
HSU	hydrostratigraphic unit
IM	Interim Measure
in/yr	inch per year
MGal/yr	million gallons per year
PEST	parameter estimation software tool
PG&E	Pacific Gas and Electric Company
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
USGS	United States Geological Survey

1.0 Introduction

Pacific Gas and Electric Company (PG&E) is addressing chromium in groundwater at the Topock Compressor Station in Needles, California under the oversight of the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC). Investigation and remediation activities at the site are being conducted under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act processes. A revised RCRA Facility Investigation (RFI) Report is currently in review, and a Corrective Measures Study is underway to review options for cleanup of site groundwater. A regional map showing the facility location is provided in Figure 1-1.

In February 2004, DTSC directed PG&E to initiate an Interim Measure (IM) in the floodplain area of the site. As stated in a DTSC letter dated June 30, 2004, the goal of the Interim Measures is "hydraulic control of the plume boundaries near the Colorado River to achieve a net reversal of groundwater gradient from the Colorado River" (DTSC 2004). The IM is currently active and involves groundwater extraction from well TW-2D, treatment, and conveyance of treated water offsite. The next phase of the IM, currently under review, calls for injection of treated water into wells IW-2 and IW-3 on PG&E property west of the plume area. A site map showing well locations is provided in Figure 1-2.

A groundwater flow model has been developed as part of the Corrective Measures Study and IM processes. The objectives of the model are to provide a tool to: (1) integrate geologic and hydraulic data, (2) estimate IM extraction rates based on anticipated river levels, (3) test groundwater flow hypotheses through the use of sensitivity analyses, and (4) assist in design and review of remedial alternatives. Data from water budget analysis, hydrostratigraphy, hydraulic testing, and regional and local topographic and geophysical surveys are incorporated into the model. Input parameters are adjusted during model calibration to achieve a reasonable match to observed data.

The finite-element model MicroFEM (Hemker 1999) was selected as the modeling code. Finite-element models are preferred when there is a need for a high degree of detail in a limited area (the floodplain area of the plume in this case) but not in the majority of the model domain. In addition, MicroFEM is preferred for its ease of use and strong "top system" packages for simulating river-groundwater interaction, evapotranspiration, and precipitation recharge.

In this report, a brief discussion of the hydrostratigraphy is provided in Section 2.1. The model framework is presented in Section 2.2, followed by model inputs in Sections 2.3, 2.4 and 2.5 (hydraulic properties, gradient targets, and water budget, respectively). Section 3.0 provides a description of the calibration process. A summary of the work, along with future anticipated model development, is discussed Section 4.0. Cited references are provided in Section 5.0.

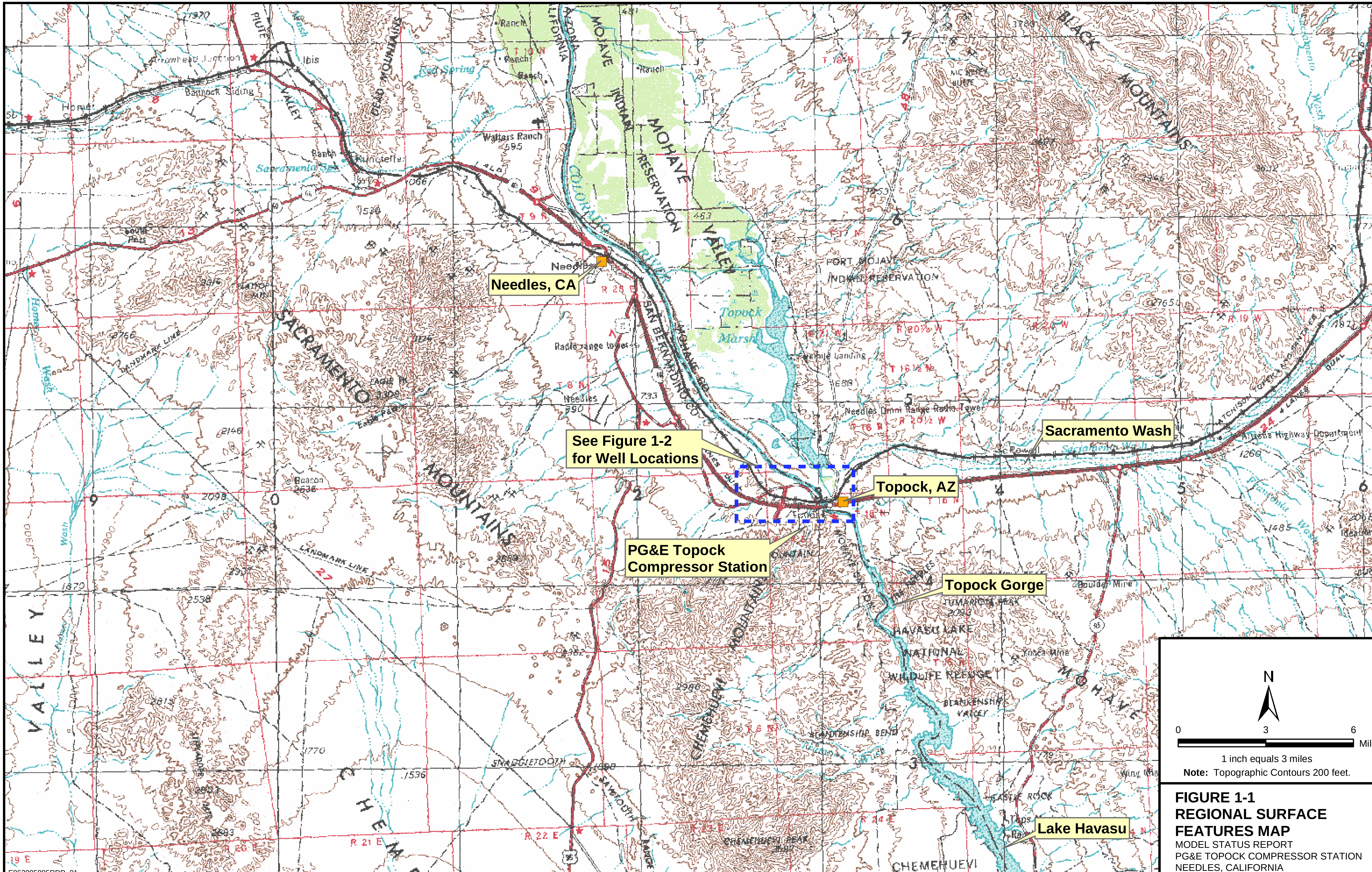


FIGURE 1-1
REGIONAL SURFACE FEATURES MAP
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

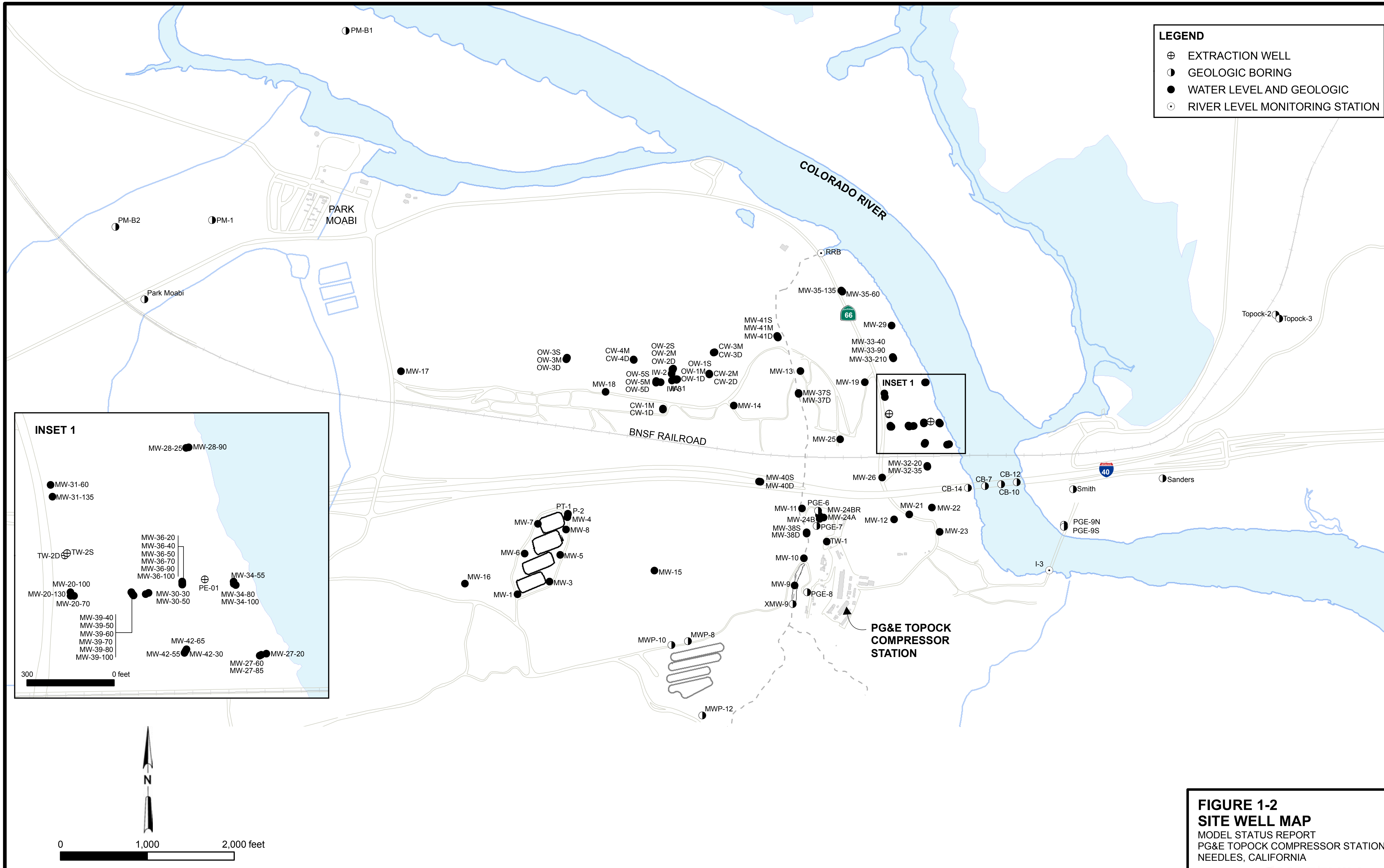


FIGURE 1-2
SITE WELL MAP
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
CH2MHILL

2.0 Model Configuration

2.1 Hydrogeology and Hydrostratigraphy

2.1.1 Hydrogeologic Setting

The Topock site is situated at the southern end of the Mohave Valley groundwater basin, a basin-and-range alluvial valley bounded by several small mountain ranges and covering approximately 450 square miles. The principal recharge to Mohave Valley groundwater is from the Colorado River (Anderson and Freethey 1995), which flows southward down the middle of the valley. There are comparatively small amounts of recharge from local mountain precipitation and associated runoff. Groundwater discharge occurs as evapotranspiration in river floodplain areas, by localized pumping, by flux to the river and Topock Marsh in the southern area, and as underflow beneath the riverbed through Topock Gorge. Groundwater flow generally parallels the path of the river through most of the valley, except where agricultural pumping creates local depressions (Metzger and Loeltz 1973). However, at the southern end of the valley, the unconsolidated aquifer materials pinch out as the river enters Topock Gorge, immediately south of the site. Fluvial deposits from a prehistoric Colorado River location are present beneath Topock Bay and extend to the present course of the river to the east of the I-3 gauging station. South of I-40, unconsolidated aquifer materials are limited to those directly beneath the present and ancient riverbeds. As a result of this geometry, the river is a net gaining stream in the southern-most portions of the valley.

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. Groundwater movement occurs primarily in the overlying unconsolidated deposits. A generalized cross section shows these relationships in Figure 2-1.

The water table in the Alluvial Aquifer has a very low gradient throughout the site and typically equilibrates to an elevation within 2 to 3 feet of the river level. Due to the variable topography at the site, the depth to groundwater ranges from as shallow as 5 feet below ground surface in floodplain wells next to the river to approximately 170 feet below ground surface at the upland alluvial terrace areas. The saturated thickness of the Alluvial Aquifer is about 100 feet in the floodplain and thins to the south, pinching out along the Miocene conglomerate and bedrock outcrops. To the north and east of the Topock site, unconsolidated thickness increases to several thousand feet, as shown in Figure 2-2.

The fluctuations in the stage of the Colorado River have a strong influence on groundwater levels at the Topock site. These effects are most notable in the floodplain area, the IM extraction area, and adjacent inland area. The stage of the Colorado River varies both daily and seasonally in response to upstream dam discharges regulated for resource management and electricity production. The fluctuations in river stage cause the surface water-groundwater interaction in the floodplain to be very dynamic. This will be discussed further in Section 2.4.

A more detailed discussion of the site hydrogeology and groundwater and surface water conditions is provided in Section 2.0 of the Draft RFI Report (CH2M HILL 2005).

2.1.2 Hydrostratigraphy

The stratigraphic units encountered in the vicinity of the Topock Site are shown in map view in Figure 2-3 and in stratigraphic section in Figure 2-4. Descriptions of these units are found in Section 2.3. 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 2-1.

Properties such as grain size distribution and degree of induration of each HSU can vary considerably in both vertical and lateral directions. As a result, hydraulic properties would also be expected to vary spatially. This will be demonstrated in later sections. A brief description of each HSU follows. For more detailed information, refer to the RFI Report (CH2M HILL 2005).

2.1.2.1 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). The latter unit is not present in all areas of the region, having been completely eroded away in some areas north of the site. Both bedrock formations are locally fractured but generally produce very little water, based on purge records from the few bedrock monitoring wells at the site (MW-23 and MW-24BR). The two formations were modeled as a single bedrock unit in the model. Some areas may produce more water locally, as demonstrated by testing of inactive injection well PGE-8. There is an upward hydraulic gradient between bedrock and Alluvial Aquifer groundwater.

2.1.2.2 Oldest Alluvium (Toa1 and Toa2)

The Oldest 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 geophysical logs, with the lower unit generally displaying lower resistivity and sometimes higher gamma counts. In some drilling locations, zones of reddish silty sand and gravel within Toa1 are inferred to be reworked Miocene Conglomerate. Properties of each unit were assigned in the model.

2.1.2.3 Basal Saline Unit (Tsu)

A basal saline unit of the Oldest Alluvium has been identified in some deeper wells. Geophysical induction logs have indicated high groundwater total dissolved solids, and boring logs note the presence of more reddish material that is often (though not always) finer grained than most of Toa1. The extent of Tsu is not known in most of the model domain due to the absence of detailed deep boring logs and geophysical logs. Model assignment was limited to areas in which Tsu is known to occur.

2.1.2.4 Bouse Formation (Tb)

Separating the Oldest Alluvium from the Older Alluvium in some areas is the Bouse Formation, which consists of interbedded clay, claystone, and sandstone, along with a basal limestone unit. The Bouse represents a lacustrine (lakebed) deposit left by a large Pliocene lake that covered a large portion of Mohave Valley (Spencer and Patchett 1997). Most of the Bouse was eroded away by the Colorado River as it cut and constantly changed direction during Pleistocene and Holocene time. The formation remains on the western and eastern flanks of the historical river floodplain. Though outcrops of Bouse are observable near the site around Park Moabi, no saturated Bouse has been encountered in site boring logs. It is present and saturated to the north of the site and has been incorporated into the model in these areas.

2.1.2.5 Older Alluvium (Qoa)

Quaternary alluvial deposits of the moderately dissected alluvial fan overlie the Bouse Formation. The Qoa is virtually indistinguishable from Toa where the Bouse is not present to separate the two (Metzger and Loeltz 1973). This is true in all site borings, though a few subtle distinctions have been made mainly through geophysical log interpretation. There is actually very little thickness of saturated Qoa (refer to Appendix A), so its occurrence is discontinuous and minimal in the model.

2.1.2.6 Fluvial (River) Deposits (Qr)

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 United States Geological Survey (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. Three model HSUs were assigned: Qr1, Qr2, and Qr3 from oldest to youngest. The Qtrg unit shown in Figure 2-4 occurs only above the water table. The RFI Report discusses these units of Qr but, when viewed in more detail, the boring log data indicate that no continuous bed of similar material exists within the Topock floodplain deposits. The deposits range from as fine as clayey sand beds to very clean gravels encountered in a few borings. The hydraulic conductivity and transmissivity of the fluvial and alluvial units were estimated by evaluation of the hydraulic response to TW-2D shutdown, response to injection at IW2 and IW3, and to river fluctuations. The methodology used to estimate these properties is discussed in more detail below.

The interpreted structure of key sections of the model domain is shown in cross section in Figures 2-5 and 2-6. The section running west to east through the main portion of the Topock site (Figure 2-5) shows alluvial material of Toa1 and Toa2 pinching out in the floodplain, with fluvial deposits Qr1, Qr2, and Qr3 deposited on the erosional surface. Data from unpublished USGS seismic data suggest that the fluvial deposits thicken to over 200 feet beneath the river. East of the Colorado River, the fluvial thickness is estimated to stay at around 250 feet, as the river channel migrated throughout the Topock Bay area. Alluvial deposits underlie the Qr series where depth to bedrock exceeds 250 feet. Figure 2-6 is a similar west-to-east cross section, only north of the Topock site, where the Bouse Formation is present below the water table.

The distributions of combined alluvial and fluvial deposits are displayed as isopach maps in Figures 2-7 and 2-8, respectively. These figures show the extent of these portions of the Alluvial Aquifer (shown as a combined isopach map in Figure 2-2). Hydraulic properties were eventually assigned to HSUs within each group, as discussed below. Isopach maps of each individual HSU are provided in Appendix A, along with bedrock elevation.

2.2 Model Domain and Structure

The current model domain covers approximately 26 square miles from about 3 miles north of the Topock site to 1.5 miles south of the site (Figure 2-3). The northern and southern model boundaries are roughly perpendicular to the Colorado River and the regional groundwater flow direction. They do not represent significant hydrogeologic features but were placed at significant distances from the site in order to avoid boundary condition effects in the site area. The eastern and western boundaries were placed about two miles on either side of the site, also to avoid boundary condition effects.

The finite-element model grid is made up of 28,762 nodes and 57,337 triangular elements. Model grid spacing is shown on Figure 2-9. Areas far from the Topock site were assigned 500-foot spacing between nodes. The general site area, from Park Moabi to about 0.75 mile into Arizona, have 200-foot spacing, fining in steps of 100-, 60-, and finally to 20-foot spacing in the floodplain and adjacent river area. With the exception of the 20-foot spacing area, the finer grid spacing extends along the river southward to the model boundary.

The model is made up of five layers: Layer 1, designating the top or shallowest layer, and Layer 5, the bottom. Layer 5 is designated as bedrock, comprising HSUs pTbr and Tmc, described above. It forms a low-permeability base for the model. Above the bedrock is the Alluvial Aquifer, which is split into Layers 1-4. Bedrock is assigned a constant thickness of 300 feet, though not always solely in Layer 5, as explained below. None of the eight HSUs comprising the Alluvial Aquifer (Toa1, Toa2, Tsu, Tb, Qoa, Qr1, Qr2, and Qr3) is continuous throughout the model domain, so model layers cannot directly correspond to HSUs. In some cases, modelers attempt to maintain correlation of HSUs and layers by reducing a layer thickness to a very small value in areas where the HSU is absent. This leads to numerical instability and difficulties with convergence. To avoid this, the following scheme was used to incorporate HSUs into the four-layer Alluvial Aquifer model structure (Figure 2-10 shows an example of how the process is applied in the floodplain area of the site):

1. Well logs and geophysical logs (if available) were used to identify HSUs encountered in each well, along with each HSU contact elevation.
2. Thickness of each HSU at all well locations were plotted and contoured to produce isopach maps, provided in Appendix A. Regional gravity surveys provided by the USGS were used to estimate unconsolidated thickness in areas of the model domain where little or no boring log data were available.

3. Contoured isopach maps for each HSU were digitized and the thickness of each HSU was calculated at each model node.
4. Thickness of each model layer (except Layer 5) was assigned at each well location, with breaks between model layers sometimes corresponding to HSU contacts and sometimes dictated by screened intervals in well clusters. It is important to note that model layers often do not correlate with HSU boundaries. A model layer may contain more than one HSU, or an HSU may be split between more than one model layers.
5. Assigned model layer thicknesses were interpolated (using kriging) between well locations so that each node had a set of layer thicknesses and that layer thickness varied smoothly around the domain. In areas far from the site with no well data, thickness of Layers 1-4 were split evenly into the estimated total unconsolidated thickness. In bedrock outcrop areas, Layers 1-4 were assigned a thickness of 10 feet each, and Layer 5 was assigned a thickness of 260 feet, consistent with the assumption that only the upper 300 feet of bedrock had any permeability at all.
6. An external program code was written to calculate the fraction of each HSU in each model layer. Output from the code was loaded into data registers of the model. These fractions were later used in combination with assigned hydraulic conductivity of each HSU to calculate overall hydraulic conductivity and transmissivity of each model layer at every node.

With this procedure, thicknesses and hydraulic properties of each HSU were incorporated into the model. Note in Figure 2-10 how the contact between HSUs Toa1 and Toa2 corresponds to the boundary between model Layers 2 and 3 at the well cluster location, but this correspondence is not maintained in other areas. The three wells in the well cluster would be assigned to Layers 1, 3, and 4 for later calibration procedures.

In areas where only bedrock is present, the 300-foot bedrock thickness is split between Layer 5 (260 feet) and 10 feet for each of Layers 1-4. In these areas, all layers are assigned the hydraulic properties of bedrock.

2.3 HSU Hydraulic Property Distribution

Hydraulic properties that were assigned to HSUs and adjusted during calibration were hydraulic conductivity (K) and the ratio of horizontal to vertical hydraulic conductivity (K_h/K_v). Initial estimates of these parameters were derived from analysis of hydraulic test data at various site locations. Locations of hydraulic tests are shown in Figure 2-11. The tests that influenced the most wells were the TW-2D shutdowns in May and November 2004 and IW-2/IW-3 testing in early 2005. Extended purging during sampling of individual floodplain wells in February 2004 provided data for early estimates of hydraulic parameters. Data from these tests were interpreted using aquifer test analysis tools and the parameter estimates are provided in Table 2-2.

Virtually all of the floodplain wells are outfitted with transducers in order to monitor gradients for IM performance evaluation. Fluctuations of the Colorado River occur on an hourly and a seasonal basis (Figure 2-12) in response to Davis Dam releases upstream and Lake Havasu elevations downstream. As shown in this figure, the floodplain wells mirror this fluctuation on both time scales. In designing the TW-2D and IW shutdown tests, care was taken to turn off the pumps during a peak or trough in the river fluctuation in order to minimize the river effects during the 2-3 hours of recovery. In addition, alluvial wells further to the west parallel the seasonal river fluctuations, as exemplified by MW-10 in Figure 2-12. Well responses to river changes provide another means by which to estimate hydraulic parameters. The common analytical solutions used to analyze aquifer tests are not designed to account for the simultaneous response from pumping and river level changes. Rather than use analytical solutions in this complicated system, the model was used to simulate the aquifer tests, and hydraulic parameters were adjusted during model calibration to achieve an acceptable match between model simulations and observed well responses. This will be discussed in more detail in Section 3.0.

Anisotropy magnitude and direction were assigned according to the assumed depositional grain of the sediments. For local alluvial materials, the estimated depositional orientation was 350° (N10W) following the slope off the Chemhuevi Mountains. Fluvial deposits follow the approximate river channel orientation, which is about 160° (S20E) around the Topock site. It was assumed that maximum transmissivity is in these directions for each deposit type, and that the minimum transmissivity, perpendicular to the assigned direction, is one-half of the maximum.

2.4 Groundwater Elevations and Gradients

As discussed in the RFI Report (CH2M HILL 2005), natural groundwater elevations are typically within 2 to 3 feet of the river level. As a result, average gradients are very slight at the site, usually on the order of 10^{-4} to 10^{-3}. This is typical for the setting, since local rainfall is less than five inches per year and recharge from local mountains is minimal. Average groundwater elevations and gradient contours for the shallow portion of the Alluvial Aquifer are shown in Figure 2-13. The east-northeast gradient direction reflects the combination of the southeast regional flow encountering thinning aquifers and bedrock at the Chemhuevi Mountains with the modest local recharge flowing northward into the aquifer from those mountains. Floodplain wells are shown separately because they are under the influence of river fluctuations and IM pumping.

Vertical gradients are generally upward from bedrock and throughout the Alluvial Aquifer. Groundwater elevations in well clusters provide quantification of these upward gradients in Table 2-3. A limited amount of rainfall recharge in the nearby mountains enters the Alluvial Aquifer via upward seepage from the underlying bedrock and also via surface recharge at the mountain front.

The patterns of groundwater elevations illustrated in Figure 2-13 and Table 2-3 were reproduced by the model during calibration, discussed below. The inferred flow patterns also influenced the chromium plume growth direction and shape, and this was another calibration target for the model.

2.5 Water Budget

As described above, the main source of recharge to the Mohave Valley 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). However, in the southern end of the valley where the Topock model domain is situated, it is a net gaining stream and as such represents the primary location of groundwater discharge in the model. This is consistent with published hydrogeologic work in the region (Anderson and Freethey 1995; Metzger and Loeltz 1973), which reports that the vast majority of surface and groundwater in any Colorado River basin is associated with the river. For the model domain, the assigned water budget components are discussed below. Recharge and discharge fluxes reported in the text below are rounded to the nearest 10 acre-feet per year (af/yr); disagreement between totals of the reported recharge and discharge is 10 af/yr due to this rounding. Actual model disagreement is 0.053 af/yr, or about 0.005 percent.

2.5.1 Recharge

The main source of recharge to the model is groundwater underflow into the northern model boundary. This represents the northern Mohave Valley river water that recharges the aquifer in that region, passing 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 all values assigned in site areas (about 30 feet per day), thickness based upon regional gravity survey (from about 900 ft in the west to about 2,700 ft in the east), and gradient based on the regional river gradient in the area (1.3×10^{-4}). This corresponds to a total flux of about 700 af/yr.

The next greatest 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. Estimates of discharge from Sacramento Wash to the Colorado River range from 250 to 600 af/yr (Peter Martin, USGS, personal communication 2005). A groundwater flux from the eastern model edge of 100 af/yr was assigned during model calibration. Calibration runs showed that greater flux values produced excessively high westward gradients from the Arizona side of the river.

Precipitation recharge was assigned in the Chemhuevi Mountains area of the model domain in the south and southwest. Though precipitation in the highest parts of these mountains is likely no more than 10 inches/year (Metzger and Loeltz 1973) and the bedrock generally has very low fracture permeability, some recharge to the site area is expected from this very large drainage area. 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 alluvium at the interface (Metzger and Loeltz 1973). The drainage areas for Bat Cave Wash and other smaller washes extend far beyond the southern model domain boundary; therefore, the area of precipitation recharge shown in Figure 2-14 was designed to consolidate the estimated recharge into a smaller area. The approximately 200 af/yr recharge in this area corresponds to about 0.1 inch per year (in/yr) over the corresponding drainage area.

A small amount (10 af/yr) 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 (Figure 2-14). The assigned flux is based on regional model estimates by the USGS (Peter Martin, personal communication

2005). As explained above, annual discharge to the Colorado River exceeds recharge from the river in the model area, though during late winter and spring there is a net loss from the river in the model area.

2.5.2 Discharge

The discharge portion of the water budget in this portion of Mohave Valley occurs as evapotranspiration in river floodplain areas, by localized pumping, by flux to the river and Topock Marsh, and as underflow beneath the riverbed through Topock Gorge. The model requires three parameters for each river node: water surface elevation, riverbed elevation, and riverbed resistance (the inverse of permeability). River surface elevations were assigned throughout the model domain using average elevation of the main Topock site measuring point (I-3) and historical average river gradients between I-3 and the USGS gauging station in Topock Gorge, between I-3 and the RRB station at the upstream end of the site, and average gradient north of the site from USGS maps. The riverbed elevation was calculated by assuming a triangular bed profile with a maximum depth of 20 feet decreasing to zero at the banks. Riverbed resistance is defined as the sum of: (1) riverbed thickness divided by its vertical hydraulic conductivity and (2) half of Layer 1 thickness divided by its vertical hydraulic conductivity.

River discharge or recharge is simulated at each model river node by computing the difference between groundwater elevation and river level. If the computed water table is above the river level, groundwater discharge into the river is computed as the groundwater river elevation difference divided by the riverbed resistance. If the computed water table is between the river water and riverbed elevations, river recharge to groundwater is computed by the same relationship. According to the model, a net groundwater flux of about 600 af/yr flows into the river across the entire model domain. This includes flux from both the Arizona and California sides of the river.

Evapotranspiration (ET) losses occur in the floodplain areas and Topock Bay/Topock Marsh. An average maximum ET rate of 0.42 in/yr was assigned to all model nodes except those in the river. This rate was not designed to correspond to published plant ET rates, but as a value averaged over nodal areas which consist of both bare soil along with plant growth. An extinction depth of 10 feet was assigned, corresponding with the assumed average root depth. In active ET areas of the model domain (i.e., the southern floodplain, Bat Cave Wash mouth, Topock Marsh area) the plants are predominantly small and the water table is within several feet of land surface, so the 10-foot extinction depth is considered appropriate. In this model package, the maximum ET rate is applied only when the water table coincides with the ground surface. The rate decreases linearly to zero at the extinction depth. Therefore, all areas of the model in which the depth to water is greater than 10 feet have zero ET applied. This results in the floodplain areas and Topock Bay/Marsh displaying ET discharge in the model. The ET rate is designed to be representative of average ground coverage of local plant species in each model element area. Individual plants have much greater ET rates, but few if any model elements are completely covered by root networks. The resulting total ET discharge from the model domain is about 140 af/yr.

Available records indicate that groundwater extraction occurs within the model domain in two areas. One 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. In reality, only about one-third of one of the sections falls within the model domain. That entire section's pumping from 2003 (about 180 af/yr) is simulated in a surrogate "well" near the northeast corner of the model. The other pumping center is the Topock 2A/Topock 3 well pair located about one mile northeast of the compressor station in Arizona. These wells supply the Topock station with water, along with four other private users based on 2004 records. In 2004, combined pumping from the wells was about 80 af/yr. Another pumping well, the Serrano Well, has recently been identified as pumping at 220 gallons per minute (gpm) (Kristie Kilgore, ADEQ, email communication July 18, 2005). The well is located at the eastern edge of the model boundary about halfway between the railroad and Golden Shores. Although not in the version of the model discussed in this report, the well's average annual activity will be evaluated and incorporated in the near future. Interim Measures extraction was included in the model during calibration of pumping test and monthly time-varying data over the past year (discussed in Section 3).

The remaining discharge is underflow in fluvial materials beneath the river that leaves the model at the southern boundary. This was simulated by applying fixed heads in Layers 1-4 in the river nodes at the southern model boundary. Because the aquifer is very narrow at this point, the simulated groundwater discharge is small (about 10 af/yr).

TABLE 2-1

Site Stratigraphic Units

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

Stratigraphic Age	Site Hydrostratigraphic Units			
	Alluvial Deposits		**Fluvial Deposits**	
Holocene	**Younger Alluvium**	**Qya**	**Dredged River Sediment**	**Qrd**
			Floodplain Sand & Silt	**Qr3**
Pleistocene	**Older Alluvium**	**Qoa**	**Older Fluvial Deposits** interbedded silt, sand, gravel	**Qr2**
			Older River Gravels subsurface paleo-channel deposits	**Qr1**
			Oldest River Gravels	**QTrg**
Pliocene	**Oldest Alluvium** Fanglomerate of Metzger & Loeltz, 1973	**Toa**	**Bouse Formation** clay & sand lacustrine deposits	**Tb**
	Basal Saline Unit	**Tsu**		
angular unconformity (post-extension erosion)				
Miocene	**Miocene Conglomerate**	**Tmc**	consolidated conglomerate & sandstone containing rock fragments & megabreccia derived from Chemehuevi Mountains	
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 are included in the model are shaded yellow
2. Bedrock formations, grey shaded, are essentially impermeable but locally yield water where fractured
3. Within study area, Younger Alluvium, Oldest River Gravels, and Bouse Formation occur above the water table. Dredged river sediment, where saturate was combined with Qr3 in the model.
4. Stratigraphic age assignments from published geologic reports and are generalized for units in study area

TABLE 2-2

Summary of Well and Aquifer Tests and Estimated Hydraulic Properties

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

Unit	Well	Stratigraphic[1] Unit	Date	Type[2] of Test	Pumping Rate (gpm)	Duration of Pumping (min)	Specific Capacity (gpm/ft)	Estimated Transmissivity (ft^2/day)	Estimated Saturated Thickness at Well (ft)	Estimated Hydraulic Conductivity (ft/day)	Reference
Fluvial											
	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											
	MW-20-100	Toa	Jan-02	Pumping	3.1	525	0.1	100 - 600	86	1-7	E&E 2002
	MW-20-130	Tsu	Jan-02	Pumping	6.9	600	0.4	1,200 - 3,400	86	14 - 40	E&E 2002
	MW-24B	Tsu	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	Tsu	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	Tsu	May-04	Develop	4.5	55					
	TW-1	Qoa, Toa, Tsu	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, Tsu	May-04	Pumping	98	480	1 - 2		40		CH2M 2004
	TW-2S & D	Qoa, Toa, Tsu	May-04	Pumping	150	300	1 - 2	3,000	100	300	CH2M 2004
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										
	IW-3										

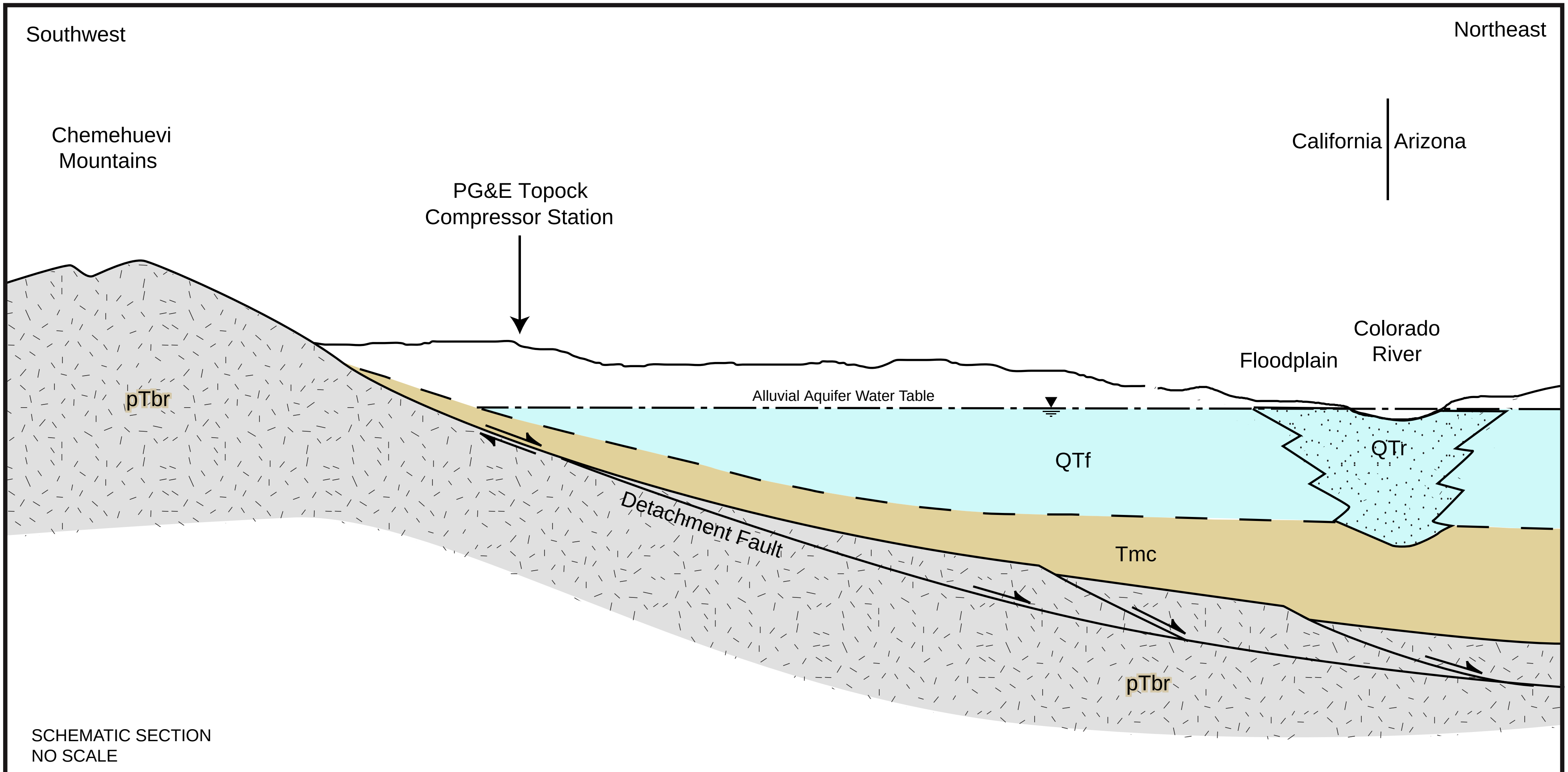
Notes:

1. See Table 2-1 for description and explanation of stratigraphic units.
2. Slug - slug injection or removal test; Devel. - testing during development; Purge - testing during purging/sampling; Step - variable rate step test; Pumping - contstant rate pumping/aquifer test.
3. Aquifer properties determined from specific capacity.

TABLE 2-3
Vertical Gradient Summary
Groundwater Model Update Report, PG&E Topock Compressor Station, Needles, California

	Well Pairs in Cluster		
MW-20 Wells[1]	**MW70 – MW100**	**MW100 – MW130**	**MW70 – MW130**
Median Head Difference (ft)	0.007	0.073	0.073
Distance Between Screens (ft)	35	32	66
Gradient (ft)	0.0002	0.0023	0.0011
MW-24 Wells[2]	**MW-24A – MW-24B**	**MW-24B – MW-24BR**	**MW-24A – MW-24BR**
Median Head Difference (ft)	0.095	--	0.865
Distance Between Screens (ft)	89	205	294
Gradient (ft)	0.0011	--	0.0029
MW-32 Wells[3]	**MW-32 – MW35**		
Median Head Difference (ft)	0.391		
Distance Between Screens (ft)	17		
Gradient (ft)	0.0237		
MW-33 Wells[3]	**MW-33-40 – MW-33-90**		
Median Head Difference (ft)	0.175		
Distance Between Screens (ft)	45		
Gradient (ft)	0.0039		
MW-34 Wells[4]	**MW-34-55 – MW-34-80**		
Median Head Difference (ft)	0.224		
Distance Between Screens (ft)	28		
Gradient (ft)	0.0081		

Notes:
Positive head difference and gradients indicate upward hydraulic gradient conditions.
Distance between screens is distance between screen midpoints.
1 MW-20 transducer data collected between August and November 2003. Manual groundwater level data not evaluated due to daily fluctuations caused by changing river levels.
2 MW-24A and MW-24BR transducer data collected between August 2001 and January 2002; MW-24A and MW-24B transducer data collected between August 2003 and February 2004.
3 Data collected between March and June 2004.
4 Data collected between August 2003 and June 2004.



PRIMARY GEOLOGIC UNITS

Alluvial Aquifer

- QTf — Alluvial Fan Deposits (Qoa, Toa, Tsu units)
- QTr — Colorado River Fluvial Deposits (Qrl, Qr2, Qr3 units)

Bedrock

- Tmc — Miocene Conglomerate
- pTbr — Metamorphic and Igneous Rocks

E062005005RDD_02

FIGURE 2-1
REGIONAL HYDROGEOLOGIC CROSS SECTION
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

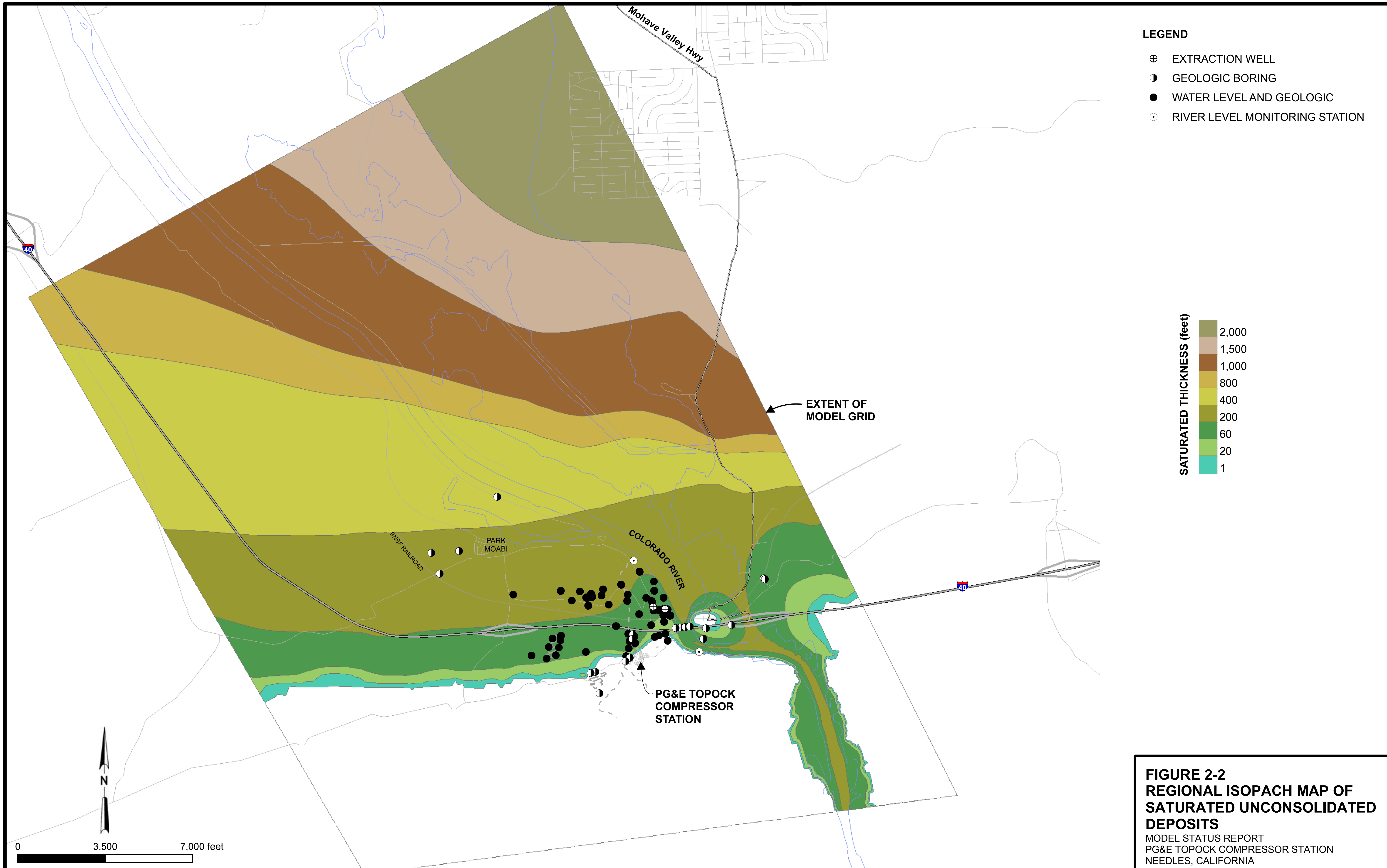


FIGURE 2-2
REGIONAL ISOPACH MAP OF SATURATED UNCONSOLIDATED DEPOSITS
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

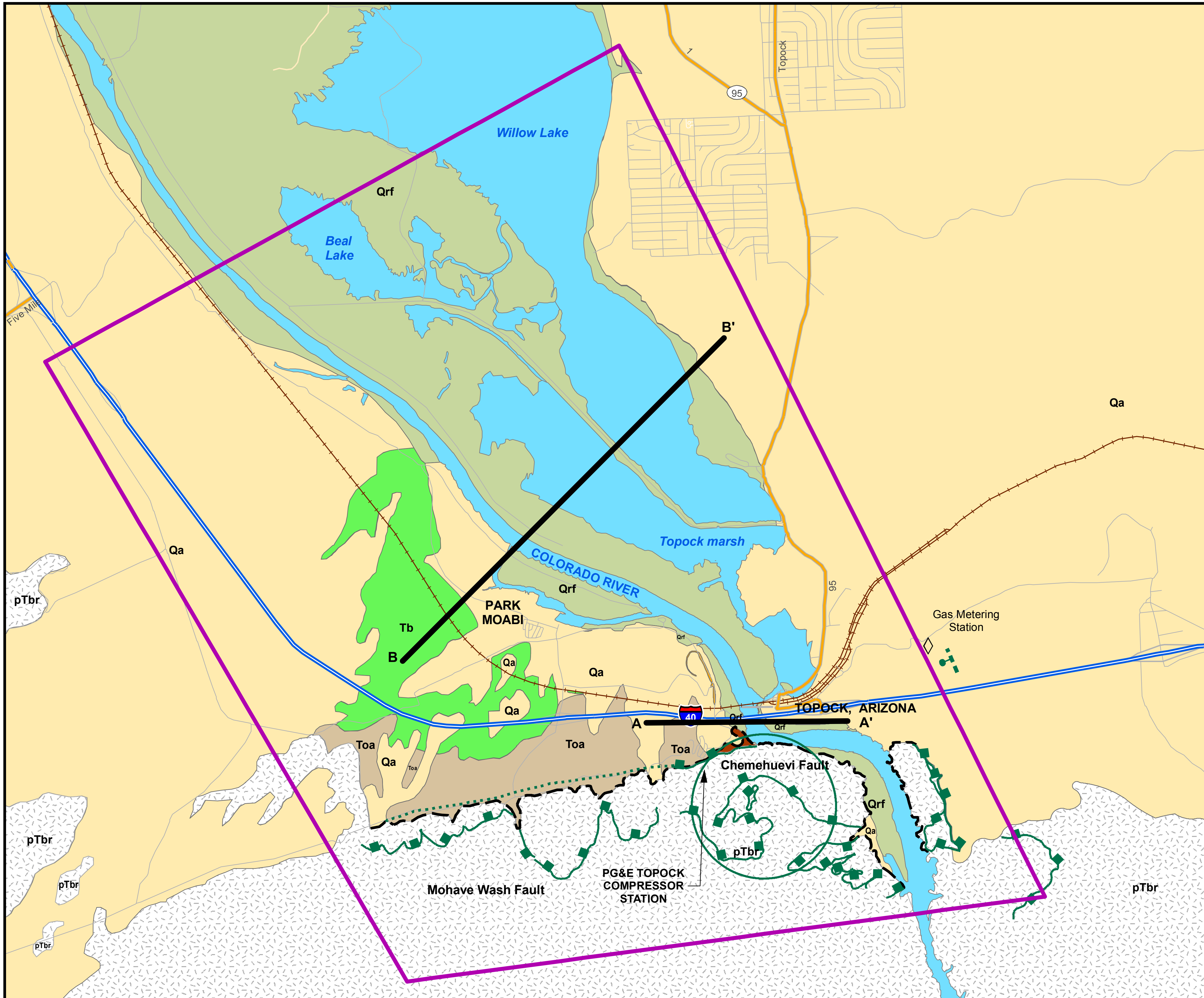


FIGURE 2-3
GEOLOGIC MAP OF STUDY AREA

JUNE 2005 MODEL UPDATE REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

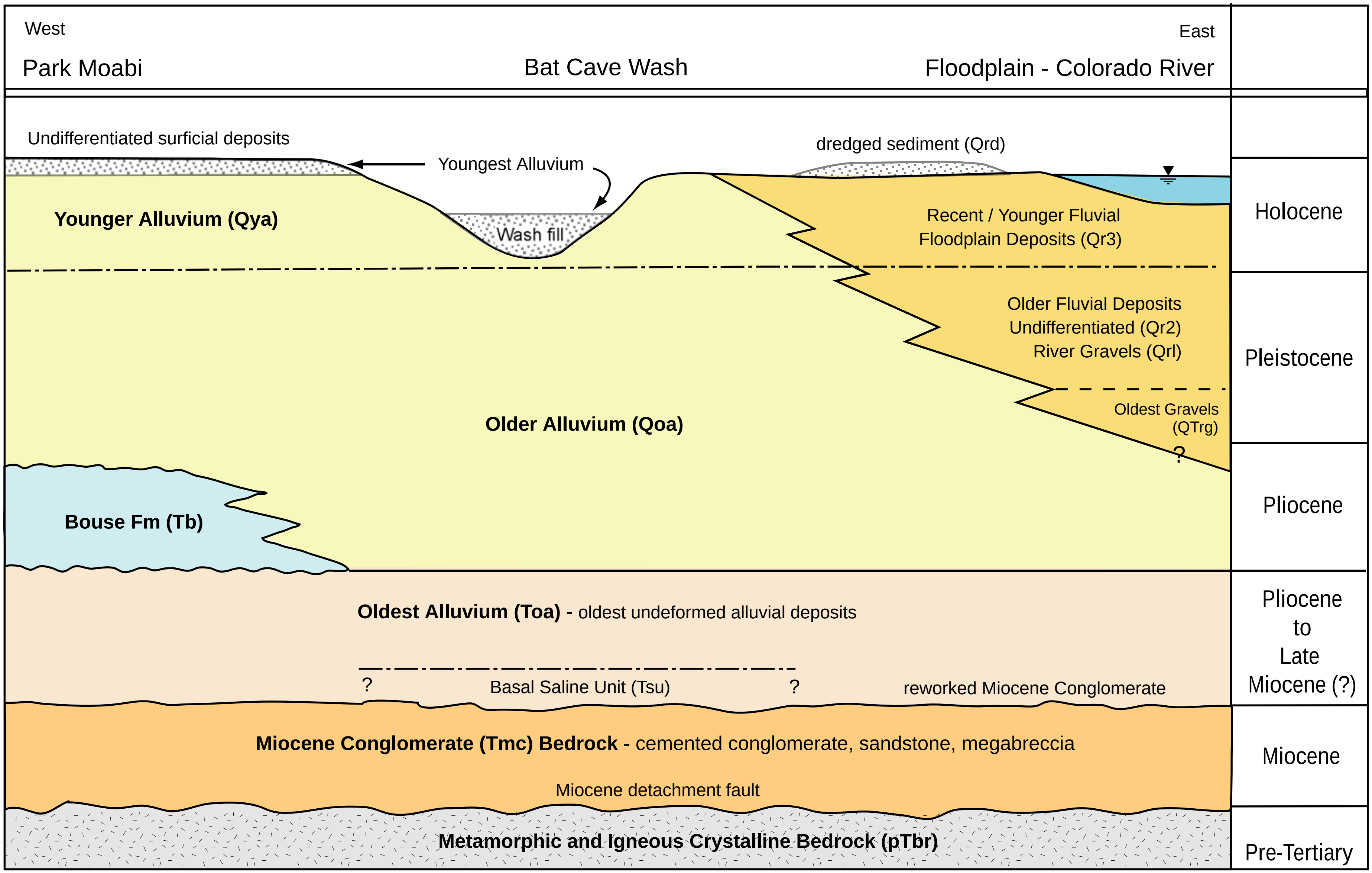


FIGURE 2-4
SCHEMATIC STRATIGRAPHIC SECTION
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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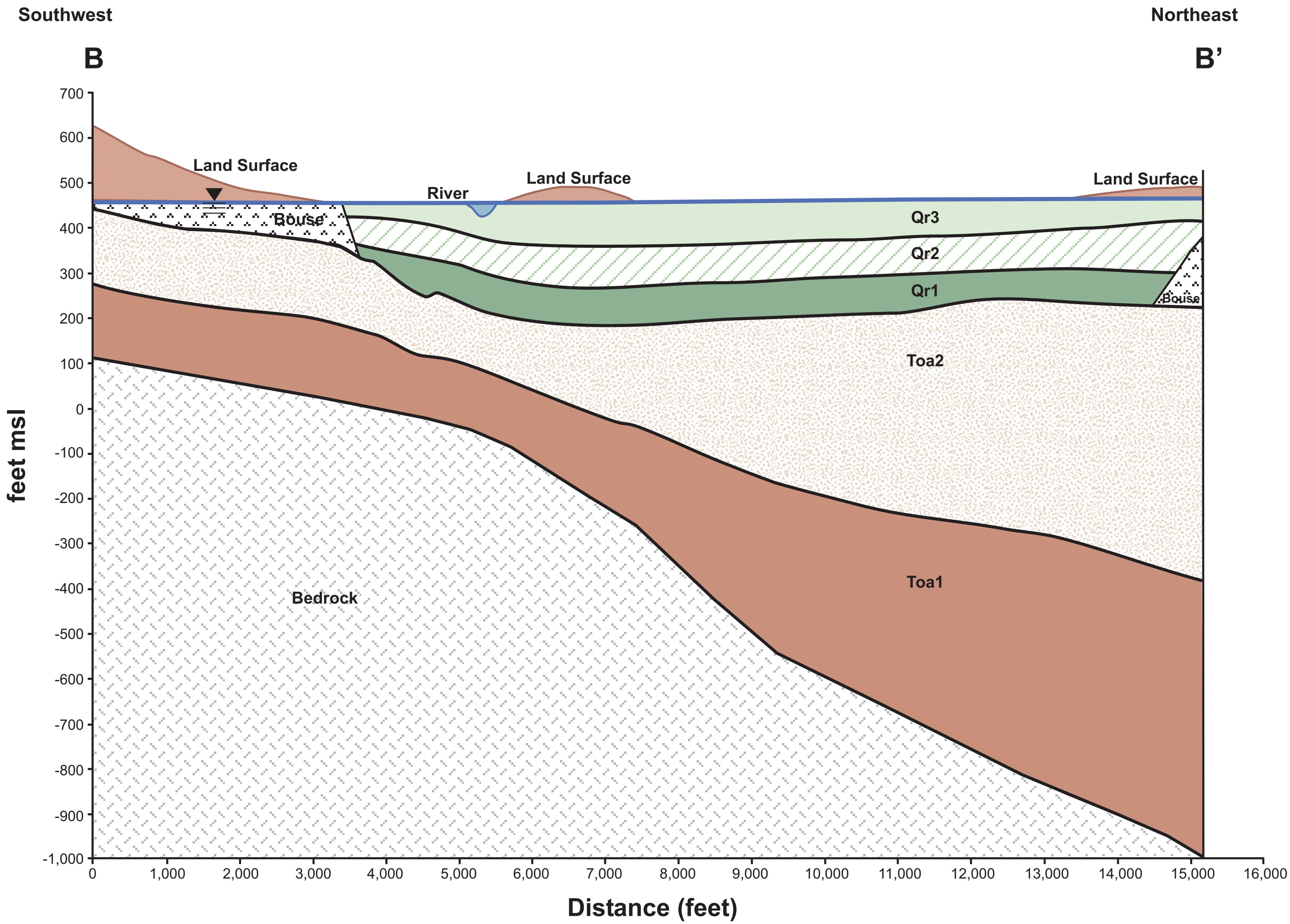

SEE FIGURE 2-3 FOR LOCATION OF CROSS SECTION.

FIGURE 2-6
HYDROGEOLOGIC CROSS SECTION B-B'
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIG02-06.FH10

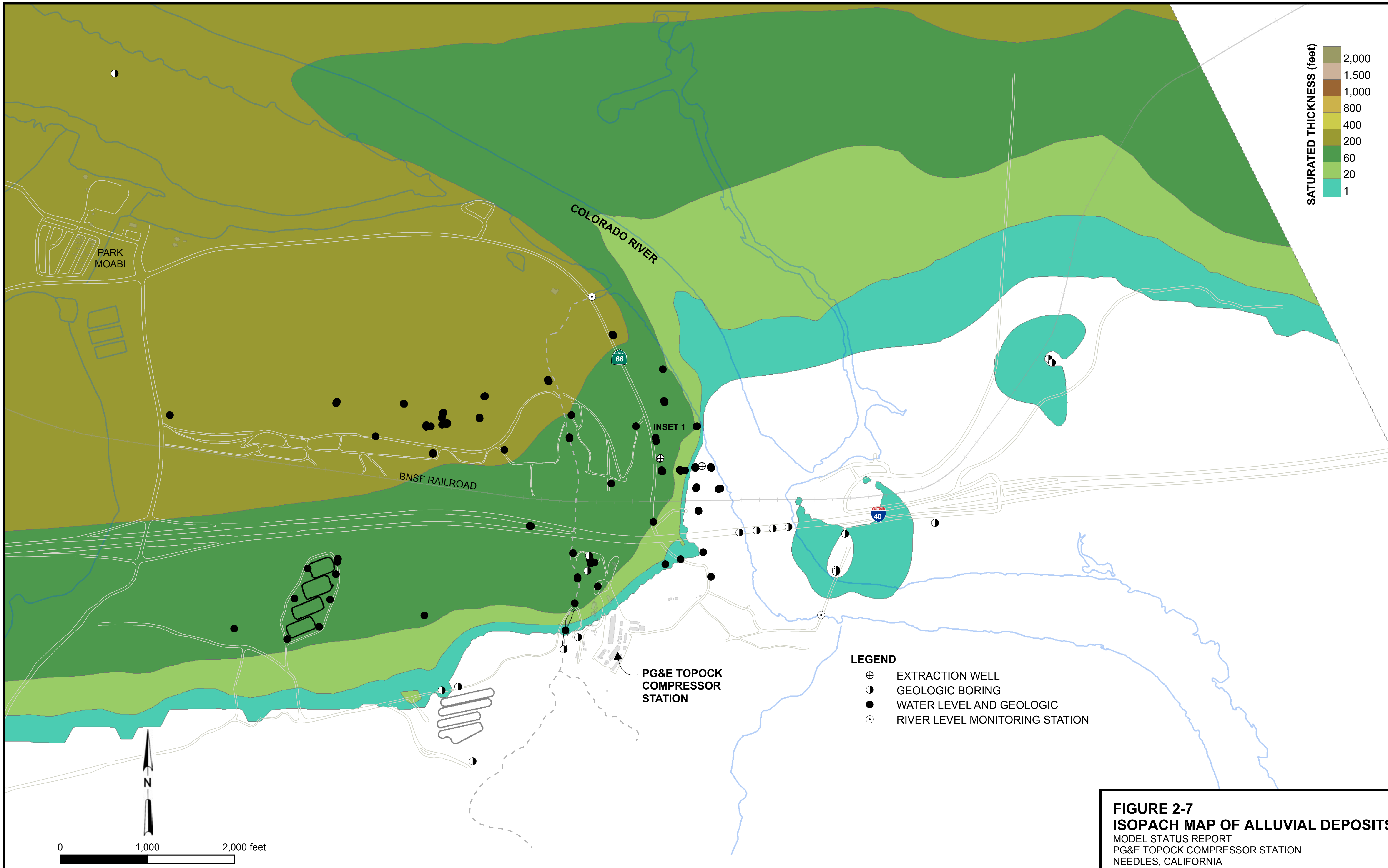

FIGURE 2-7
ISOPACH MAP OF ALLUVIAL DEPOSITS
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_FIG02-07.MXD 0605TM_FIG02-07.PDF 7/22/2005 16:26:49

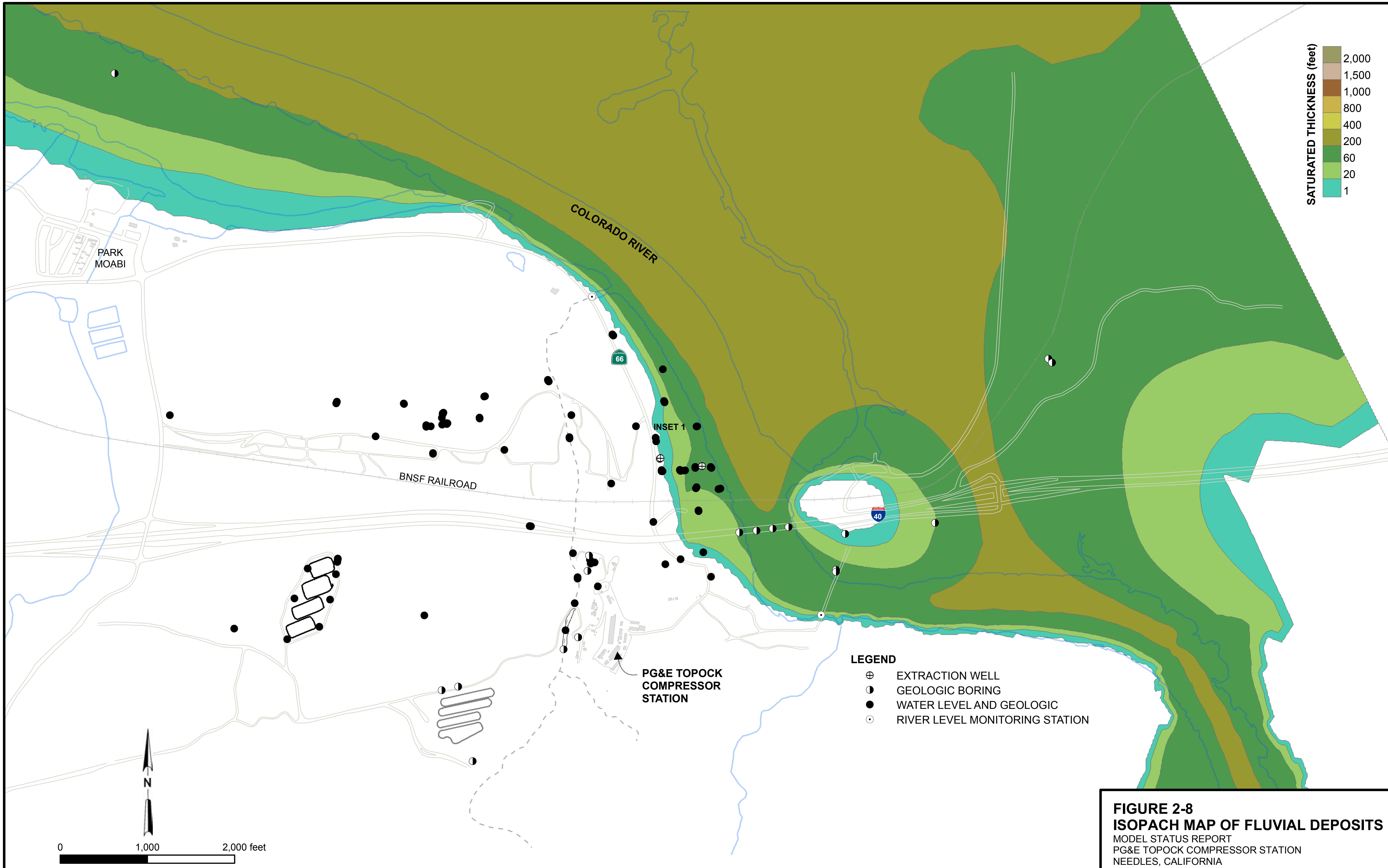

FIGURE 2-8
ISOPACH MAP OF FLUVIAL DEPOSITS
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_FIG02-08.MXD 0605TM_FIG02-08.PDF 7/29/2005 17:36:23

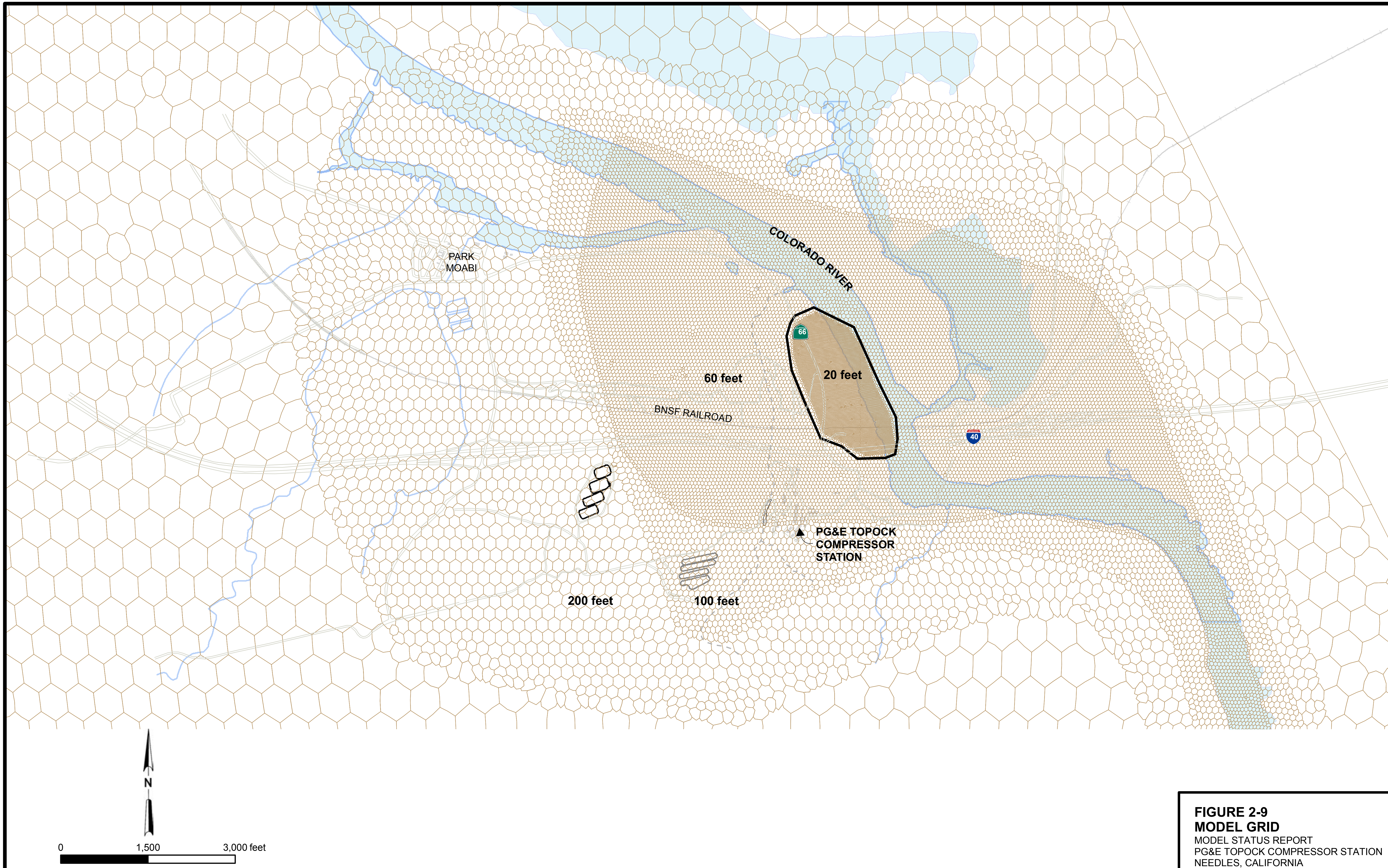

FIGURE 2-9
MODEL GRID
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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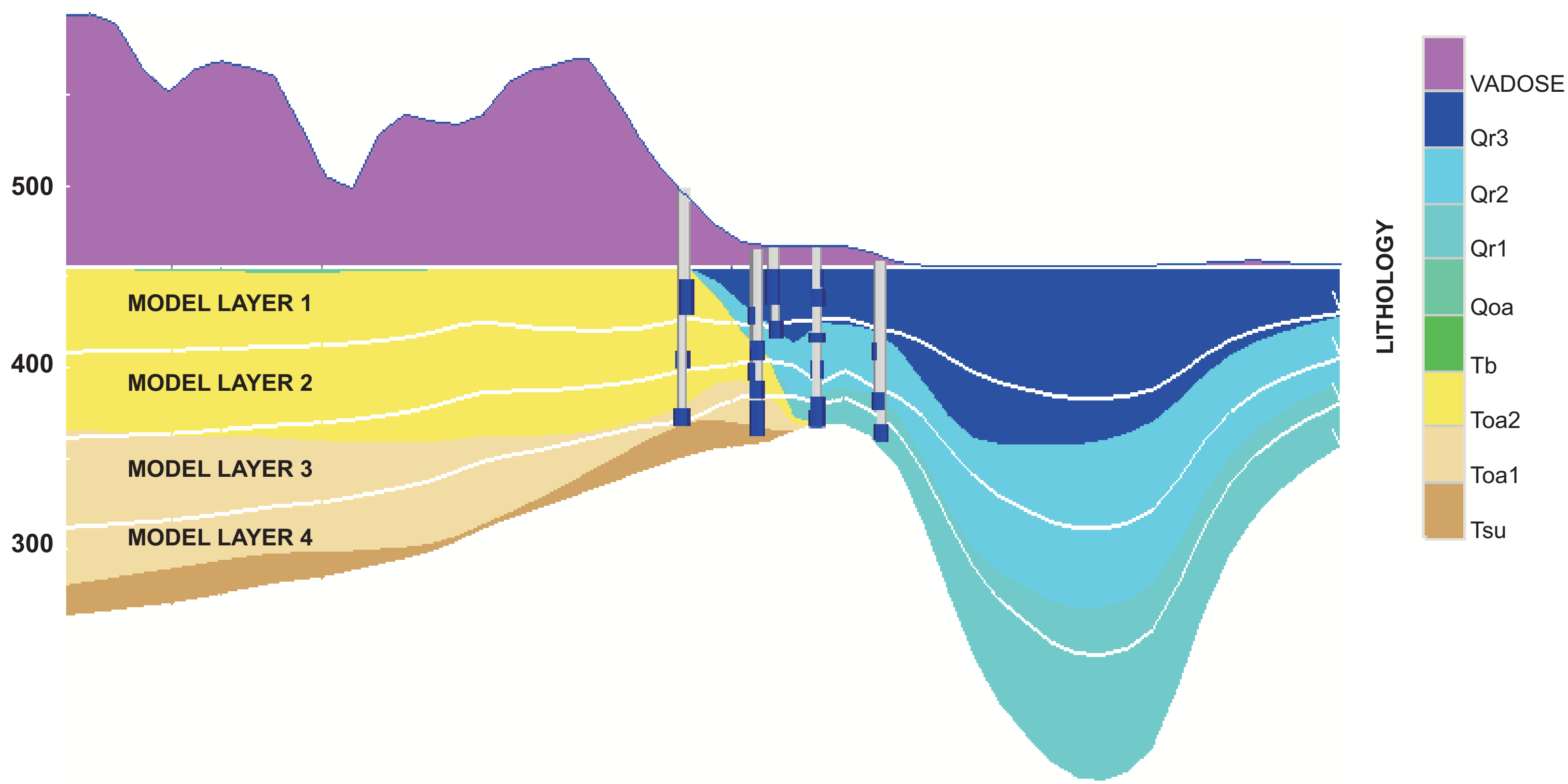
RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_FIG02-10.MXD 0605TM_FIG02-09.PDF 7/22/2005 18:38:19



NOTES:

1. MODEL LAYERS CORRESPOND TO WELL CLUSTER SCREEN INTERVALS.
2. MODEL LAYERS ALSO CORRELATE WITH HSUs WHERE FEASIBLE.
3. HSUs ARE CALLED OUT IN BORING LOGS AND CONTACTS ARE KRIGED ACROSS MODEL DOMAIN.
4. SEE CROSS SECTION A-A' ON FIGURE 2-5.

FIGURE 2-10
MODEL LAYERS
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIG02-10.FH10

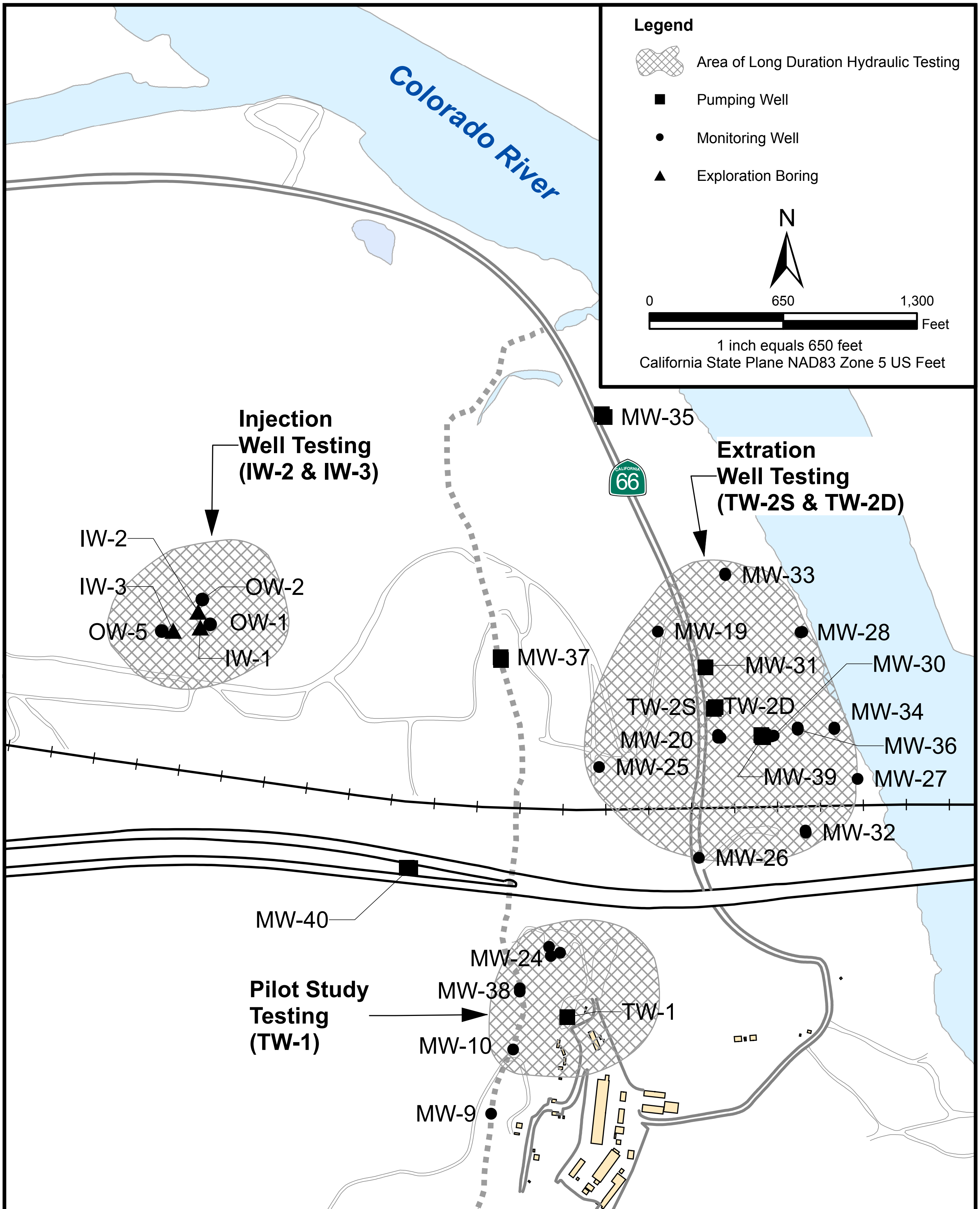

FIGURE 2-11
HYDRAULIC TESTING LOCATIONS
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

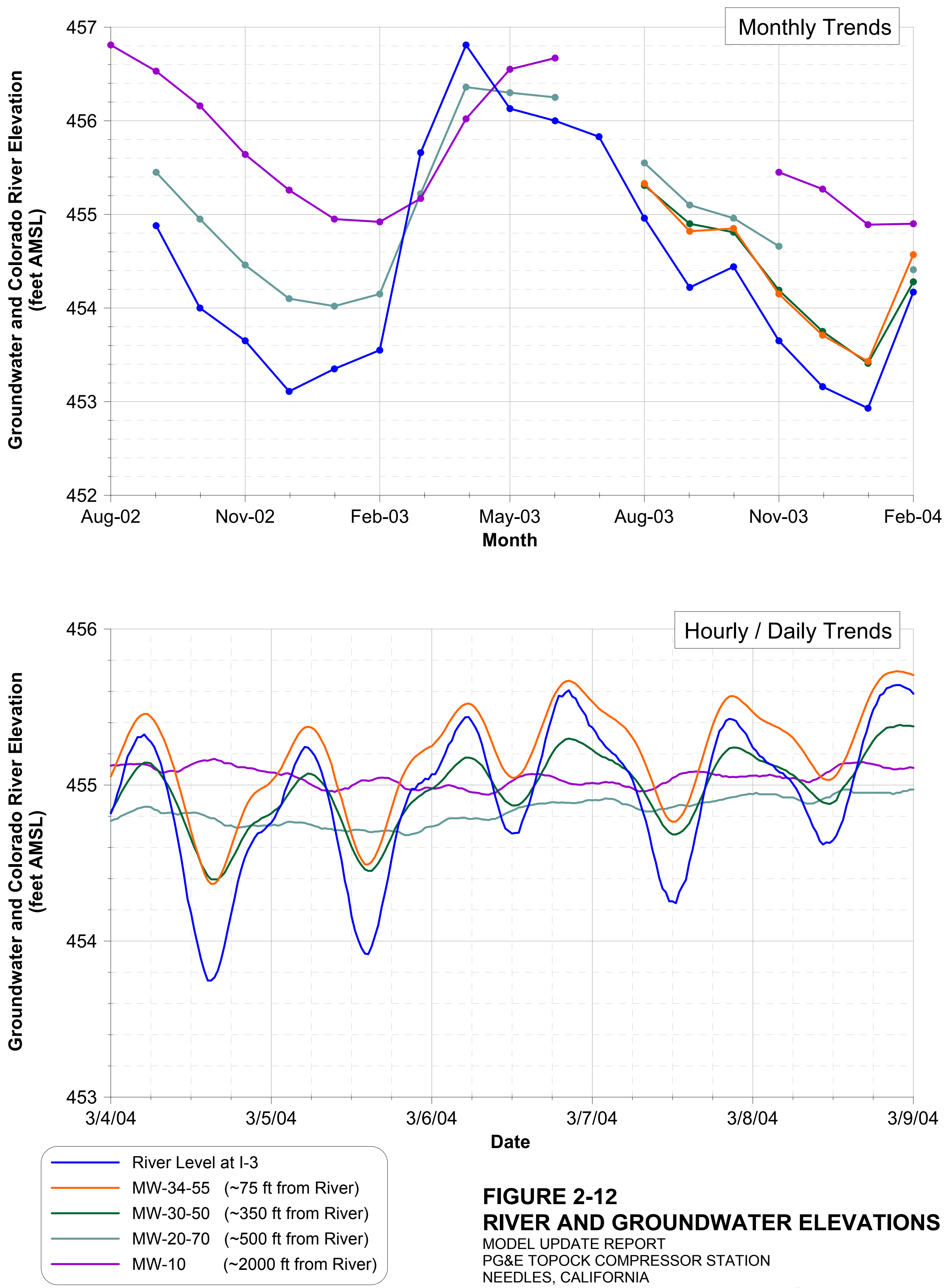

FIGURE 2-12
RIVER AND GROUNDWATER ELEVATIONS
MODEL UPDATE REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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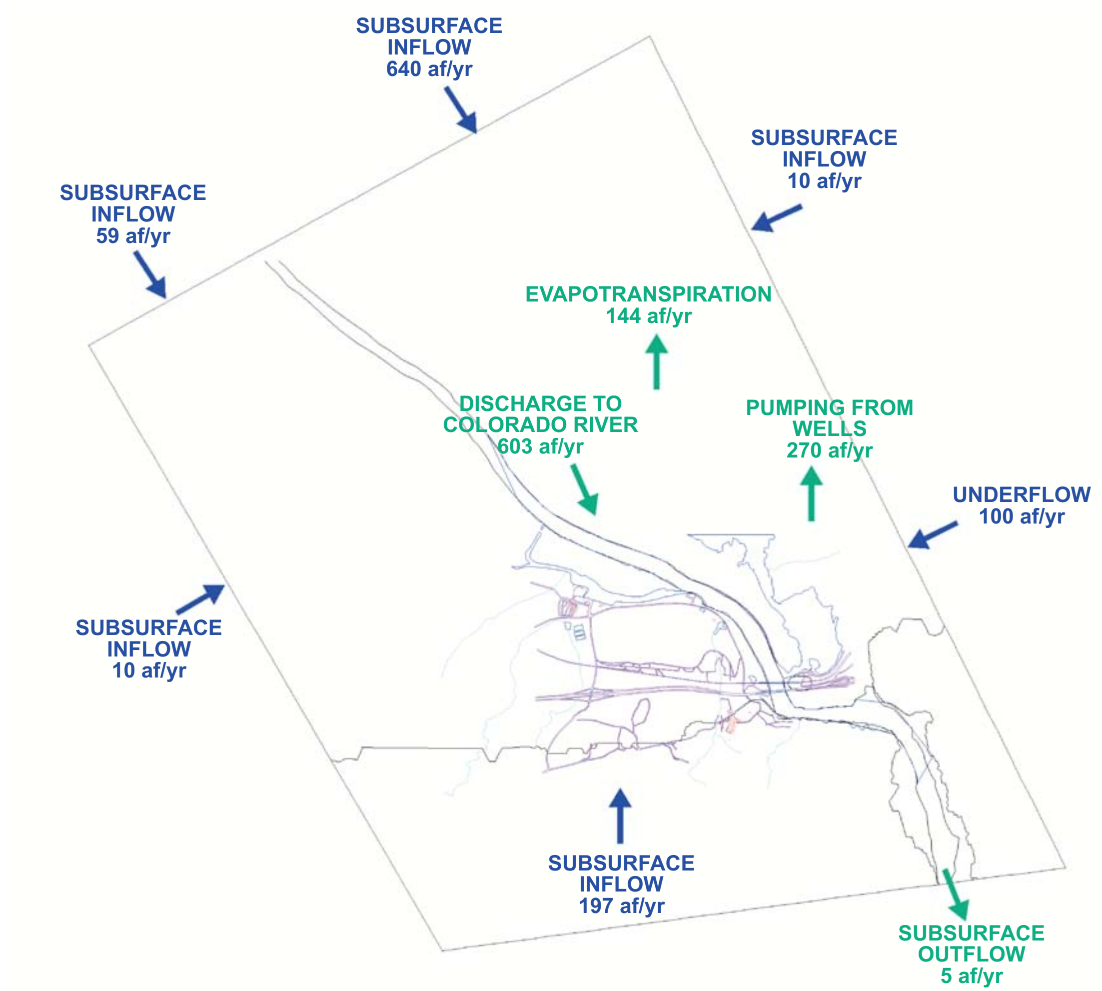
CH2MHILL



NOTE:

BLUE = GROUNDWATER RECHARGE
GREEN = GROUNDWATER DISCHARGE

FIGURE 2-14
MAP OF MODEL BOUNDARIES AND TOP SYSTEM
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIG02-14.FH10

3.0 Model Calibration

This section presents a description of these procedures, along with selected results. The full suite of calibration plots are provided in Appendix B.

3.1 Calibration Targets

The following sets of measured data were used as calibration targets:

- Recovery in transducer-equipped monitoring wells following shutdown of TW-2D in November 2004
- Average monthly groundwater elevations in transducer-equipped monitoring wells (available data between 2003 and March 2005)
- Recovery in Observation Wells during injection well testing at IW-2 and IW-3 in January 2005
- Estimated velocity and flow orientation of chromium plume development between initial discharge in 1951 to detection at MW-20 in 1999.

For other hydraulic data, independent estimates of hydraulic parameters were made outside of the model, and those were compared to calibrated model parameters in those areas. These testing data were from February 2004 purging data from floodplain wells and a step test at TW-1 in November 2003. Parameter estimates from these tests are listed in Table 2-2.

The most reliable data among the calibration targets were from TW-2D and injection well testing and the monthly average heads, since all of these employed an extensive transducer network with excellent data quality control. Historical manual measurements of groundwater elevations are far less reliable due to field measurement errors and time-dependency of the water table elevation.

The chromium plume evolution calibration required many assumptions, since the historical discharge methods and rates were not well documented (CH2M HILL 2005); therefore, this calibration target did not involve quantitatively matching measured data. Instead, the general modeled flow direction and speed were compared to the current plume shape.

3.2 Calibration Procedure

Model calibration was carried out in two stages. In each case, the intent was to match the measured data from the various calibration targets to a reasonable degree. The first stage was "manual" calibration, in which model parameters were adjusted on a trial-and-error basis until an approximate match to calibration targets was achieved. The second stage employed the use of PEST (Doherty 2002), a parameter estimation software tool in which the model is automatically run many times with incremental parameter adjustments until agreement to measured data falls within a specified error.

Estimated parameters listed in Table 2-2 were used to initially populate the model domain. Hydraulic conductivity (K) values and vertical anisotropy ratios (K_h/K_v) were assigned to each HSU, and an outside program (written by CH2M HILL in FORTRAN) was run to calculate transmissivity (T) for each model layer, along with interlayer vertical resistance (VR). As described in Section 2.0, the fraction of each HSU in each model layer was assigned on the basis of HSU isopach maps and model layer structure. For each node, the K and K_h/K_v values were calculated as a weighted average of the K and K_h/K_v values for the HSUs that make up the model layer at that node. A MicroFEM batch file: (1) exported the HSU values (K, K_h/K_v, and layer fractions), (2) calculated the transmissivity (T) and vertical resistance (VR) values for that each model node, (3) loaded the program output (T, VR values) back into the model, and (4) ran the model with the revised parameters. Model calibration was performed by altering the K and/or K_h/K_v values for individual HSUs in selected areas of the model and then running the batch file.

For the steady-state calibration, model boundary conditions were adjusted along with HSU parameters to match regional and sitewide gradients. Measured and computed average heads at monitoring wells were compared and the sum of squared residuals was minimized by adjusting model parameters.

Calibrating to match the water level recovery data from the TW-2D shutdown tests required transient or time-dependent runs, where heads at monitoring wells were matched over 15-minute intervals. Recovery in each test lasted 2 to 3 hours. During the “manual” stage of calibration, the HSUs were assumed to be homogeneous, and K and K_h/K_v values were selected to give the best fit to monitoring wells. A storage coefficient, a requirement for transient runs, was assigned and adjusted for each model layer, rather than HSU. A similar process was followed for monthly average head matching. The time period for this calibration exercise required running the model on a 28- to 31-day time step (depending on the month), where river water elevation, ET rate, and pumping rate from the TW-2 and/or MW-20 clusters was input for each simulated month. The river and pumping levels were the measured averages for those months, while the ET rate was adjusted for seasonal fluctuations based on local published trends (Consumptive Use Program 2005). Because the time scale of head changes was quite different between the recovery testing and monthly trends, a different set of storativity values was assigned for each calibration. The release of groundwater from storage was greater with the longer response duration of the monthly trends.

After reasonable fits were achieved with the manual calibrations, PEST was employed to improve the fits and to account for HSU heterogeneity. PEST is an external software package that essentially automates the calibration process. The user provides ranges of acceptable parameter values, residual error criteria, and other instructions, and PEST uses an algorithm to adjust the parameters within their ranges to minimize the overall residual. PEST was set up to run the model hundreds of times using a network of computers. PEST sessions were run to find the best simultaneous fit for: (1) steady state heads, (2) TW-2D recovery data, and (3) monthly average heads. For each PEST run, each of these three model conditions were run, one after the other, the residuals compiled, parameters readjusted, and the next run commenced. Initial PEST sessions maintained the homogeneous HSU criterion.

PEST was then used to allow for heterogeneity of the HSUs. To achieve this, a set of pilot points was employed where parameters at each pilot point were varied to achieve the best fit to observed data. Locations of pilot points were strategically placed surrounding areas of known data and more pilot points were located in high well density areas, such as the floodplain. As parameters were changed for each pilot point, PEST interpolated parameter values for all nodes between pilot points. For areas away from the site where no well data were available, PEST was instructed to assign the geometric mean of parameter values for each HSU. These heterogeneity sessions were conducted in similar fashion to the initial PEST runs but took significantly more time due to increased complexity.

In the months following the initial PEST calibration process, a number of new wells were installed at the Topock site, including the injection wells and observation wells on the East Mesa. An external program was used to estimate parameters for the injection well testing (IW-2 and IW-3 were interpreted together). The estimated parameters were then applied to this area of the model, replacing the geometric mean values from the PEST runs.

Data from the short-duration TW-1 step test were similarly interpreted with non-model tools, and the estimated parameters were applied to that area of the model domain. The geometric mean values in this area were actually very similar to the TW-1 estimates, so no changes were made.

The calibrated model was then used to simulate the evolution of the chromium plume. Only groundwater flow was simulated here, and the direction and approximate speed were examined to ensure that the model would predict discharge water to flow as far as the MW-20 cluster by the time of its installation in 1999. Hexavalent chromium is generally mobile in the oxidizing conditions of the alluvial area between Bat Cave Wash and the MW-20 cluster, and so Cr(VI) would be expected to travel at the approximate speed of groundwater. This was simulated in three stages, discussed below.

3.2.1 Stage 1: 1951 – 1960

It was estimated that the cooling tower blowdown discharged to Bat Cave Wash resulted in recharge to groundwater of 8 million gallons per year (MGal/yr). In the model, this volume was distributed in nodes located along Bat Cave Wash between MW-9 and the railroad tracks. This was meant to simulate the time before the bermed area was constructed. Records of actual discharge rates to the wash are sparse and range between 6 MGal/yr to nearly 18 MGal/yr, so the recharge value represents a very rough estimate. Original supply wells PGE-1 and PGE-2, located near where the freeway crosses Bat Cave Wash, were simulated to pump an average of 60 gpm (30 gpm each); the 2004 water usage was 45 gpm, and it was assumed that the original cooling towers were less efficient. No actual records of pumping from these wells were available.

3.2.2 Stage 2: 1960 – 1970

In the groundwater model, the same volume of recharge is assigned to a smaller area of nodes located in Bat Cave Wash within the bermed area (described in the RFI Report), running approximately between MW-9 and MW-10. PGE-1 and PGE-2 have stopped pumping, and pumping to supply the compressor station has shifted to wells Topock 1 and 2, located near the Topock Marina.

3.2.3 Stage 3: 1970 – 1999

In the groundwater model, recharge in Bat Cave Wash is removed from the simulation. Groundwater flow is simulated under ambient conditions with no enhanced recharge.

Each stage was simulated under steady-state conditions. Flowlines were run for the number of years indicated for each stage, assuming an effective porosity of 0.1 (lower than measured values to account for any preferred pathways). Flowlines for Stage 1 were started from the water table over the area of assigned recharge. The area covered by the flow lines in Stage 1 was marked and saved, and flow lines for Stage 2 were started from that area and in the top four model layers. Finally, Stage 3 flowlines were run for 29 years from the area covered by Stage 2 flowlines. Results are discussed below.

3.3 Calibration Results

The model was successfully calibrated following the procedures described in Section 3.2. As discussed above, the most accurate calibration targets were the TW-2D shutdown/recovery data and the monthly head fluctuations, all collected using calibrated transducers. Matches to average groundwater elevations are also presented, along with injection well test data matches and plume evolution patterns.

Model fits to selected TW-2D data are provided in Figure 3-1, while the complete set is found in Appendix B1. In general, the recovery data were matched well, especially toward the end of the test and in the deeper wells. Late time data are considered most important for matching because they represent a state closer to the long-term behavior of the stressed system, such as long-term pumping. The deeper wells are most important for the control of the plume. Hexavalent chromium is present in the more oxidizing medium and deep floodplain zones, but is consistently below detection limits in the reducing shallow floodplain zone.

Simulated monthly groundwater elevations are compared to measured values in Figure 3-2 for selected wells. The entire set is provided in Appendix B2. The purpose of this calibration target was to ensure the model could duplicate the river influence on groundwater changes across the site. To best highlight the monthly fluctuations, the data are plotted as deviations from average value for the displayed time period. Modeled elevations did not agree as closely to measured elevations in the western part of the site (this will be shown in the steady-state discussion below). A hydrograph of measured I-3 river elevation is included in each figure to demonstrate the river's influence on the fluctuations. These river fluctuations were input for each monthly model run, demonstrating that the model duplicates this influence.

Following model calibration to the two targets described above, injection wells IW-2 and IW-3 were installed along with three clusters of nearby observation wells. Data from step tests and short-term aquifer testing at these wells were analyzed with MLU (Hemker 1999), an analytic/numerical aquifer test matching tool designed for multi-layer systems. The estimates were input to this area of the model, replacing the geometric mean values from the previous PEST runs. The model was then run to duplicate the injection well tests, with good fits to observation well data in all layers. Model simulation of the injection well testing is presented in Appendices B3 and B4.

The combined calibration described above resulted in K and K_h/K_v distributions for each of the HSUs, provided in Appendices B5 and B6. As an example, K distributions for the deepest fluvial HSU (Qr1) and the deepest extensive alluvial HSU (Toa1) are presented in Figure 3-3. To illustrate how these were combined into model layers, Figure 3-4 provides a K map of model Layer 4, which is dominated by either one of these HSUs in the site area. In the floodplain, where there is a high density of monitoring wells, model K values vary significantly. This pattern would be expected throughout the model domain, but average K values were used for each HSU in areas where data were not available to justify a K distribution. The model uses layer T values and vertical resistance (VR) between layers to calculate heads at each node (along with boundary conditions and top system parameters). Maps of T and VR for each layer are provided in Appendices B7 and B8. Tabulated model residuals for transient and steady-state analyses are located in Appendix B9.

As an additional check on model effectiveness, the flow of discharge water from the original Bat Cave Wash disposal was simulated in three stages, described in the previous section. By the end of Stage 3 in 1999, the discharge water had reached the MW-20 cluster (where monitoring wells were drilled and hexavalent chromium was detected in 1999) and the floodplain, according to the simulation. In addition, the flowlines indicate a northeast to eastern "turn" that defines the general shape of the current plume. Because these are groundwater flowlines and not solute transport pathways, the simulated flowlines do not include dispersive processes that would spread the hexavalent chromium over a somewhat wider area. This exercise serves as demonstration that the model provides reasonable predictions of groundwater behavior under stressed and unstressed conditions.

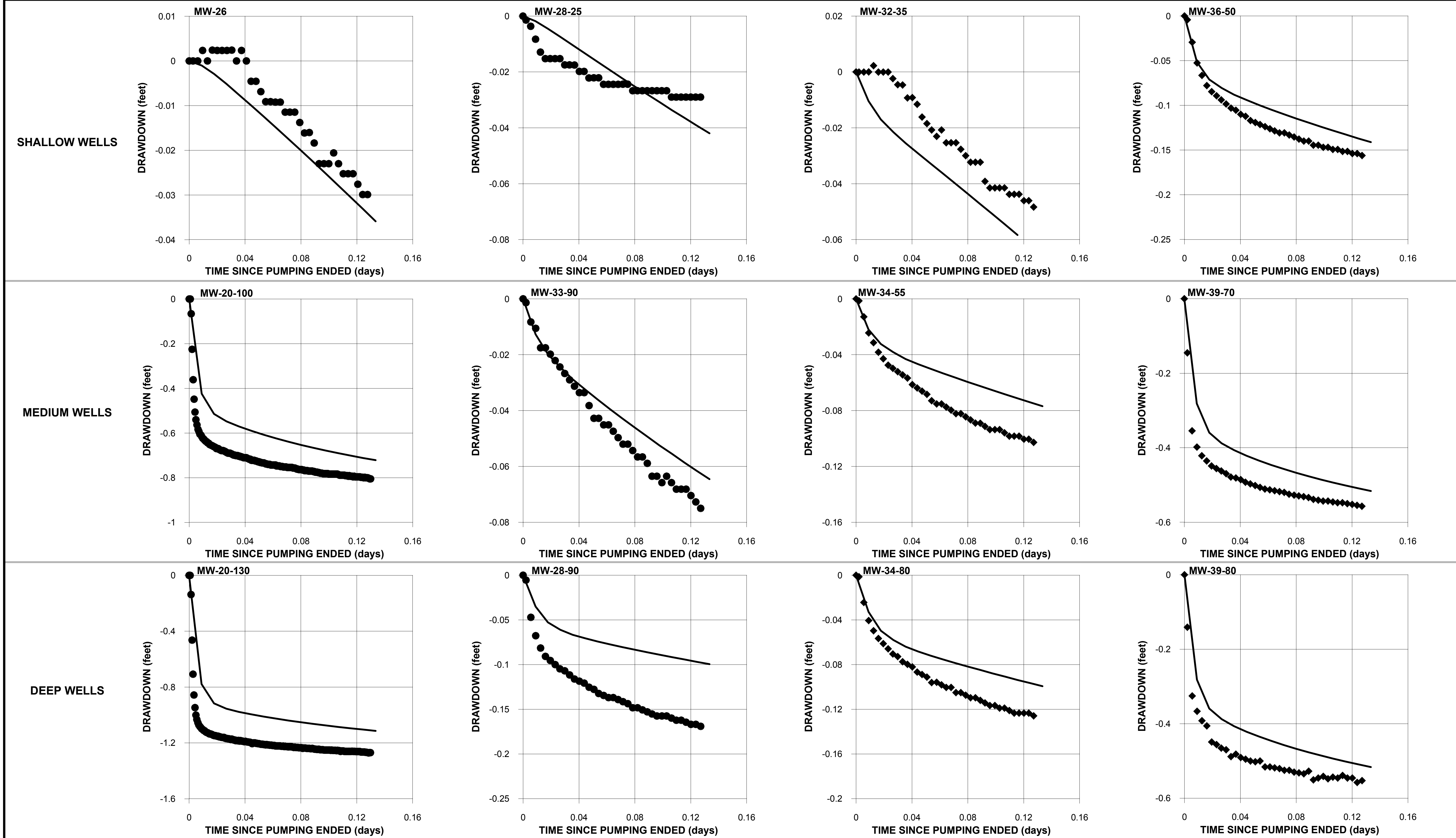
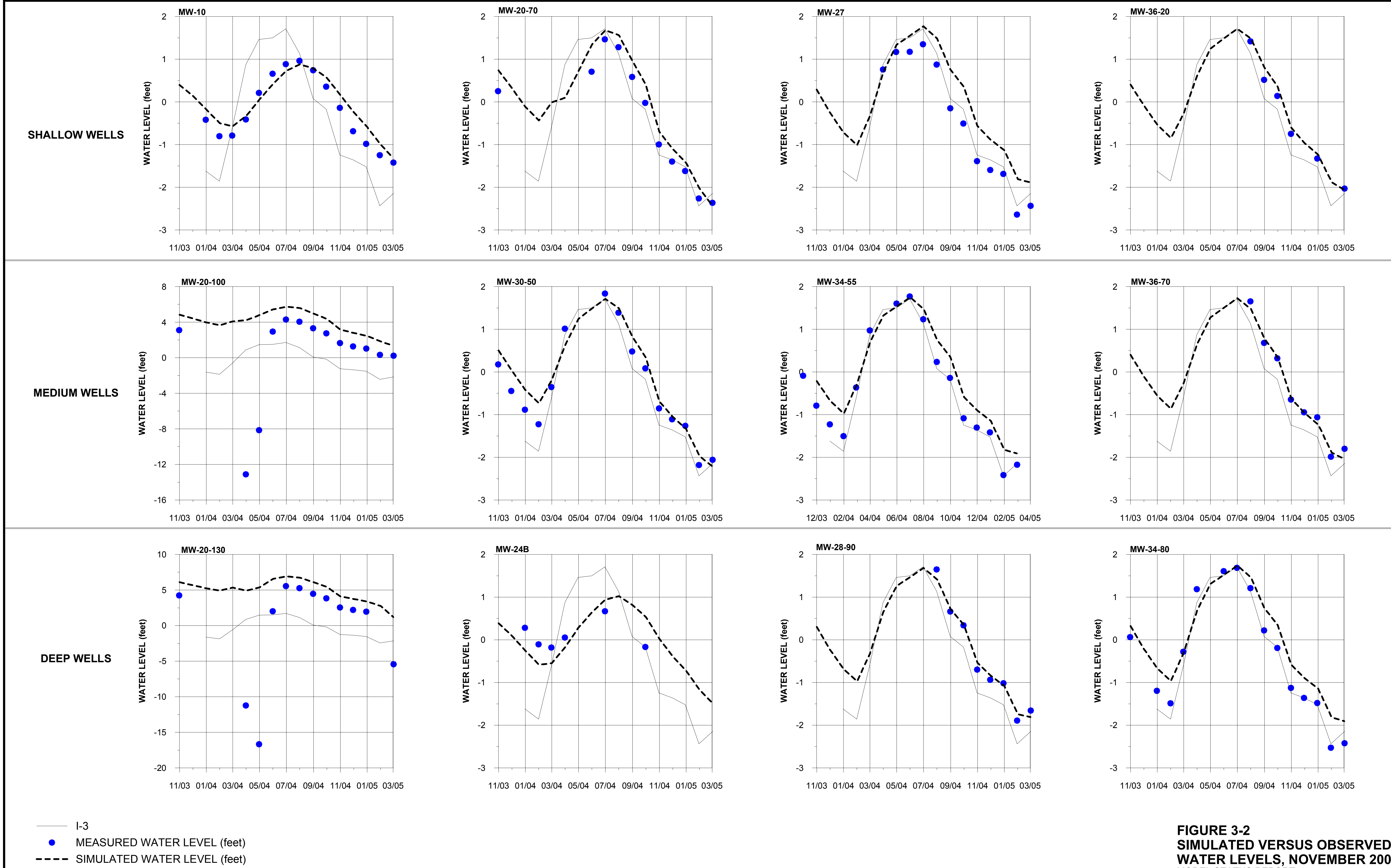


FIGURE 3-1
SIMULATED VERSUS OBSERVED RESPONSES TO TW-2D SHUTDOWN NOVEMBER 2004
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

0605TM_FIG03-01.GRF



0605TM_FIG03-02.GRF

FIGURE 3-2
SIMULATED VERSUS OBSERVED WATER LEVELS, NOVEMBER 2004
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

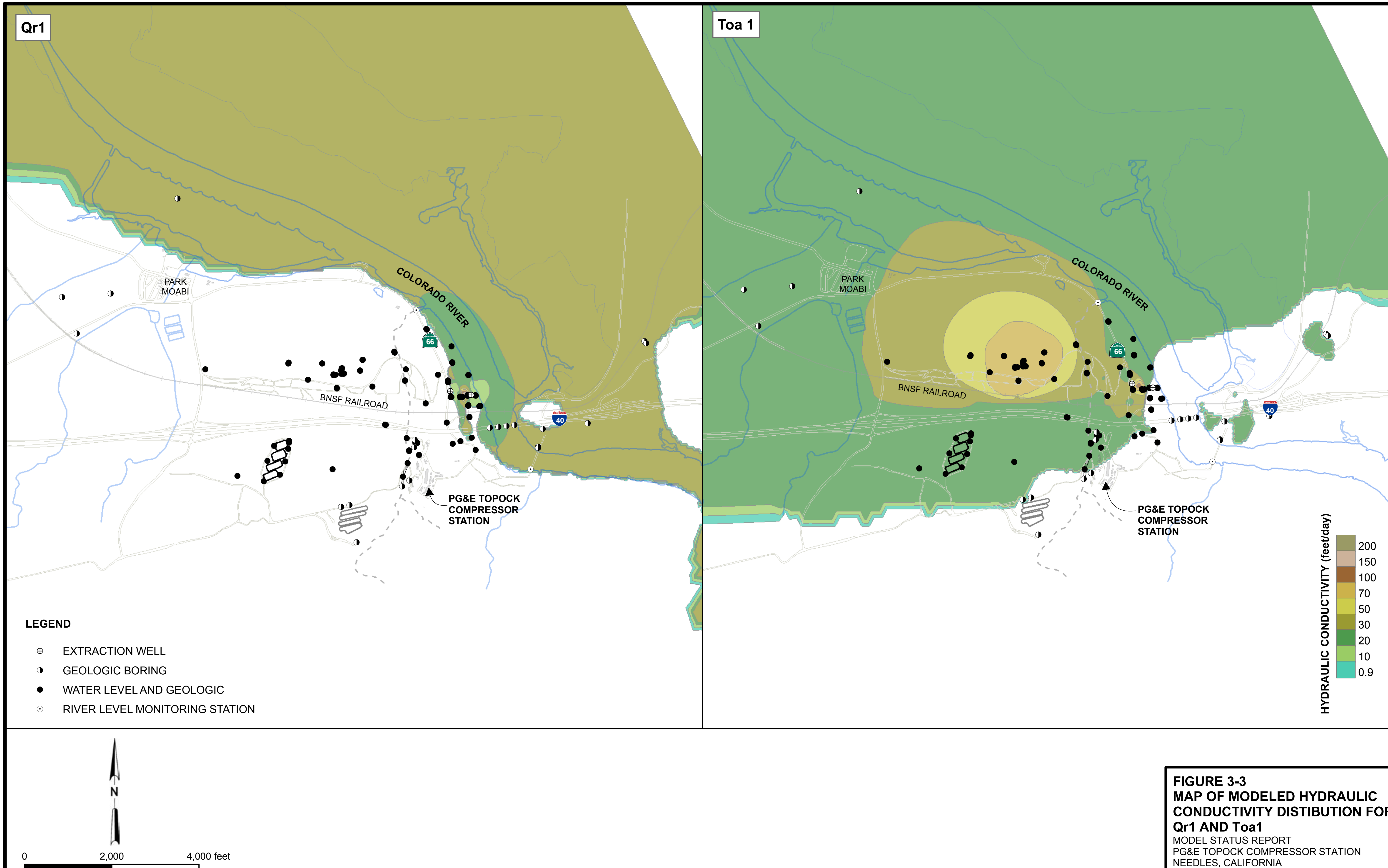


FIGURE 3-3
MAP OF MODELED HYDRAULIC CONDUCTIVITY DISTIBUTION FOR Qr1 AND Toa1
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_FIG03-03.MXD 0605TM_FIG03-04.PDF 7/31/2005 12:56:41

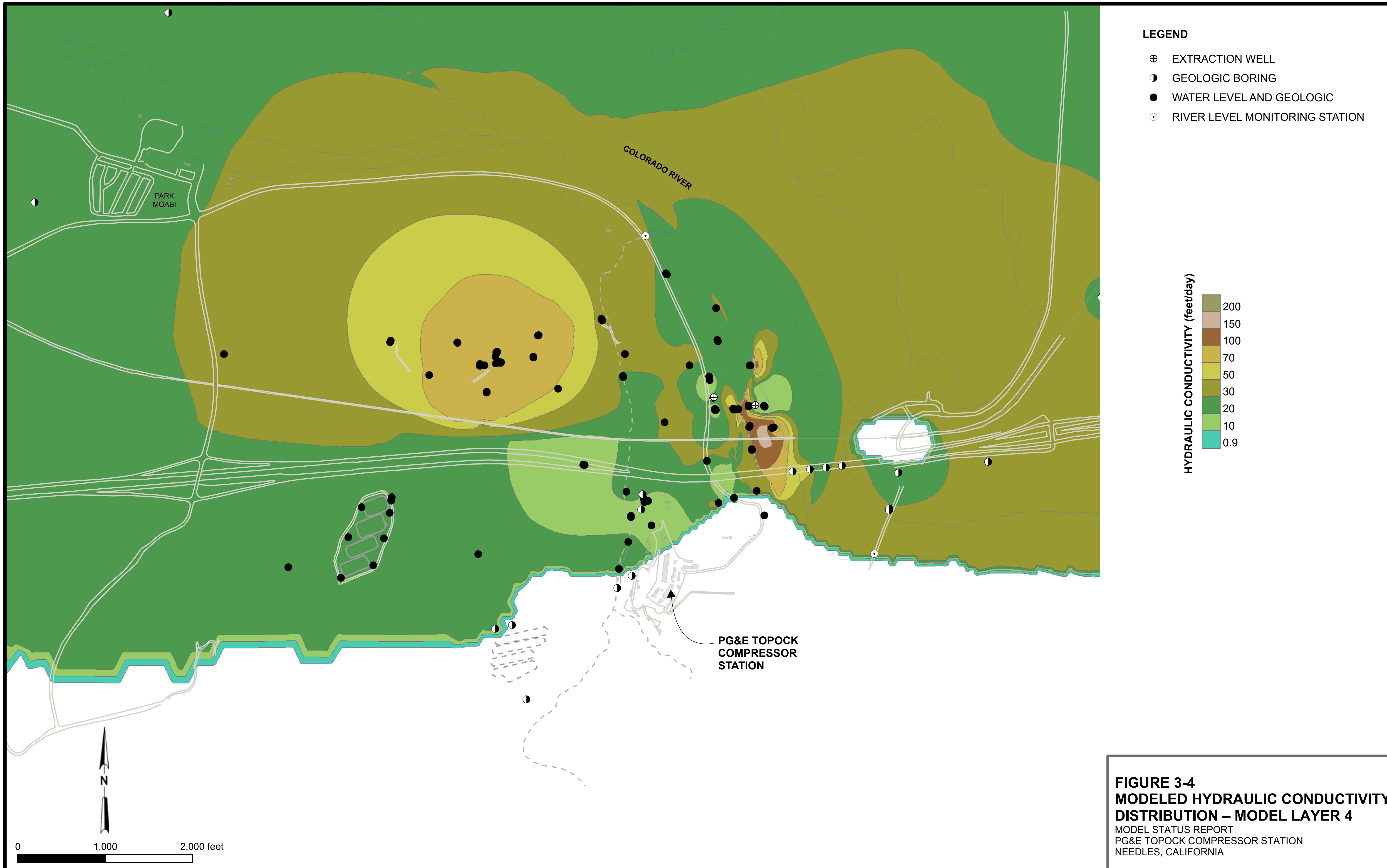


FIGURE 3-4
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION – MODEL LAYER 4
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

4.0 Conclusions

The Topock groundwater model has evolved over the past 18 months of data collection, well drilling and testing; Technical Work Group feedback; and suggestions to provide a working tool to examine interim measures strategies and long-term corrective measures options. The model incorporates geologic, hydraulic, and topographic data and interpretations to form a realistic depiction of groundwater flow conditions near the Topock site. In an area made complex by intersecting alluvial fan and fluvial deposits (both with highly variable hydraulic properties), constantly changing river elevations, and salinity and temperature variability in three dimensions, the model is a simplified version of actual conditions but is considered a valuable tool to apply to evaluation of target pumping rates and remedial alternatives in the immediate site area. Groundwater level changes in response to river fluctuations and to well pumping have been matched to a reasonable degree in areas where data are available. Average groundwater elevations are also reasonably well-matched, given the less reliable data quality. Simulations of historical Bat Cave Wash discharge have shown general agreement with the current groundwater plume, both in spatial position and in time of travel.

As additional information is collected in and around the site, the model will be improved with the new data. Improvements either planned or anticipated for the near future are: (1) calibration to measured heads on the Arizona side of the river; (2) longer-term monitoring of planned injection at IW-2/IW-3; (3) test data from the new PE-1 well near MW-36 in the floodplain; and (4) continuing data collected each month from TW-2D pumping and river fluctuations, including future TW-2D temporary shutdowns.

5.0 References

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Appendix A
Bedrock Elevation and HSU Isopach Maps

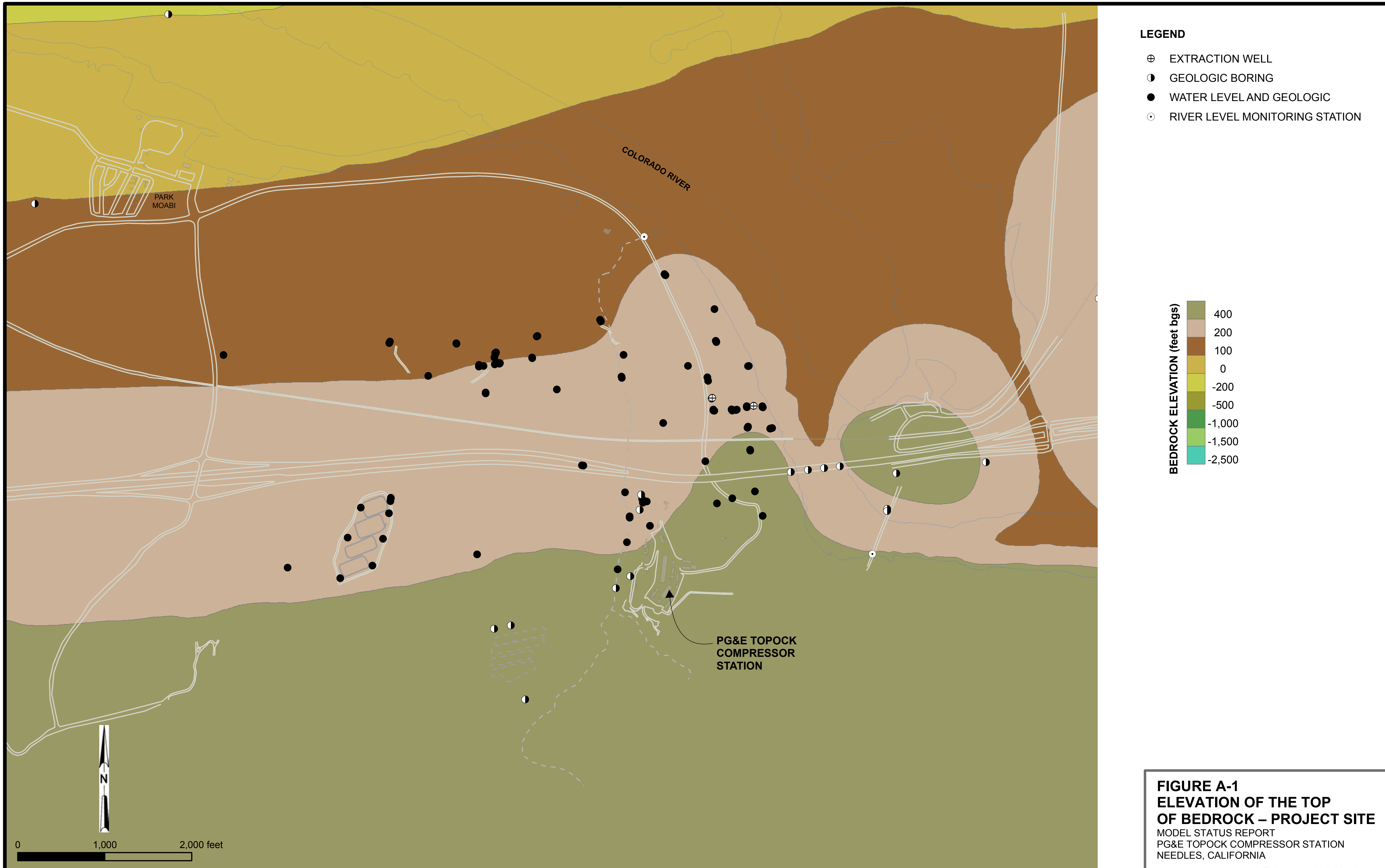

FIGURE A-1
ELEVATION OF THE TOP OF BEDROCK – PROJECT SITE
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_BEDROCK_L.MXD 0605TM_FIGA-01_L.PDF 7/29/2005 12:06:29

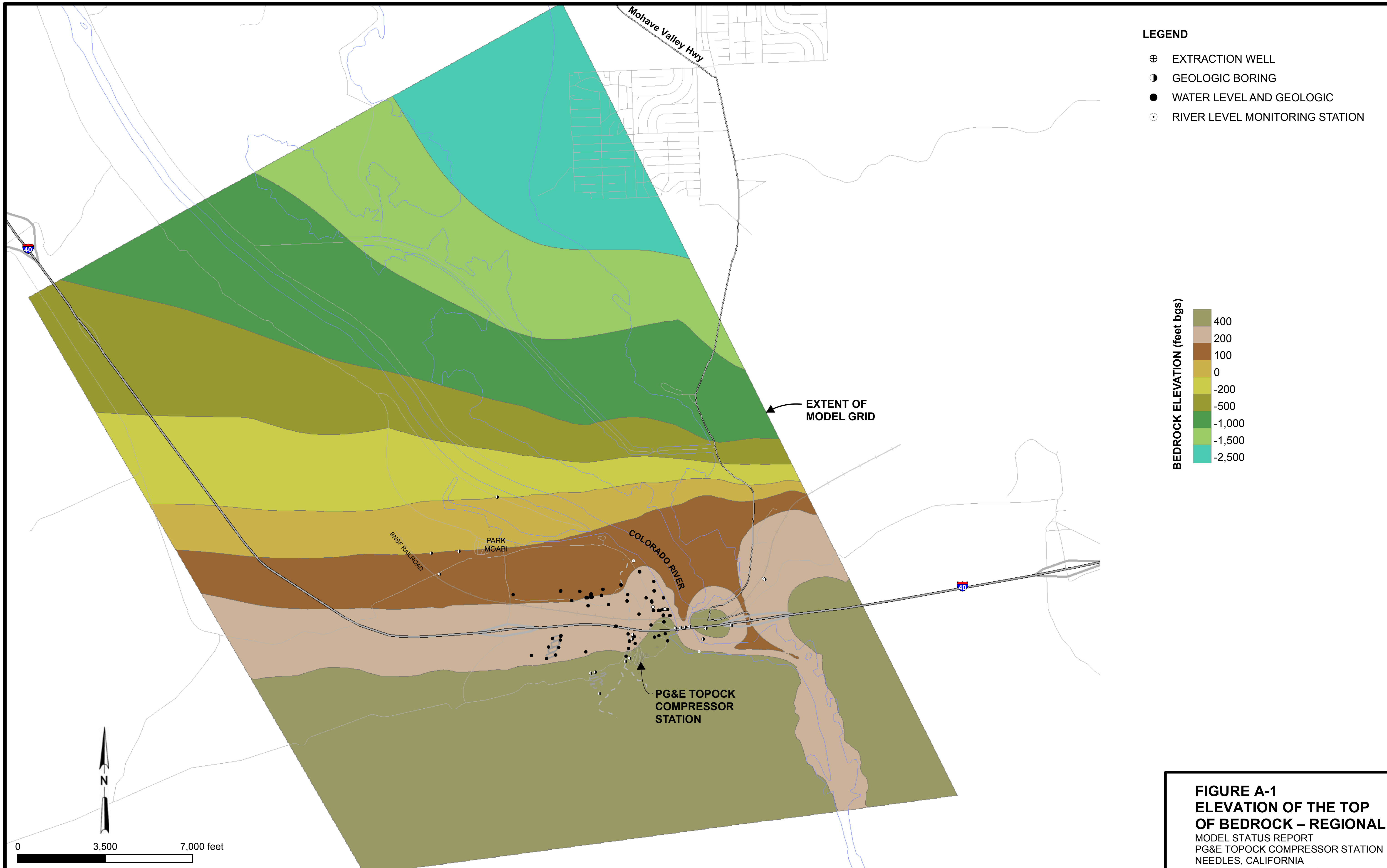

FIGURE A-1
ELEVATION OF THE TOP OF BEDROCK – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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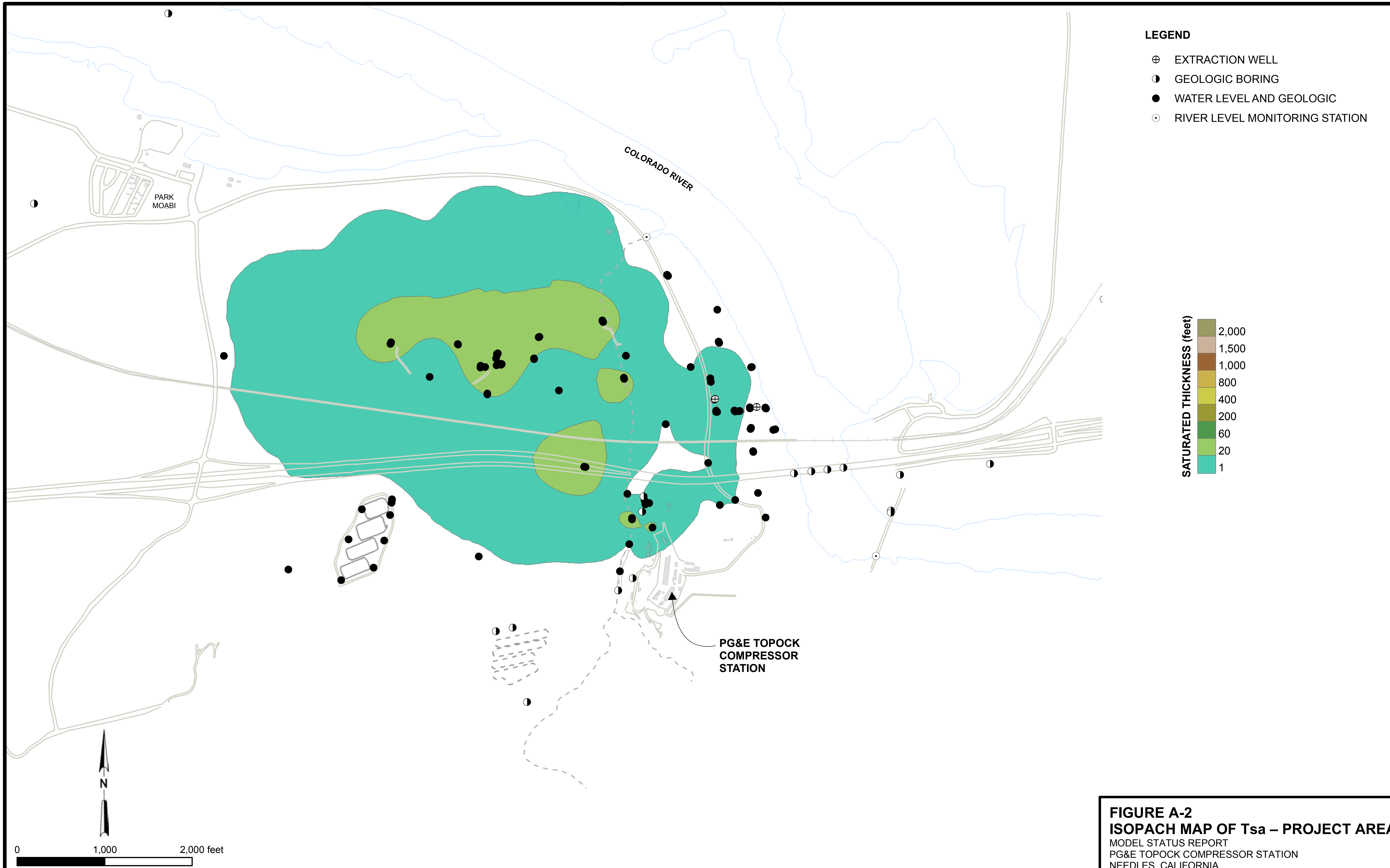

FIGURE A-2
ISOPACH MAP OF Tsa – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_TSA_L.MXD 0605TM_FIGA-02_L.PDF 7/29/2005 12:58:45

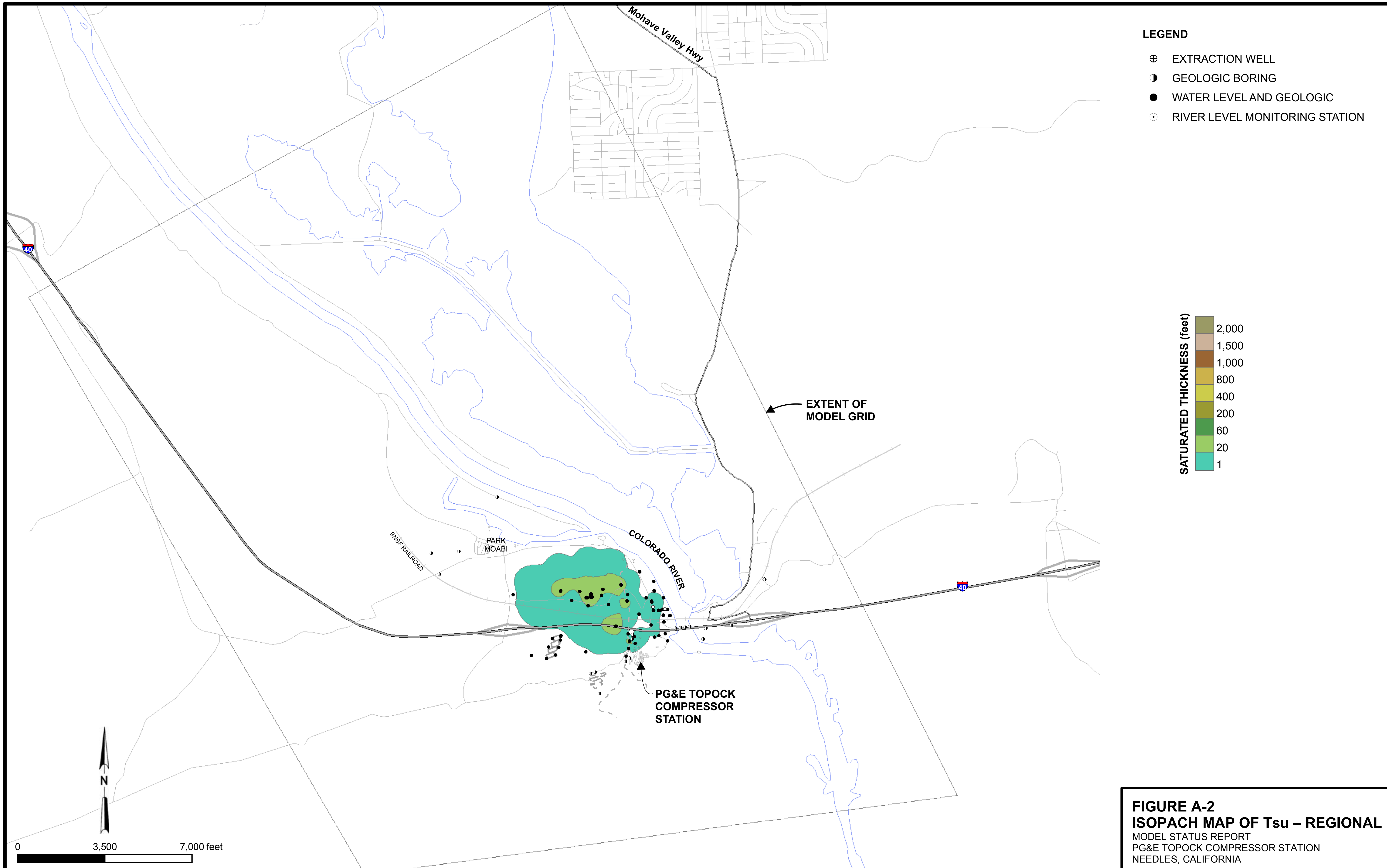

FIGURE A-2
ISOPACH MAP OF Tsu – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_TSA_R.MXD 0605TM_FIGA-02_TSU_R.PDF 7/29/2005 17:12:25

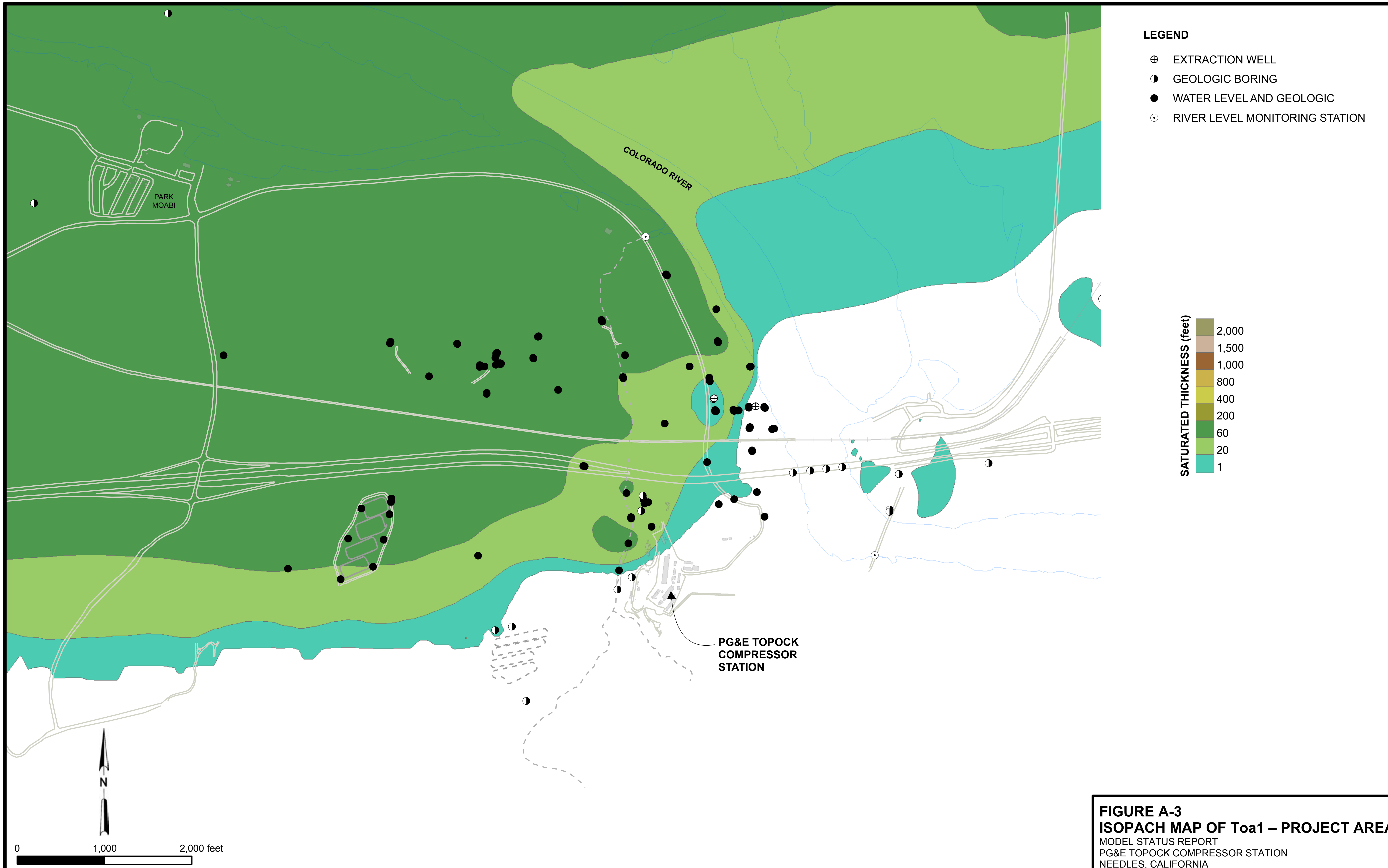

FIGURE A-3
ISOPACH MAP OF Toa1 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_TOA1_L.MXD 0605TM_FIGA-03_L.PDF 7/29/2005 13:06:15

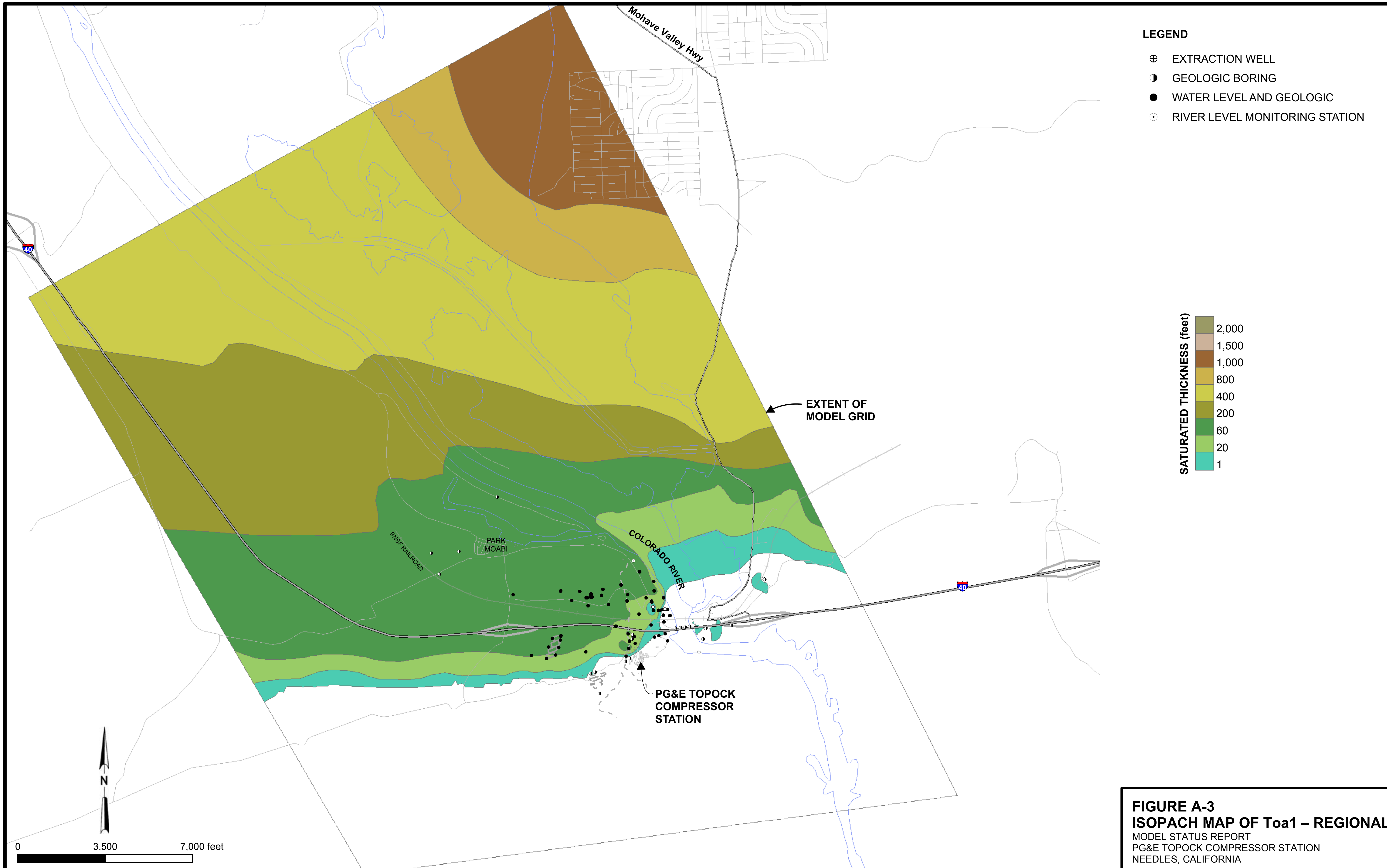

FIGURE A-3
ISOPACH MAP OF Toa1 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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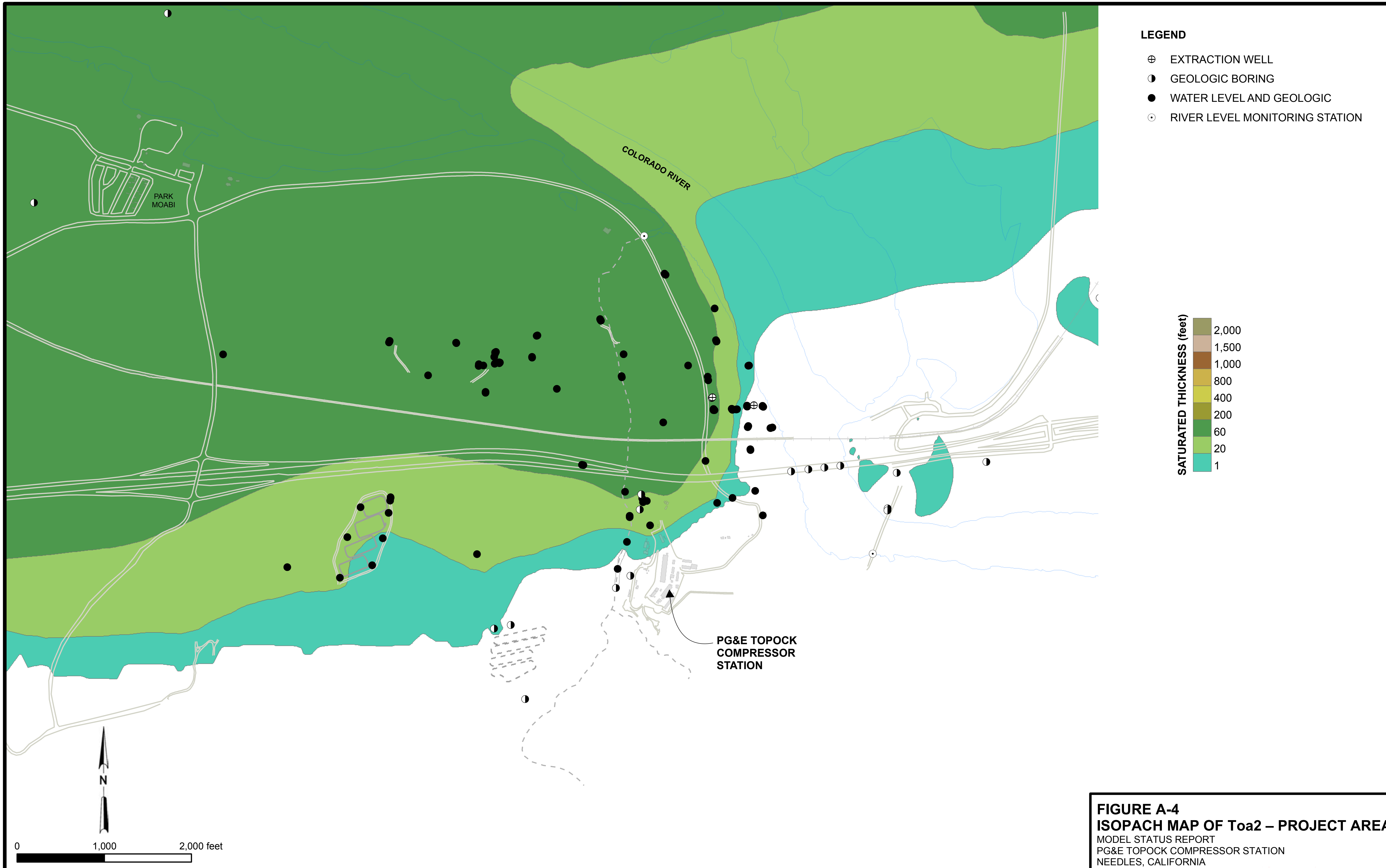

FIGURE A-4
ISOPACH MAP OF Toa2 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_TOA2_L.MXD 0605TM_FIGA-04_L.PDF 7/29/2005 13:07:59

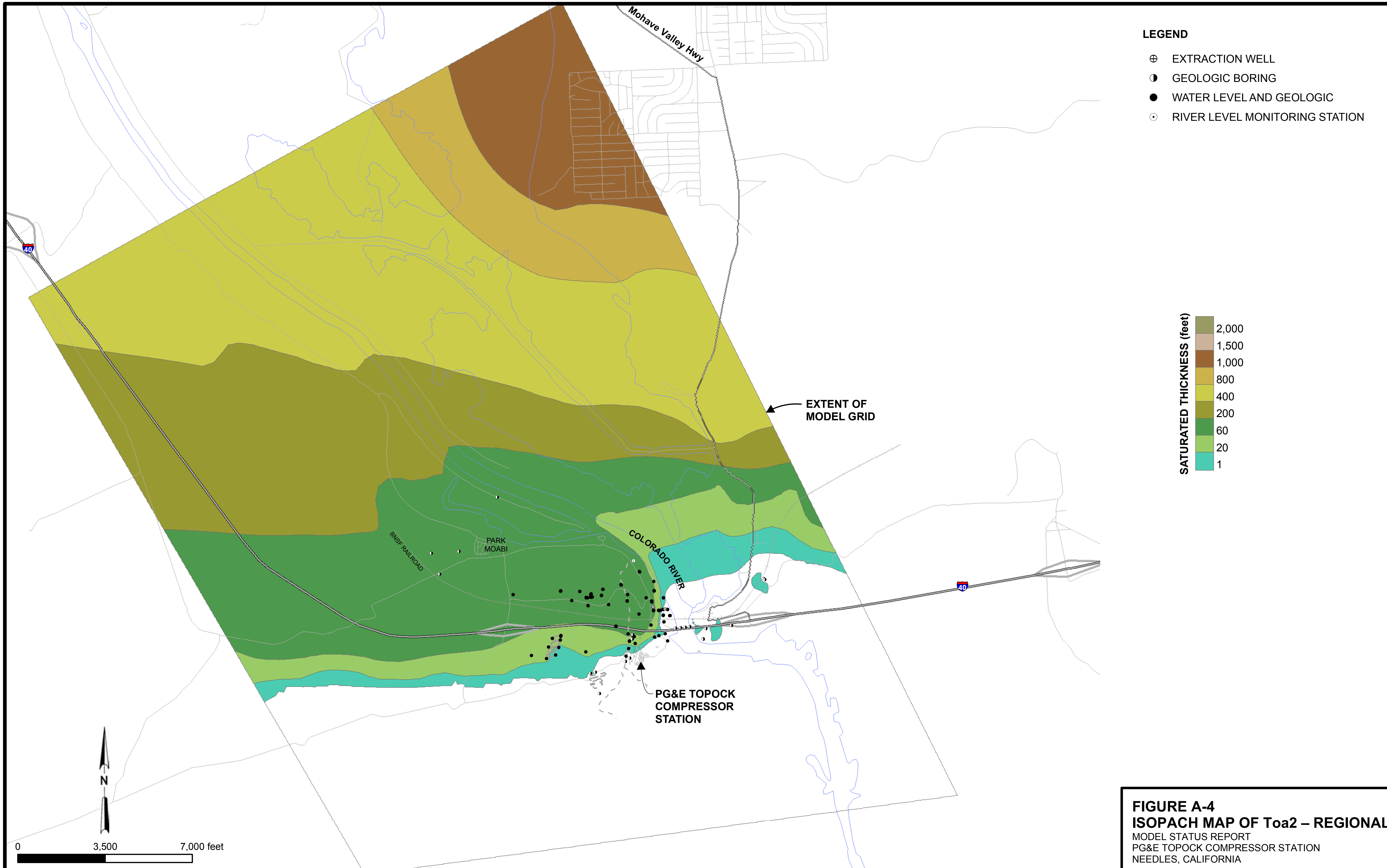

FIGURE A-4
ISOPACH MAP OF Toa2 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_TOA2_R.MXD 0605TM_FIGA-04_TOA2_R.PDF 7/29/2005 13:24:14

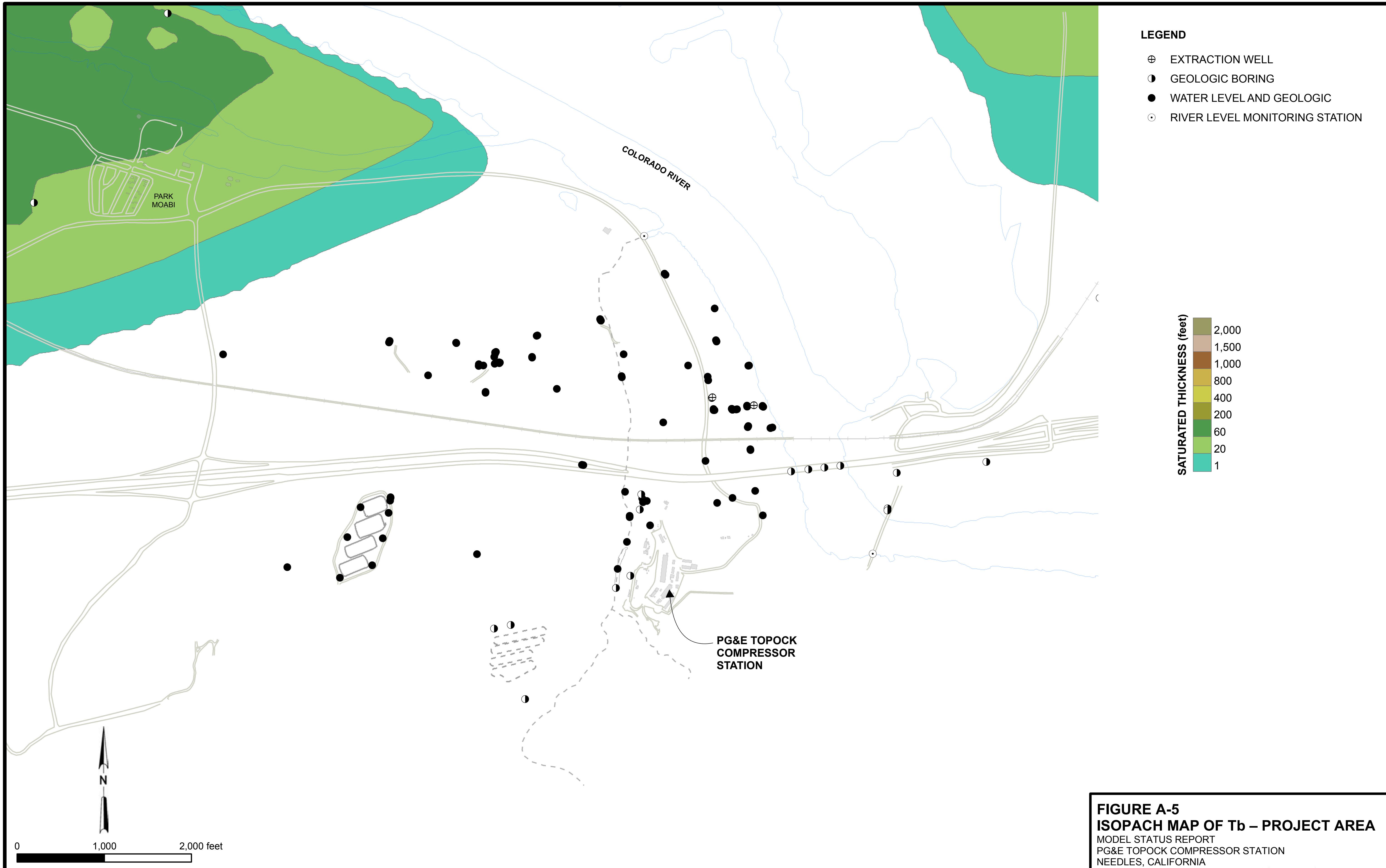

FIGURE A-5
ISOPACH MAP OF Tb – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_TB_L.MXD 0605TM_FIGA-05_L.PDF 7/29/2005 13:09:26

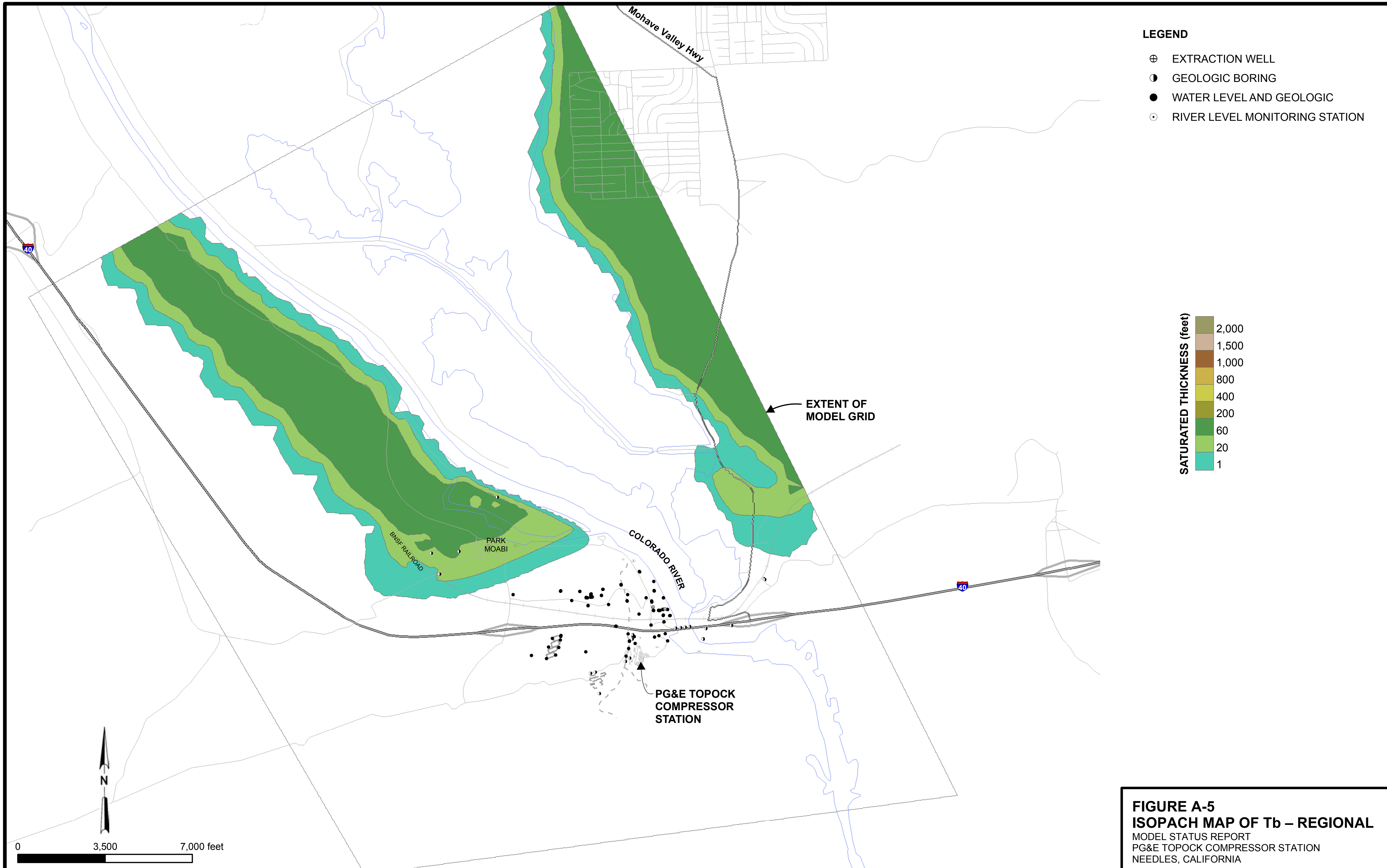

FIGURE A-5
ISOPACH MAP OF Tb – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_TB_R.MXD 0605TM_FIGA-05_TB_R.PDF 7/29/2005 13:24:58

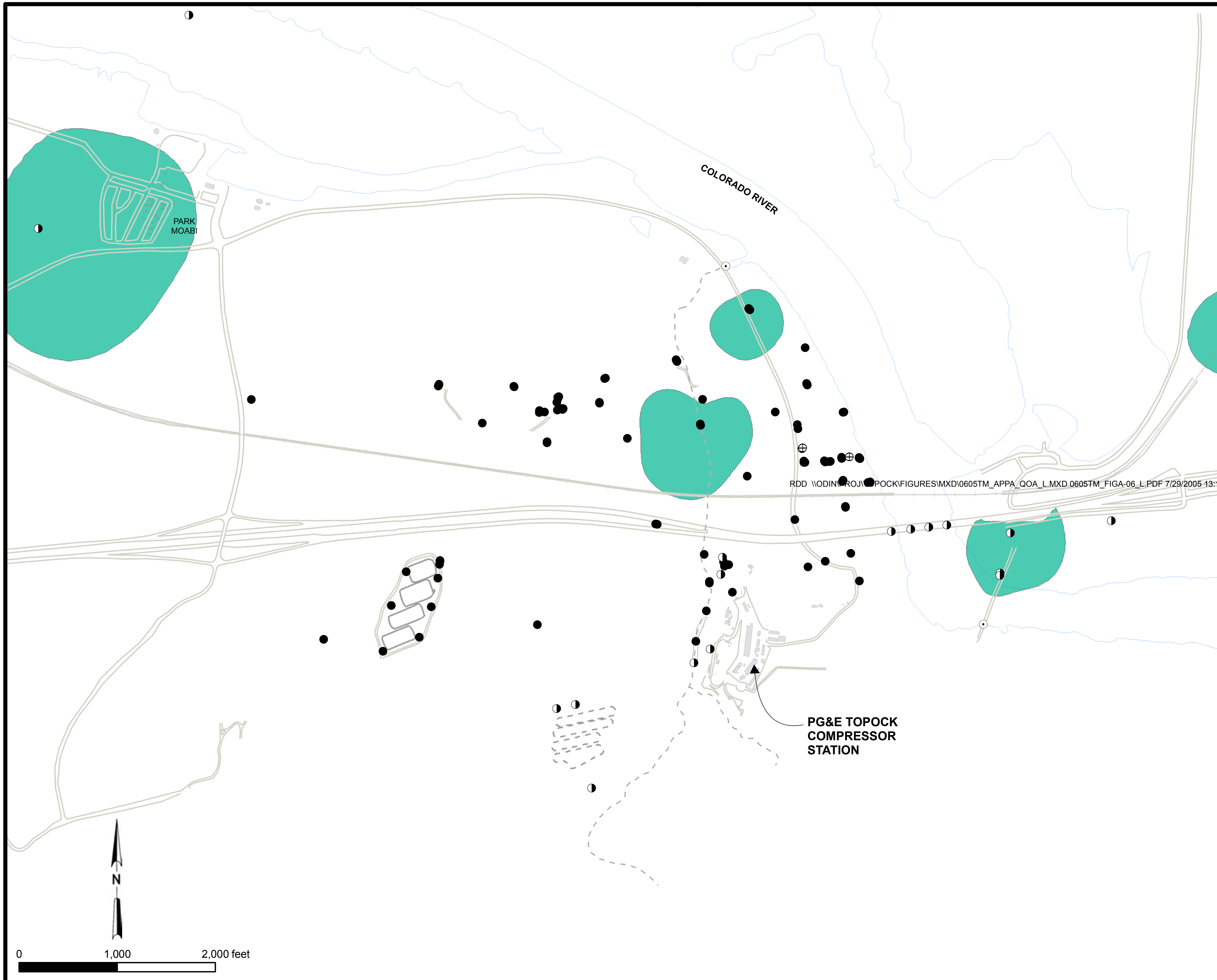

FIGURE A-6
ISOPACH MAP OF Qoa – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
CH2MHILL

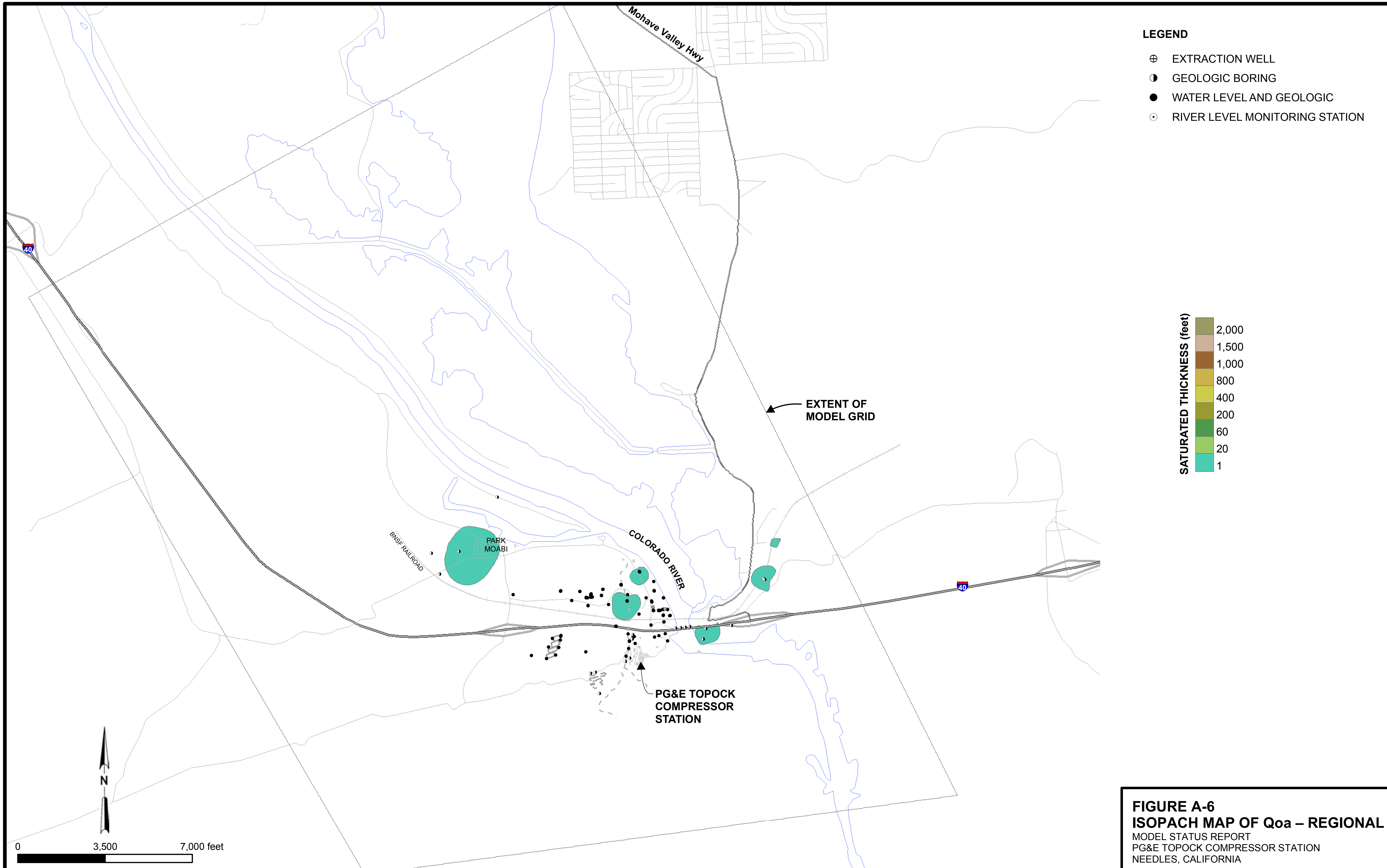

FIGURE A-6
ISOPACH MAP OF Qoa – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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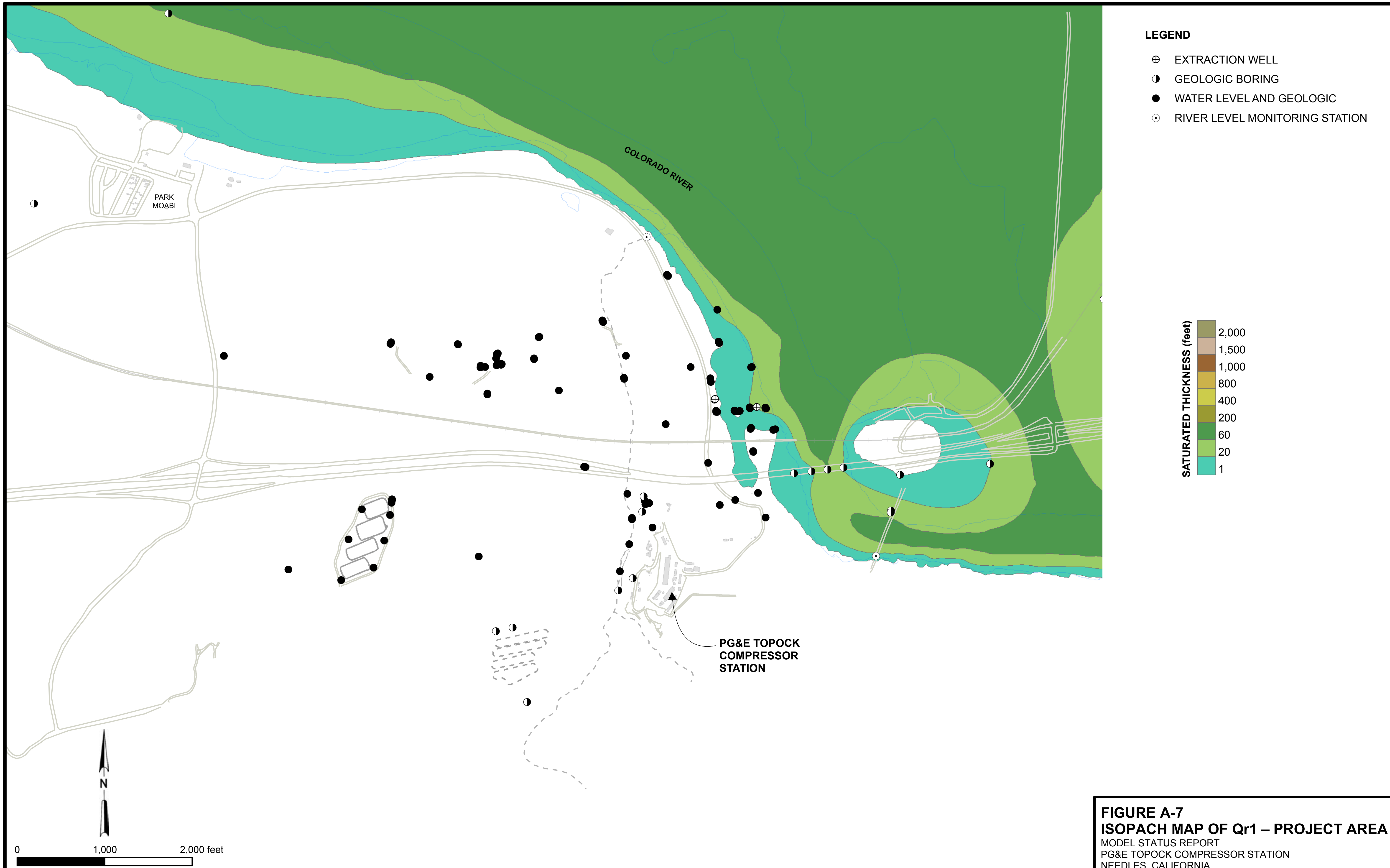

FIGURE A-7
ISOPACH MAP OF Qr1 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_QR1_L.MXD 0605TM_FIGA-07_L.PDF 7/29/2005 13:13:14

FIGURE A-7
ISOPACH MAP OF Qr1 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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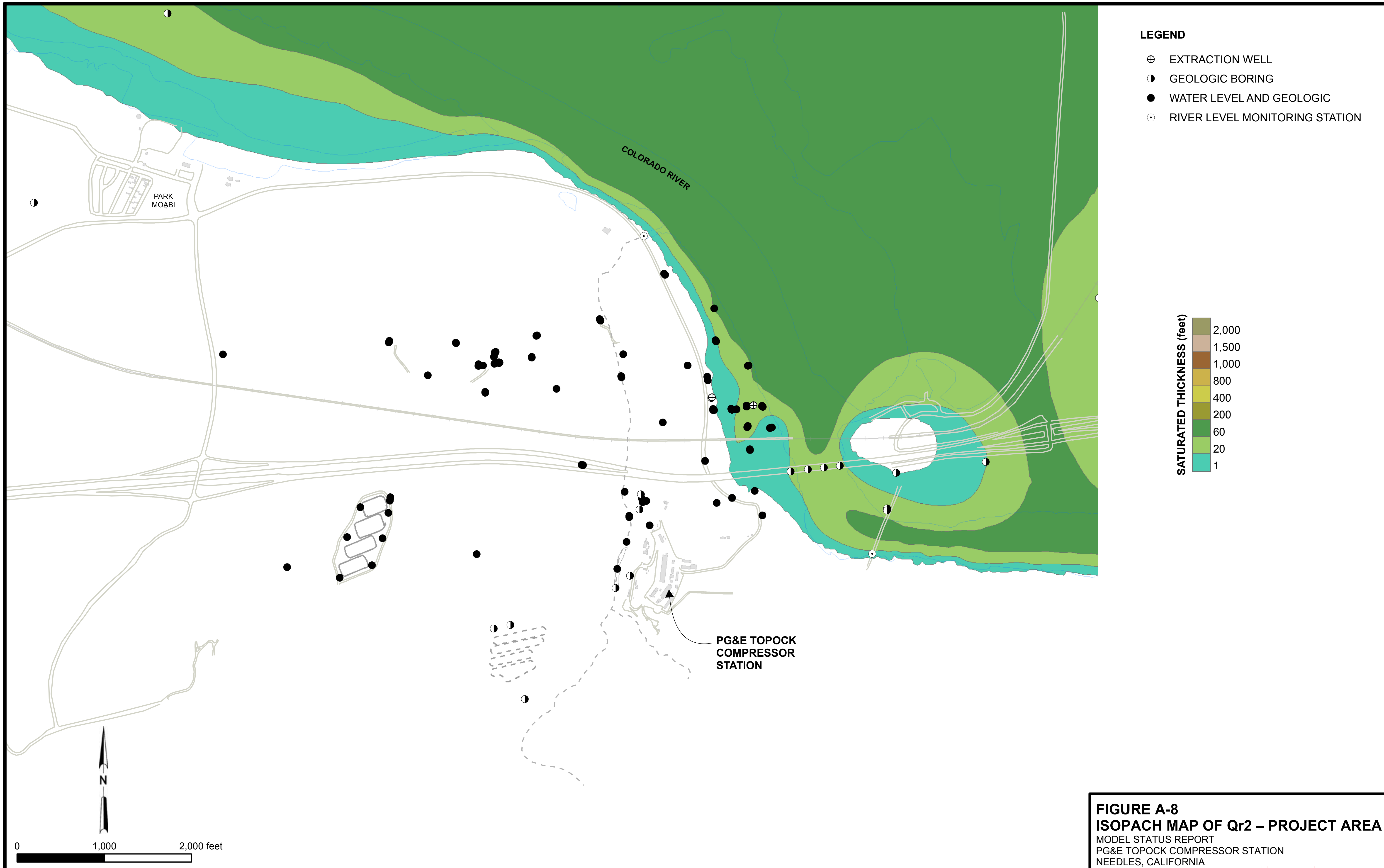

FIGURE A-8
ISOPACH MAP OF Qr2 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_QR2_L.MXD 0605TM_FIGA-08_L.PDF 7/29/2005 13:13:57

FIGURE A-8
ISOPACH MAP OF Qr2 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_QR2_R.MXD 0605TM_FIGA-08_QR2_R.PDF 7/29/2005 13:28:10

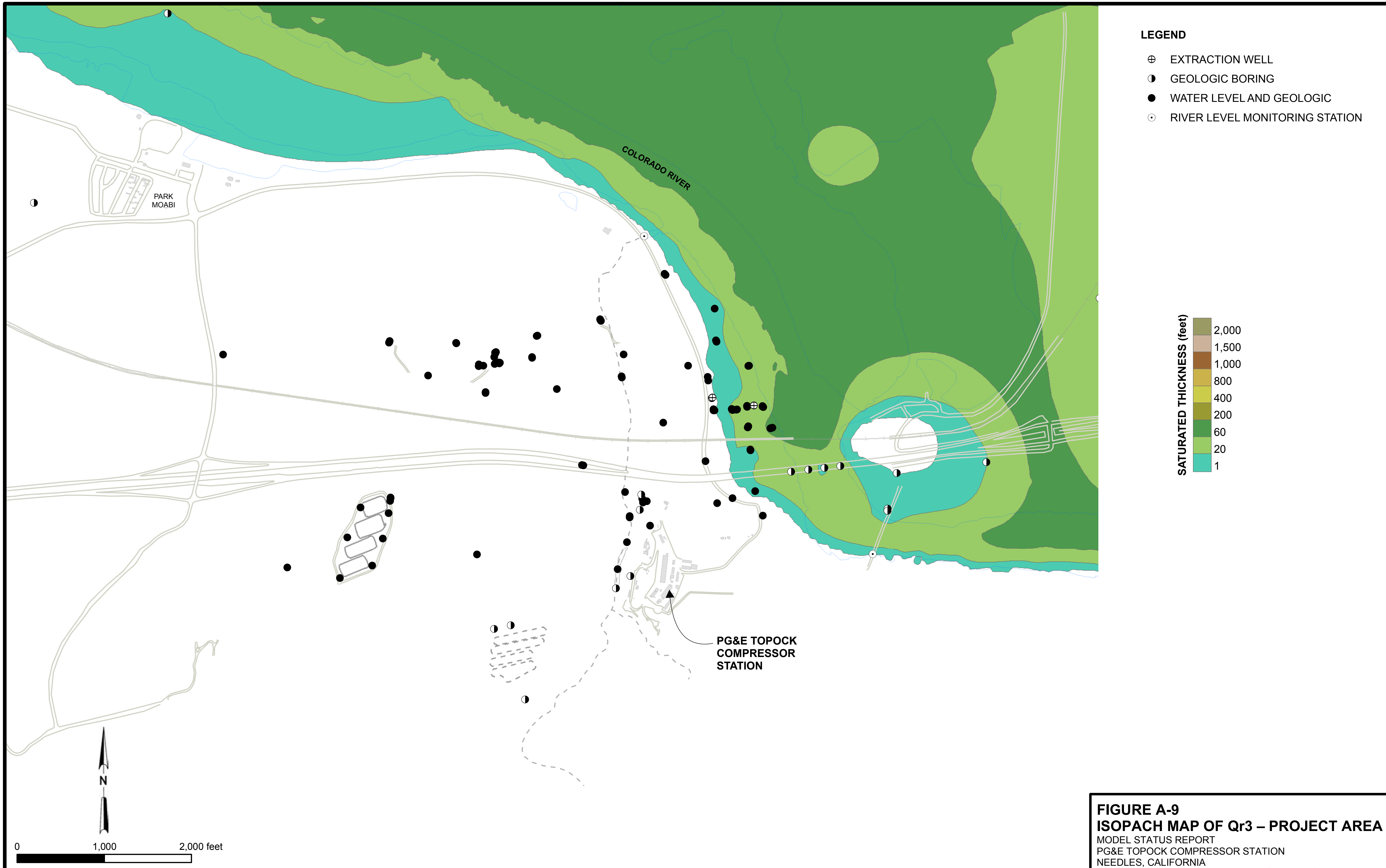

FIGURE A-9
ISOPACH MAP OF Qr3 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_QR3_L.MXD 0605TM_FIGA-09_L.PDF 7/29/2005 13:17:21

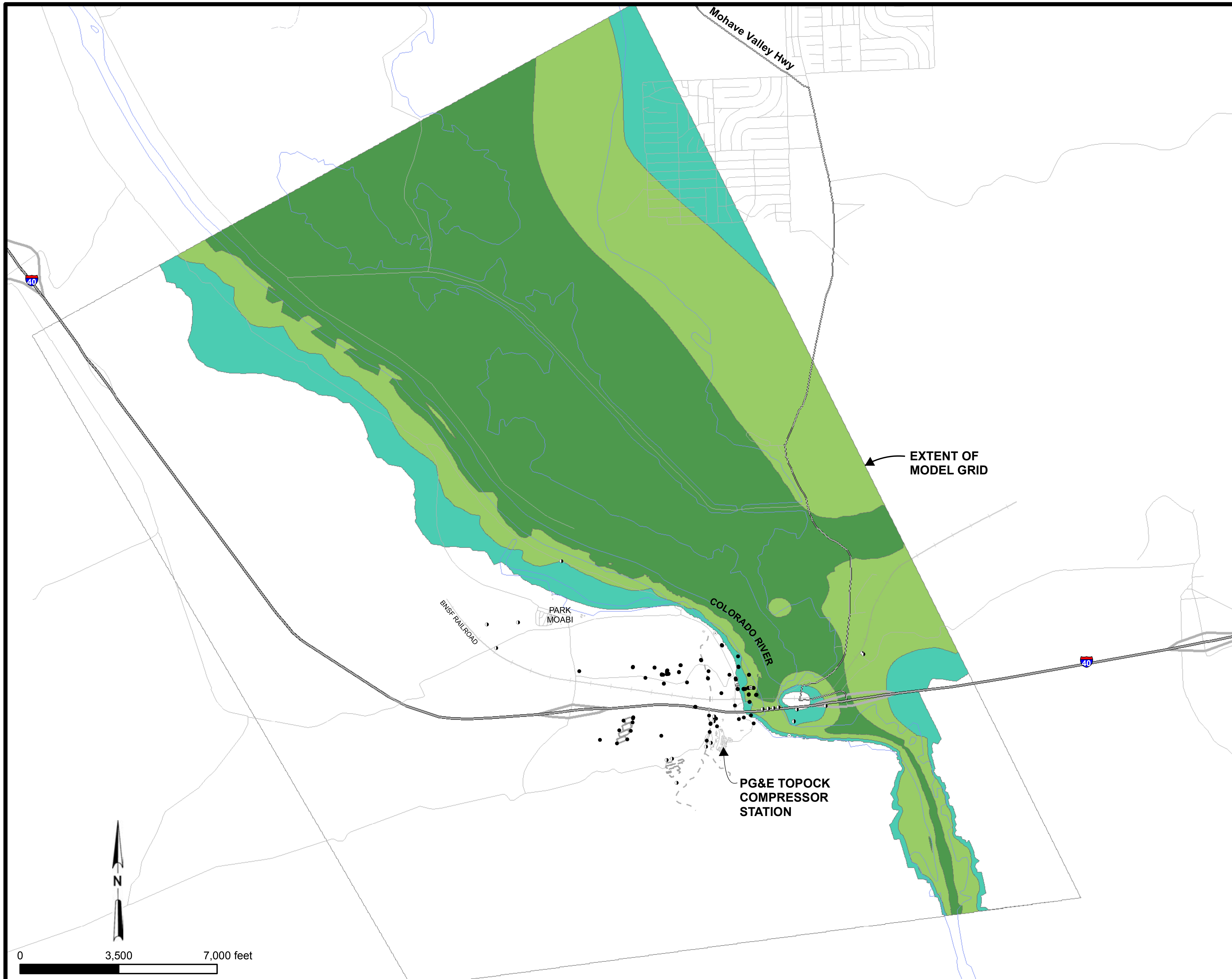

FIGURE A-9
ISOPACH MAP OF Qr3 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPA_QR2_R.MXD 0605TM_FIGA-08_QR2_R.PDF 7/29/2005 13:28:10

Appendix B
Model Hydraulic Parameter Distributions

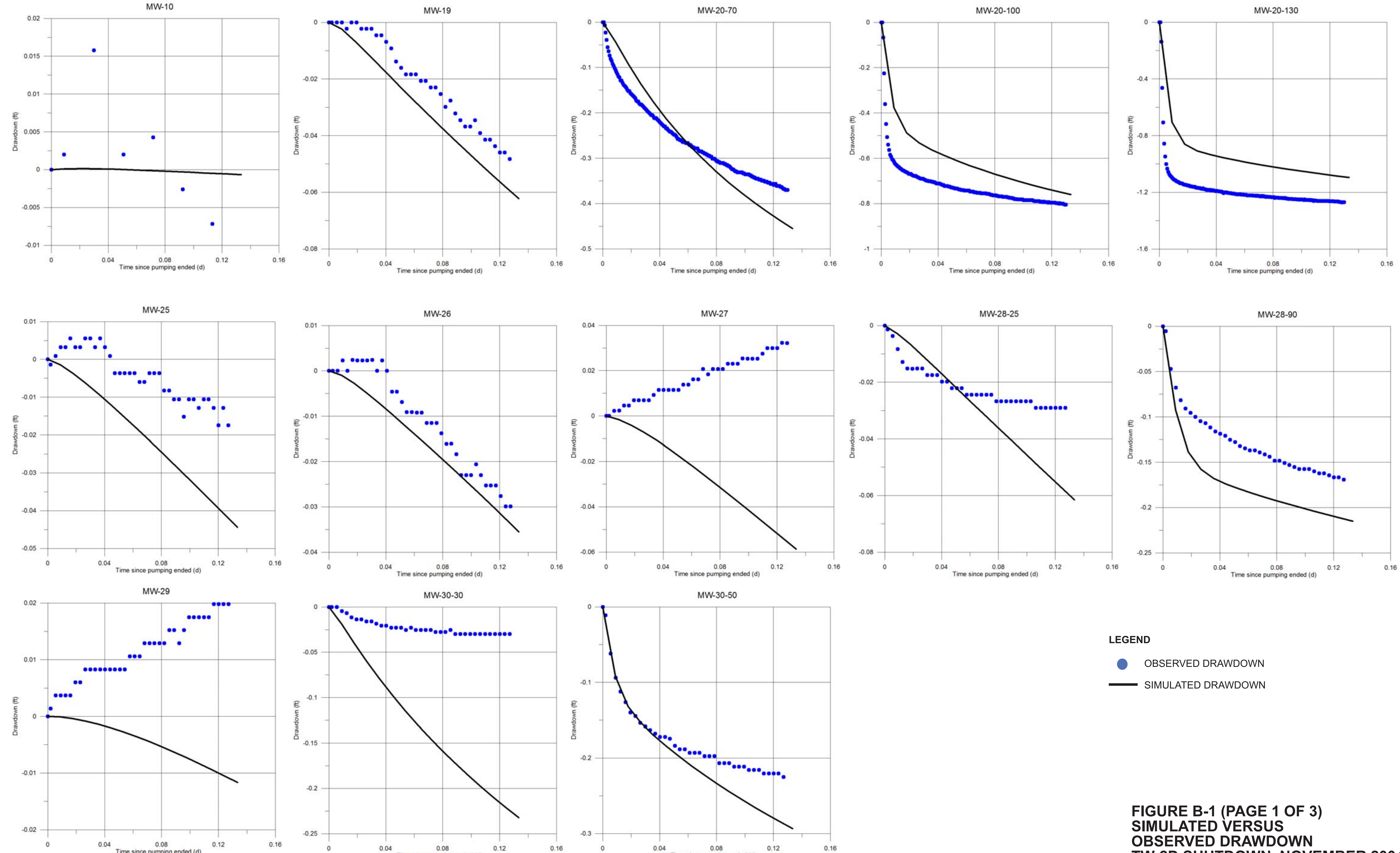

FIGURE B-1 (PAGE 1 OF 3)
SIMULATED VERSUS OBSERVED DRAWDOWN
TW-2D SHUTDOWN, NOVEMBER 2004
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-01.FH10

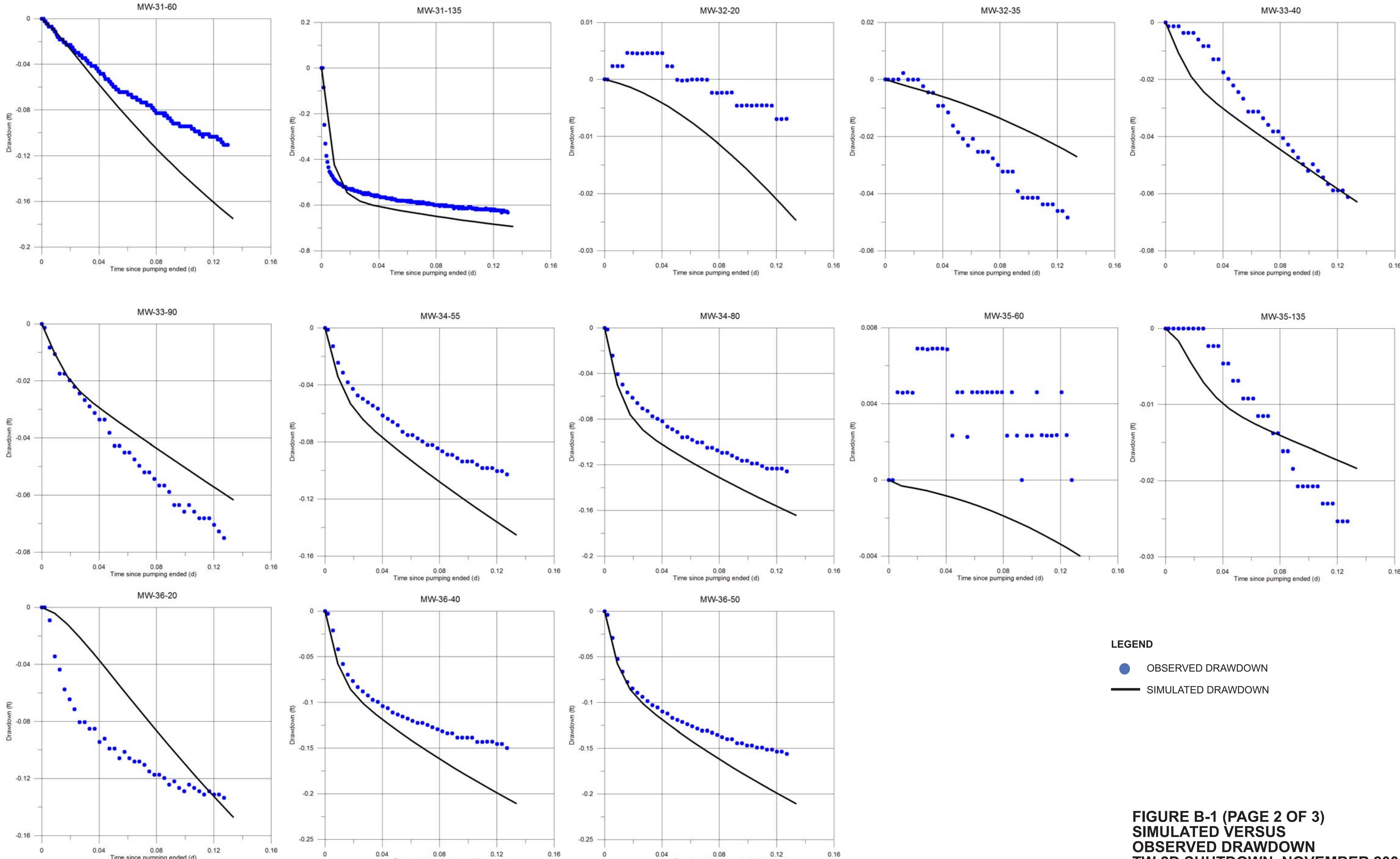

FIGURE B-1 (PAGE 2 OF 3)
SIMULATED VERSUS OBSERVED DRAWDOWN
TW-2D SHUTDOWN, NOVEMBER 2004
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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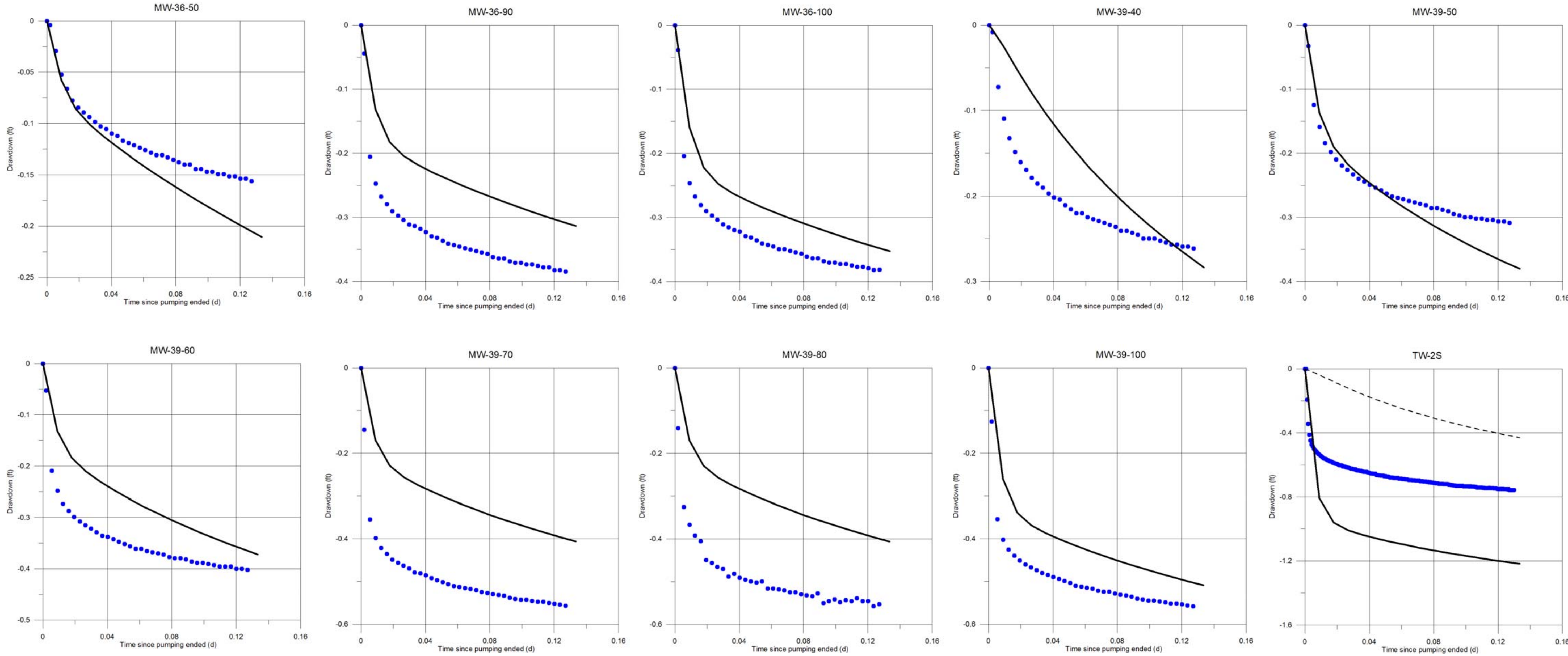
\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-01.FH10



LEGEND

OBSERVED DRAWDOWN

SIMULATED DRAWDOWN

FIGURE B-1 (PAGE 3 OF 3)
SIMULATED VERSUS OBSERVED DRAWDOWN TW-2D SHUTDOWN, NOVEMBER 2004

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

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\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-01.FH10

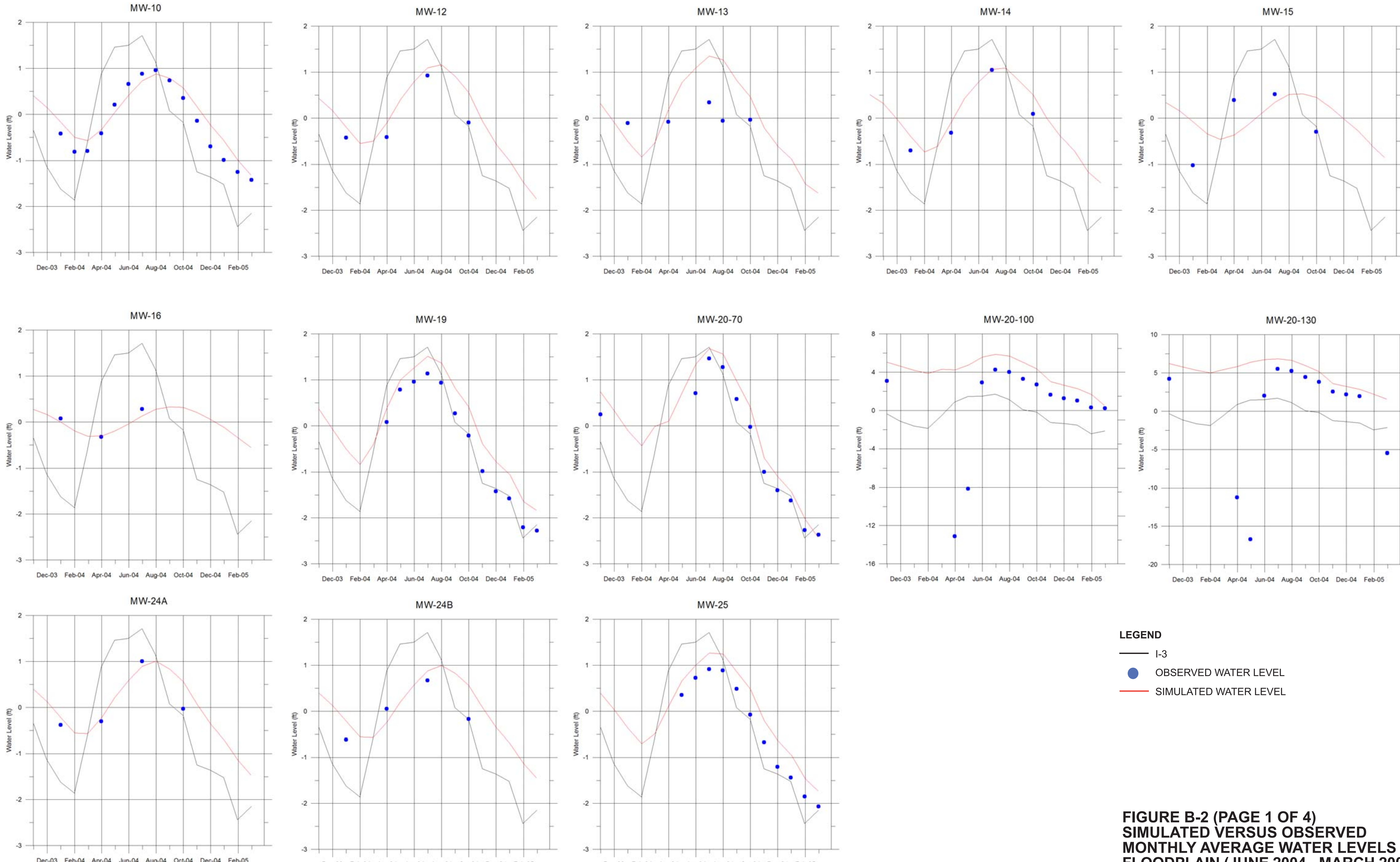


FIGURE B-2 (PAGE 1 OF 4)
SIMULATED VERSUS OBSERVED MONTHLY AVERAGE WATER LEVELS IN FLOODPLAIN (JUNE 2004 - MARCH 2005)
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-02.FH10

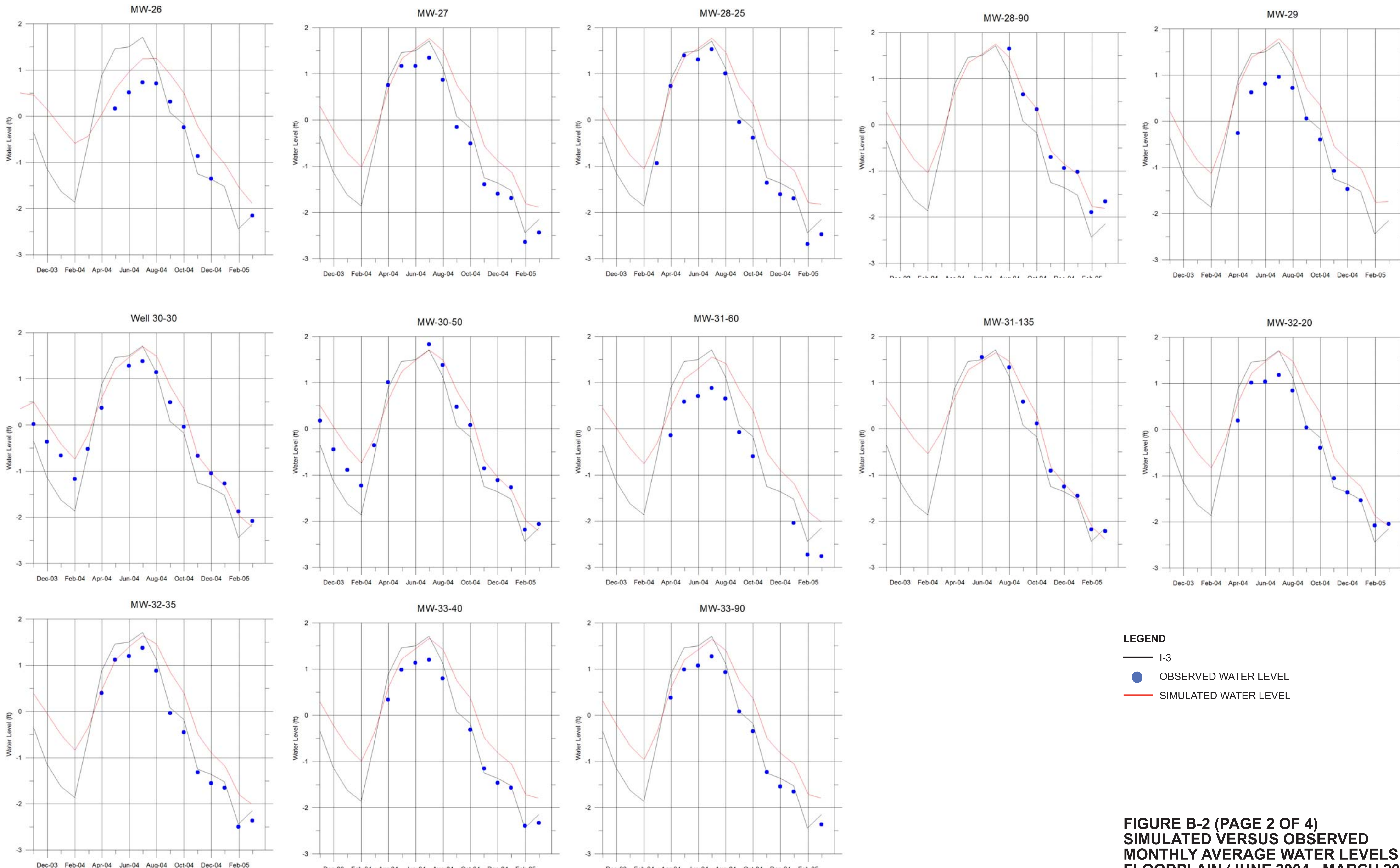


FIGURE B-2 (PAGE 2 OF 4)
SIMULATED VERSUS OBSERVED MONTHLY AVERAGE WATER LEVELS IN FLOODPLAIN (JUNE 2004 - MARCH 2005)
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-02.FH10

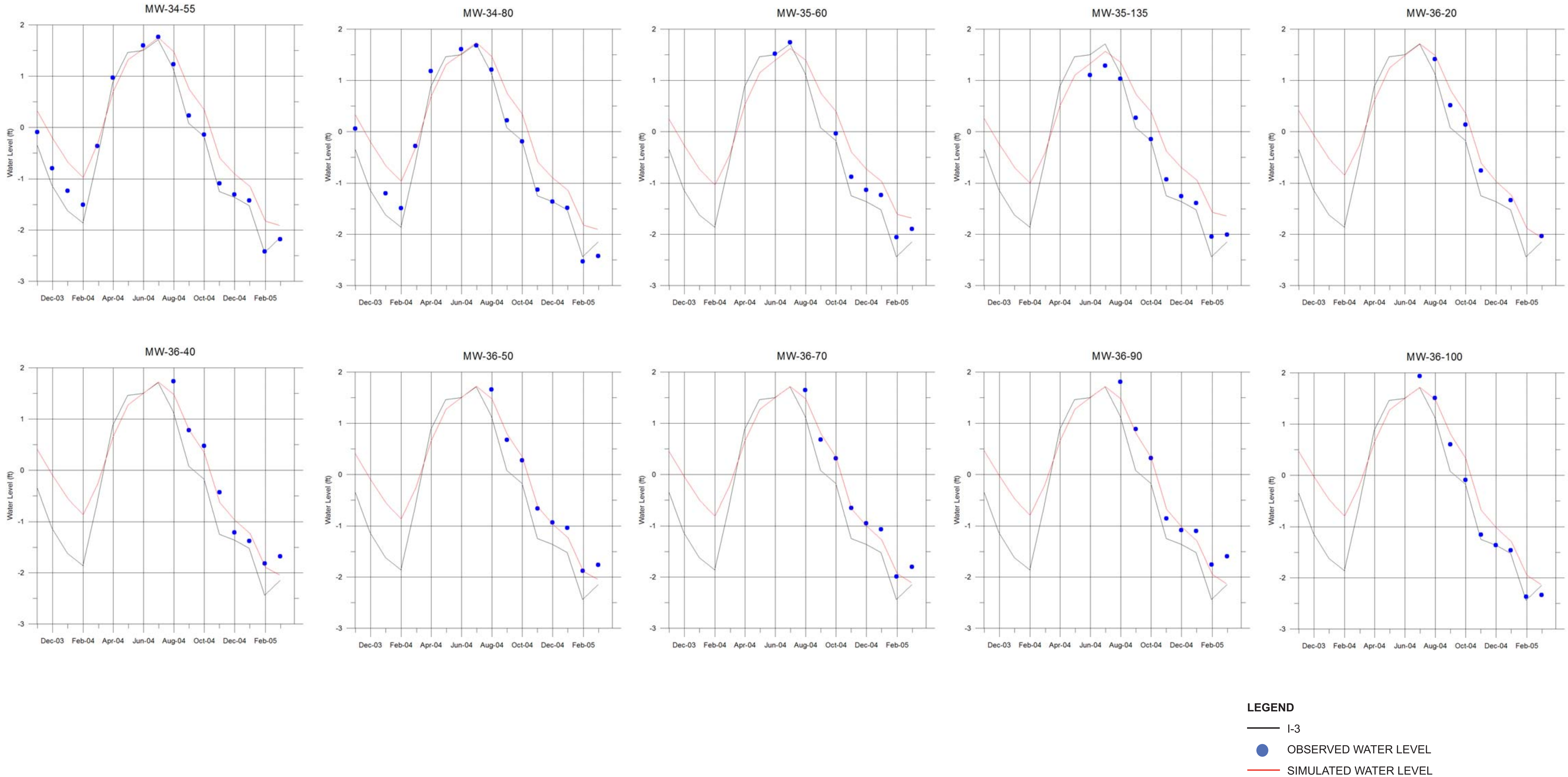
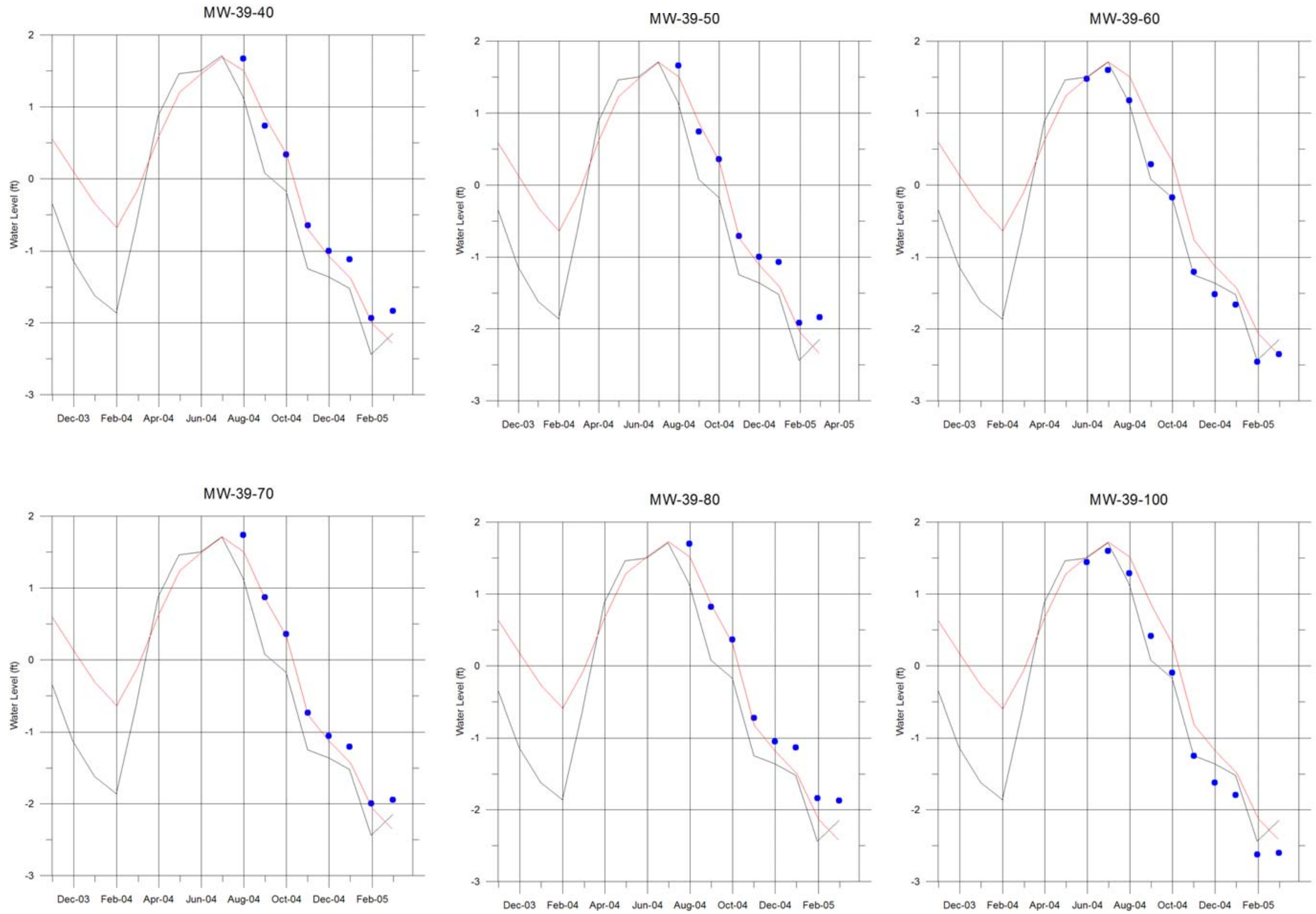


FIGURE B-2 (PAGE 3 OF 4)
SIMULATED VERSUS OBSERVED MONTHLY AVERAGE WATER LEVELS IN FLOODPLAIN (JUNE 2004 - MARCH 2005)
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-02.FH10



LEGEND

- I-3
- OBSERVED WATER LEVEL
- SIMULATED WATER LEVEL

FIGURE B-2 (PAGE 4 OF 4)
SIMULATED VERSUS OBSERVED MONTHLY AVERAGE WATER LEVELS IN FLOODPLAIN (JUNE 2004 - MARCH 2005)

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

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-02.FH10

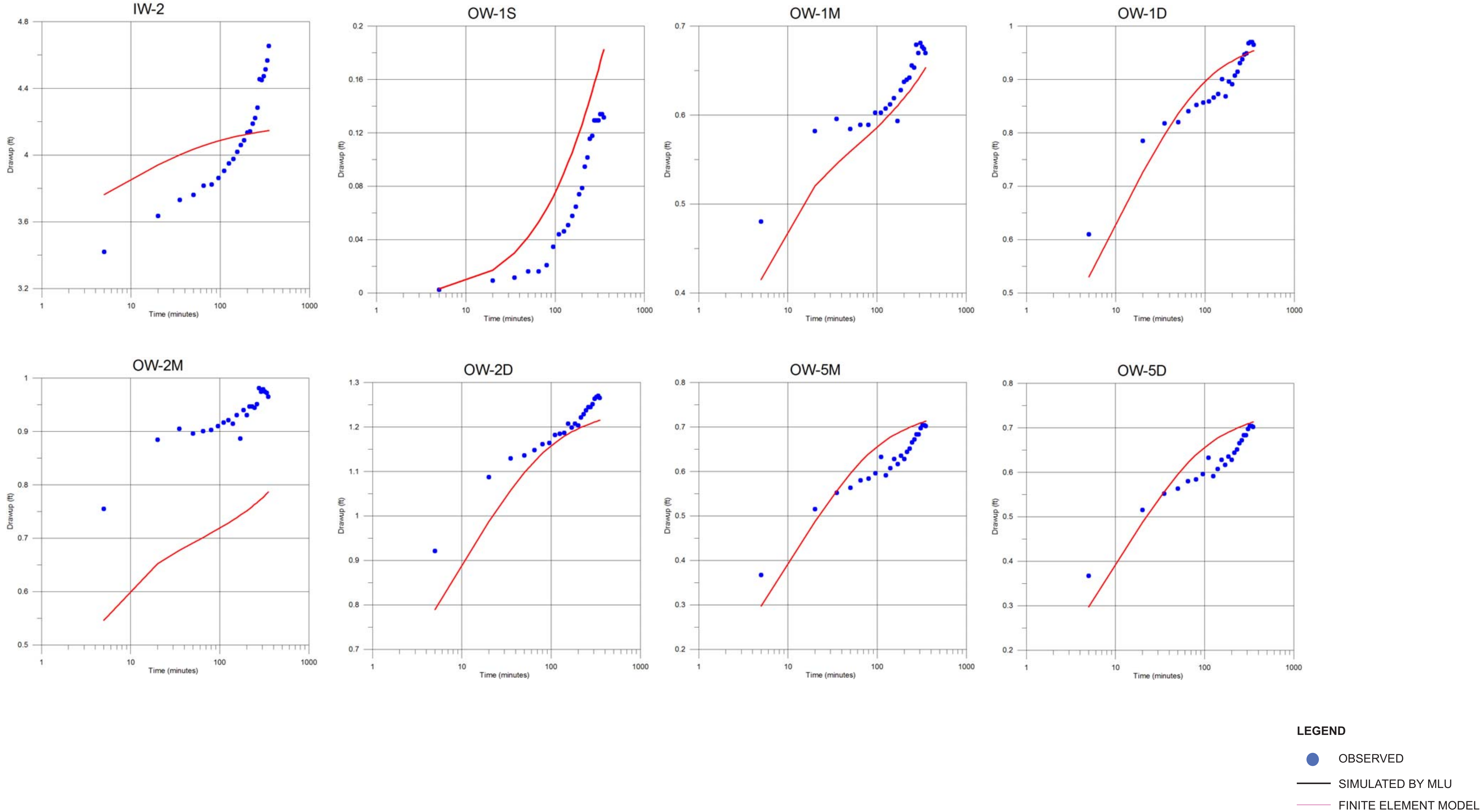
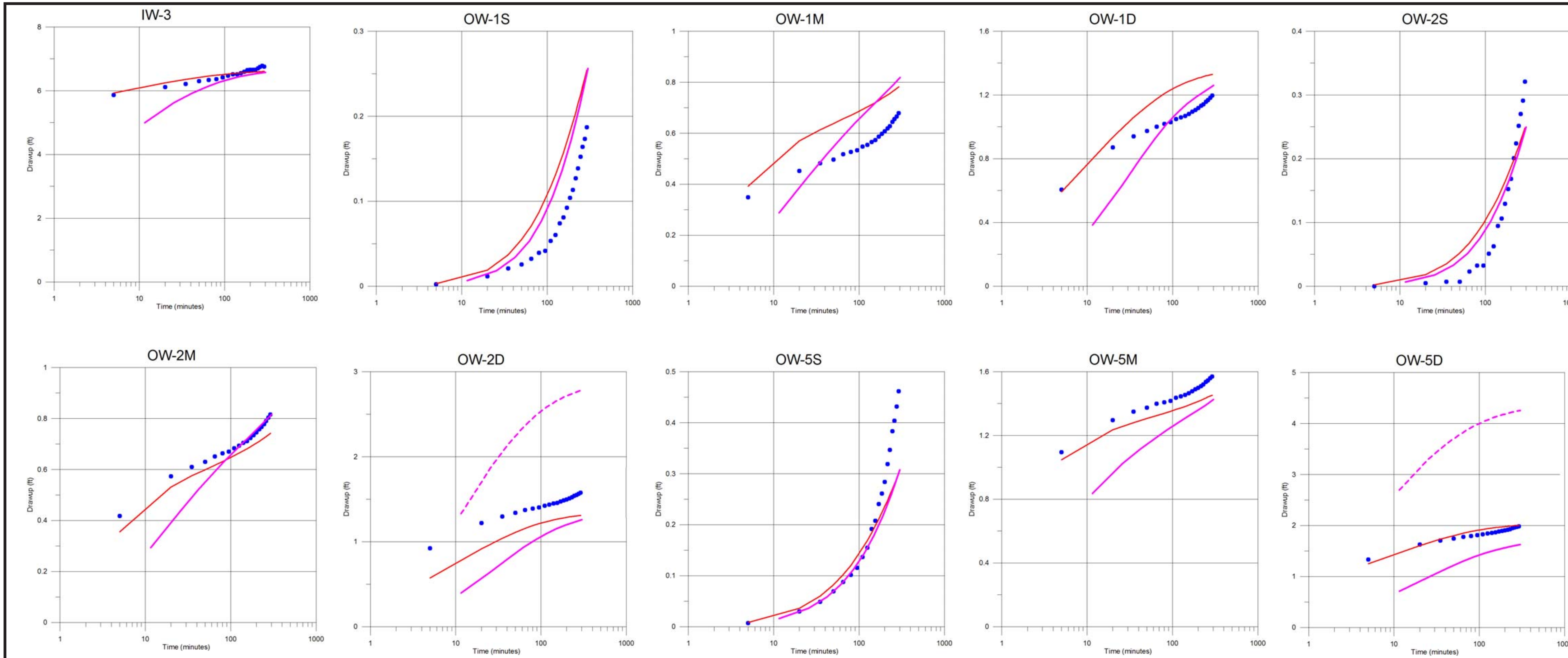


FIGURE B-3
SIMULATED VERSUS OBSERVED HYDROGRAPHS, IW-2 RECOVERY TEST
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-03.FH10



LEGEND

- OBSERVED
- SIMULATED BY MLU
- FINITE ELEMENT MODEL

FIGURE B-4
SIMULATED VERSUS OBSERVED HYDROGRAPHS,
IW-3 RECOVERY TEST
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

\\ODIN\PROJ\TOPOCK\FIGURES\FREEHAND\0605TM_FIGB-03.FH10

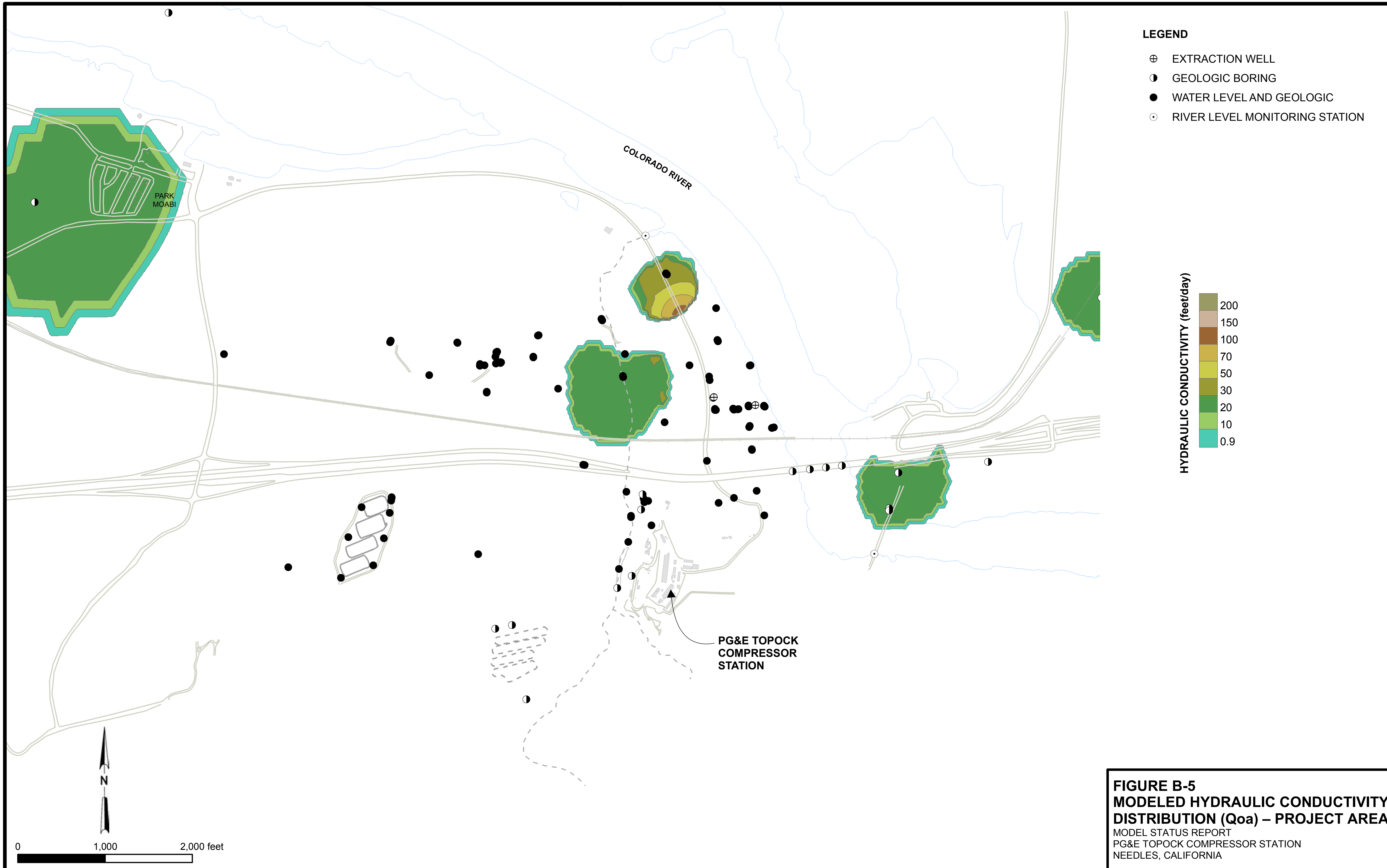


FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qoa) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_QOA_L.MXD 0605TM_FIGB-05_QOA_L.PDF 7/29/2005 17:14:53

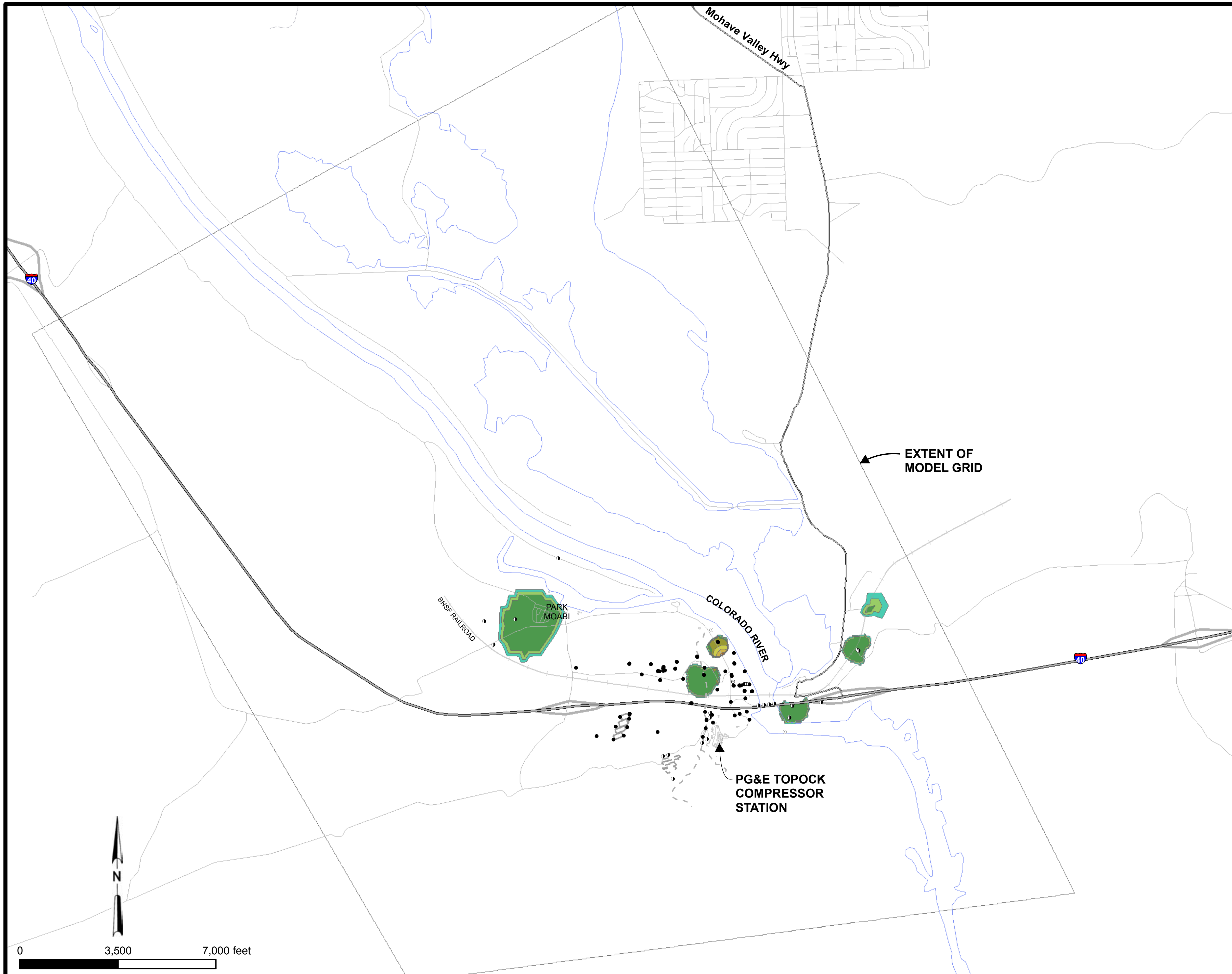


FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qoa) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_QOA_R.MXD 0605TM_FIGB-05_QOA_R.PDF 7/29/2005 14:03:15

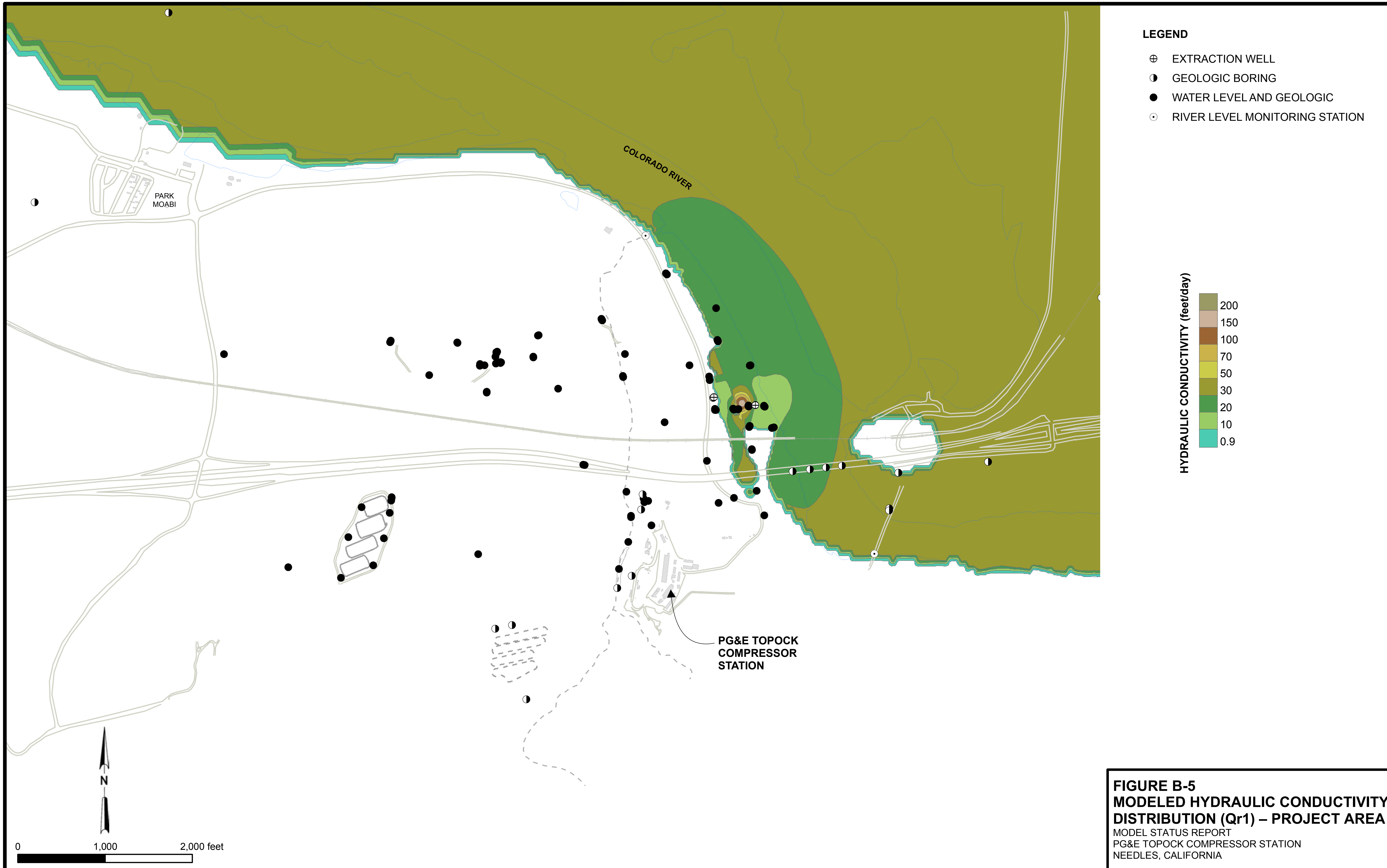


FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qr1) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_QR1_L.MXD 0605TM_FIGB-05_QR1_L.PDF 7/29/2005 13:47:14

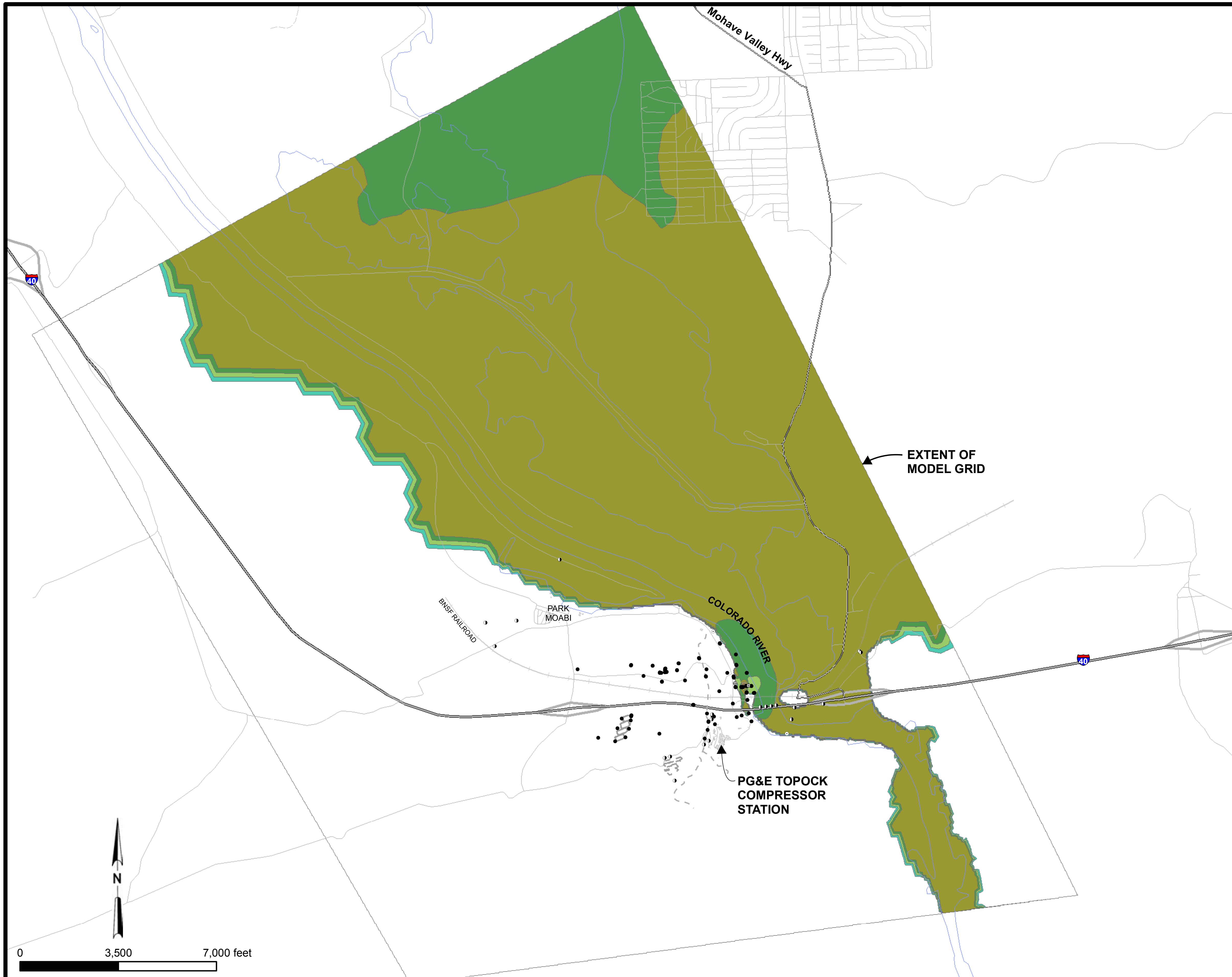


FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qr1) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_QR1_R.MXD 0605TM_FIGB-05_QR1_R.PDF 7/29/2005 14:22:32

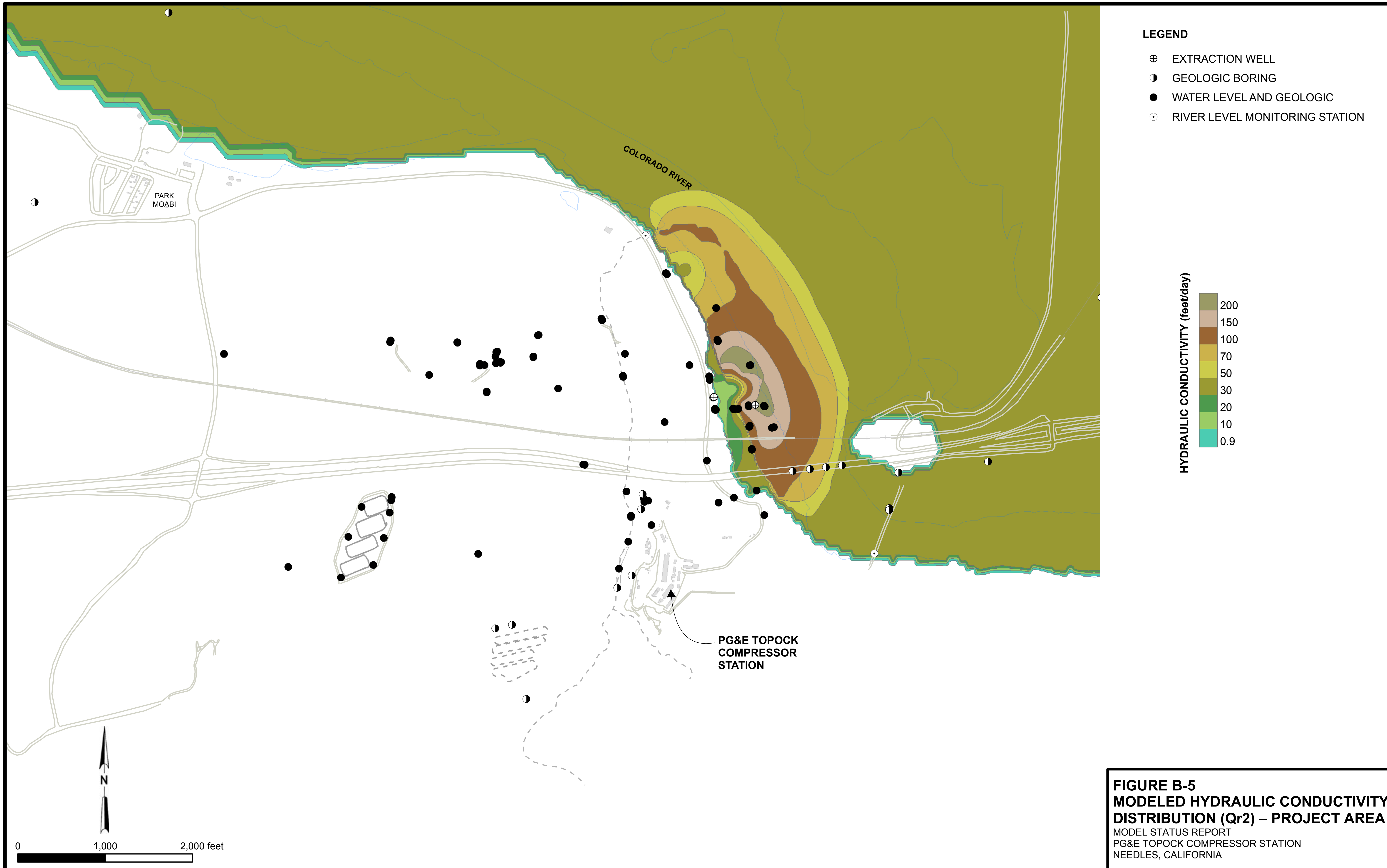


FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qr2) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

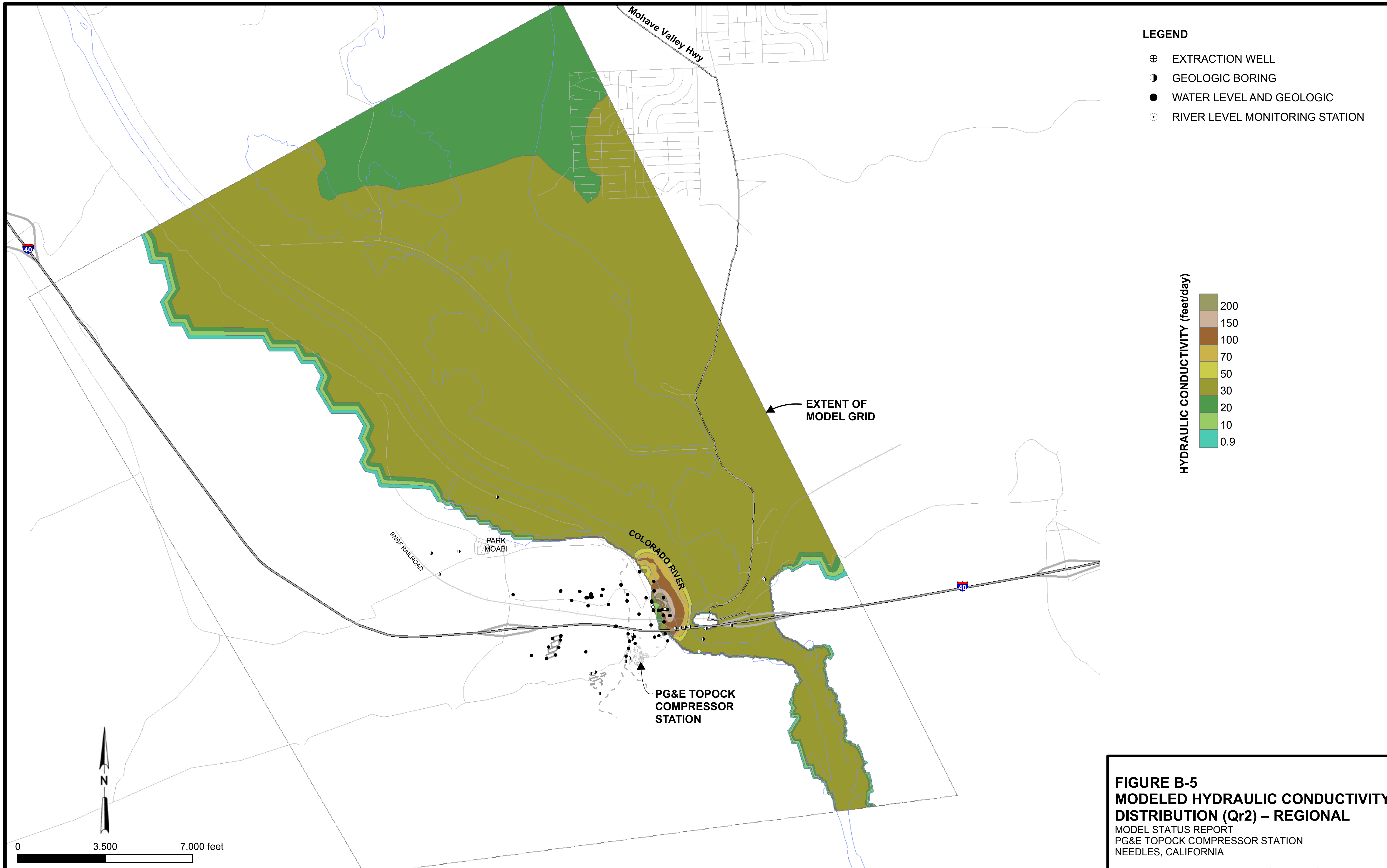


FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qr2) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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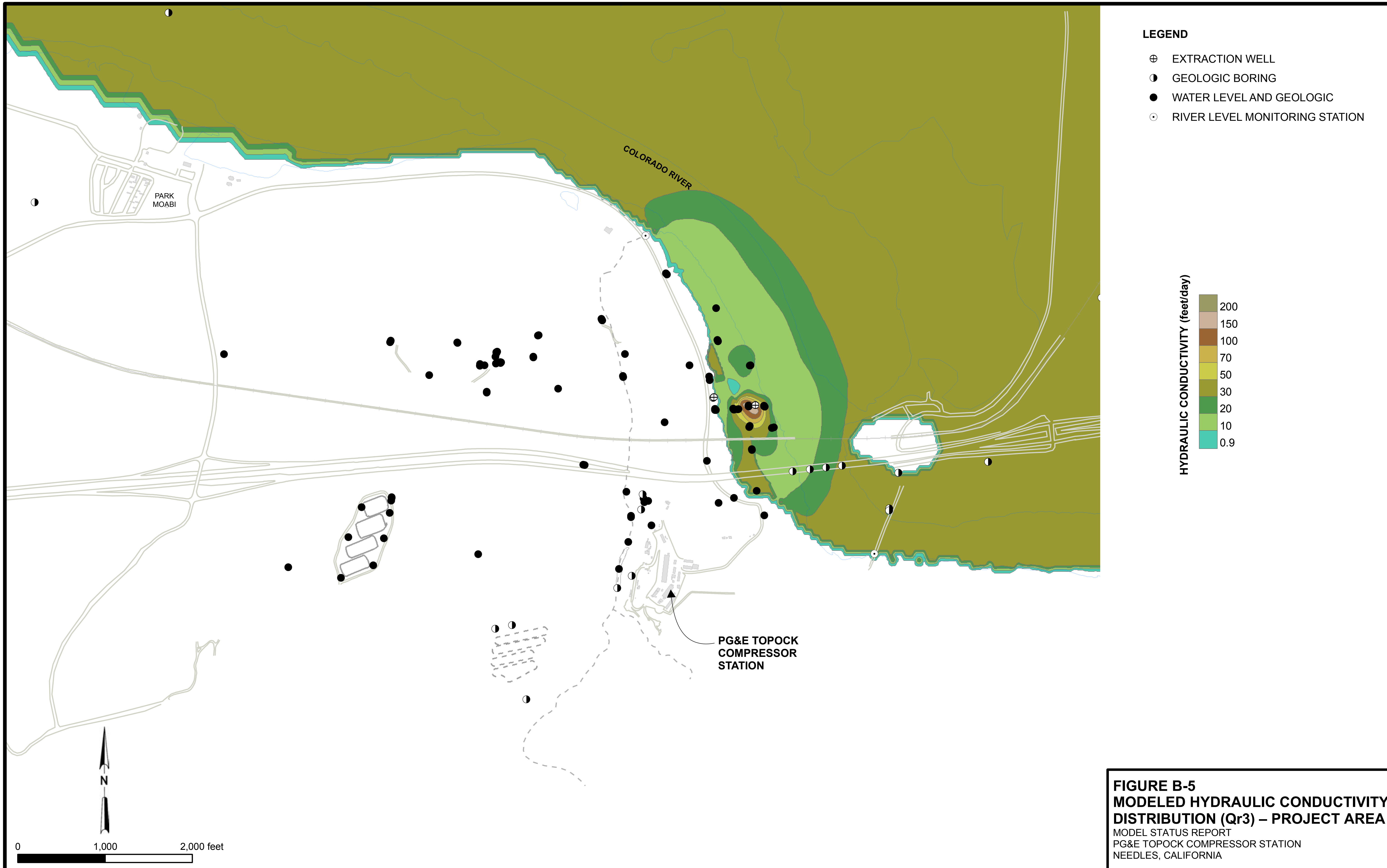

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qr3) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_QR3_L.MXD 0605TM_FIGB-05_QR3_L.PDF 7/29/2005 13:50:06

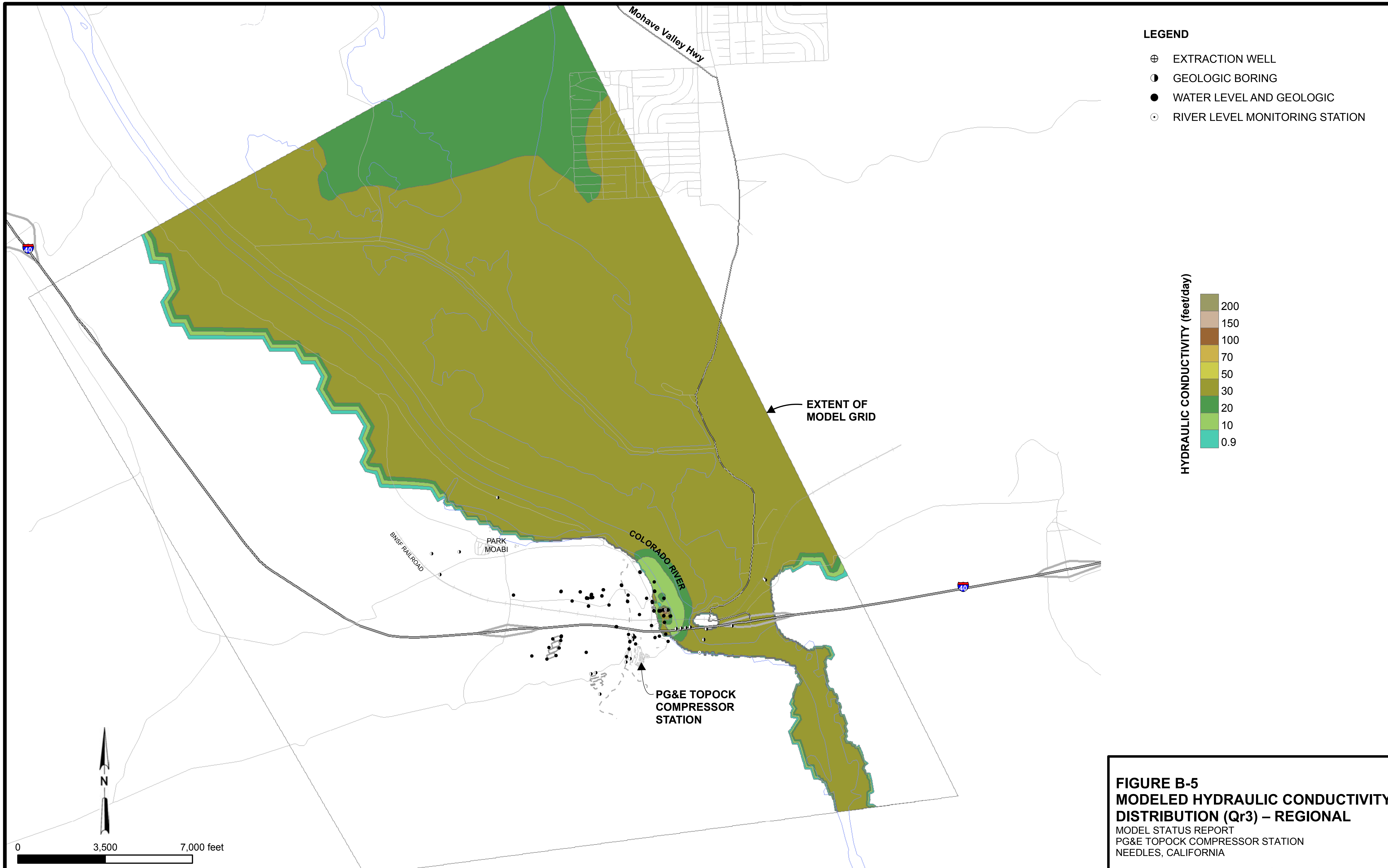

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Qr3) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_QR3_R.MXD 0605TM_FIGB-05_QR3_R.PDF 7/29/2005 14:25:21

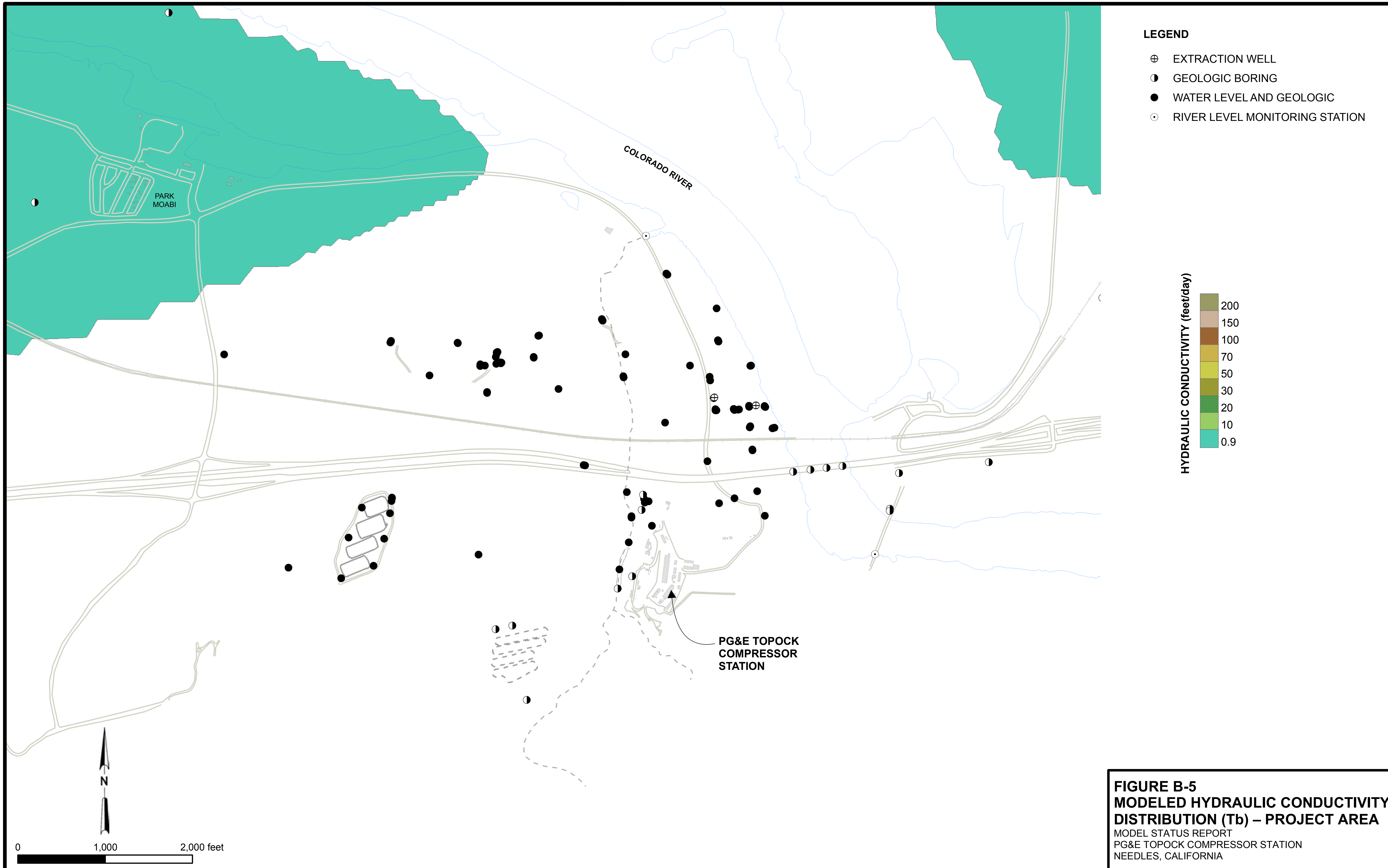

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Tb) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

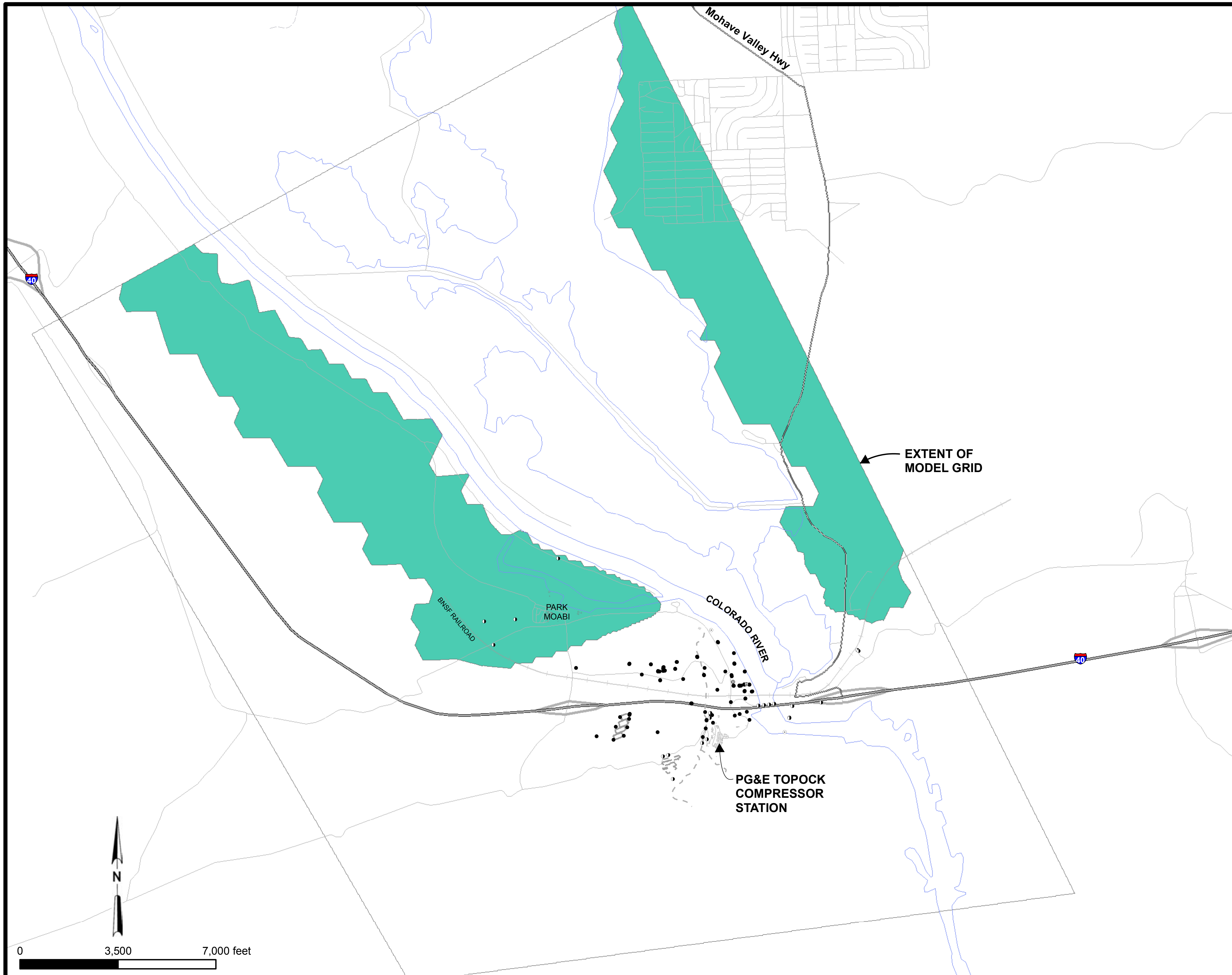

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Tb) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_TB_R.MXD 0605TM_FIGB-05_TB_R.PDF 7/29/2005 14:02:23

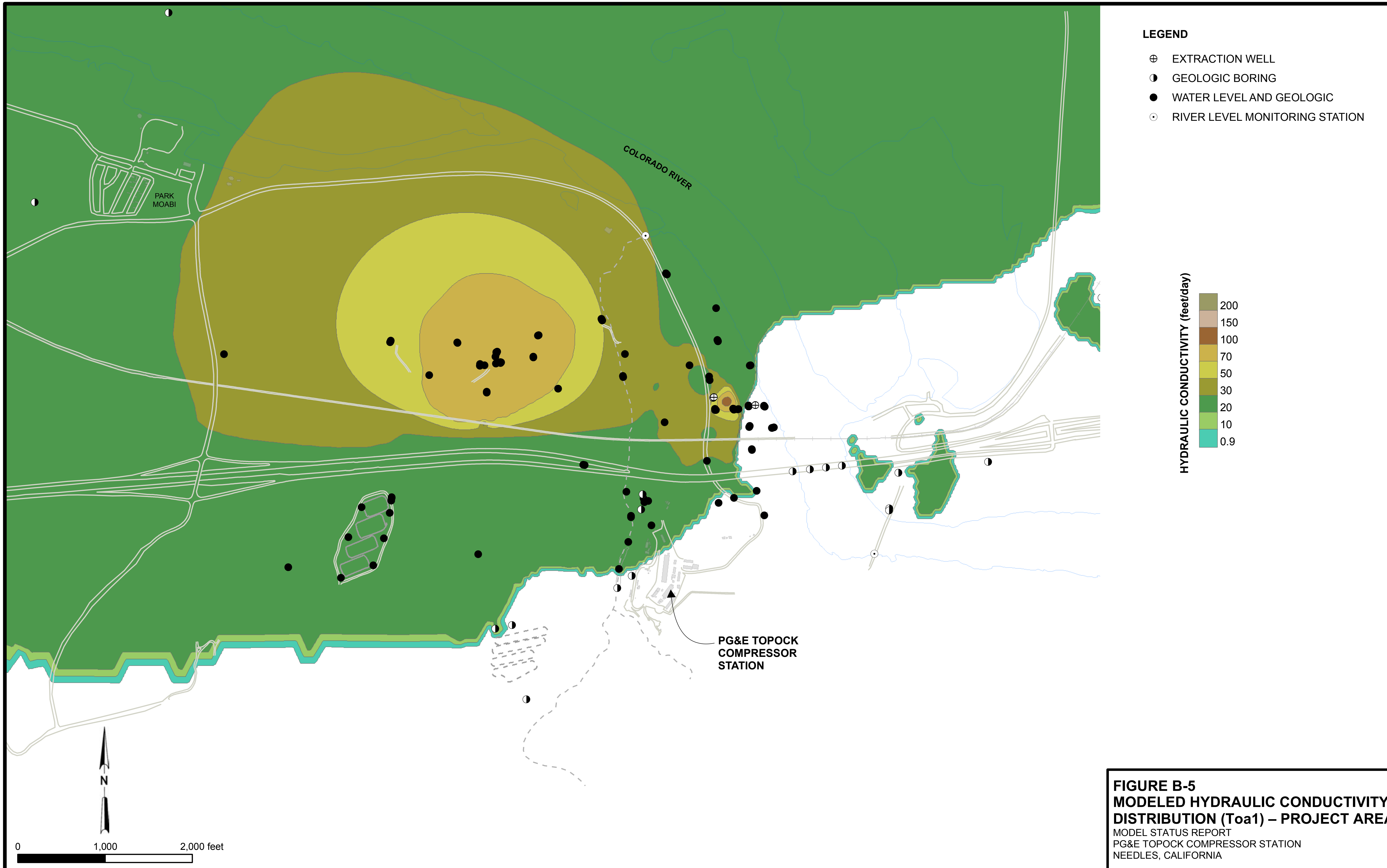

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Toa1) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_TOA1_L.MXD 0605TM_FIGB-05_TOA1_L.PDF 7/29/2005 13:40:46

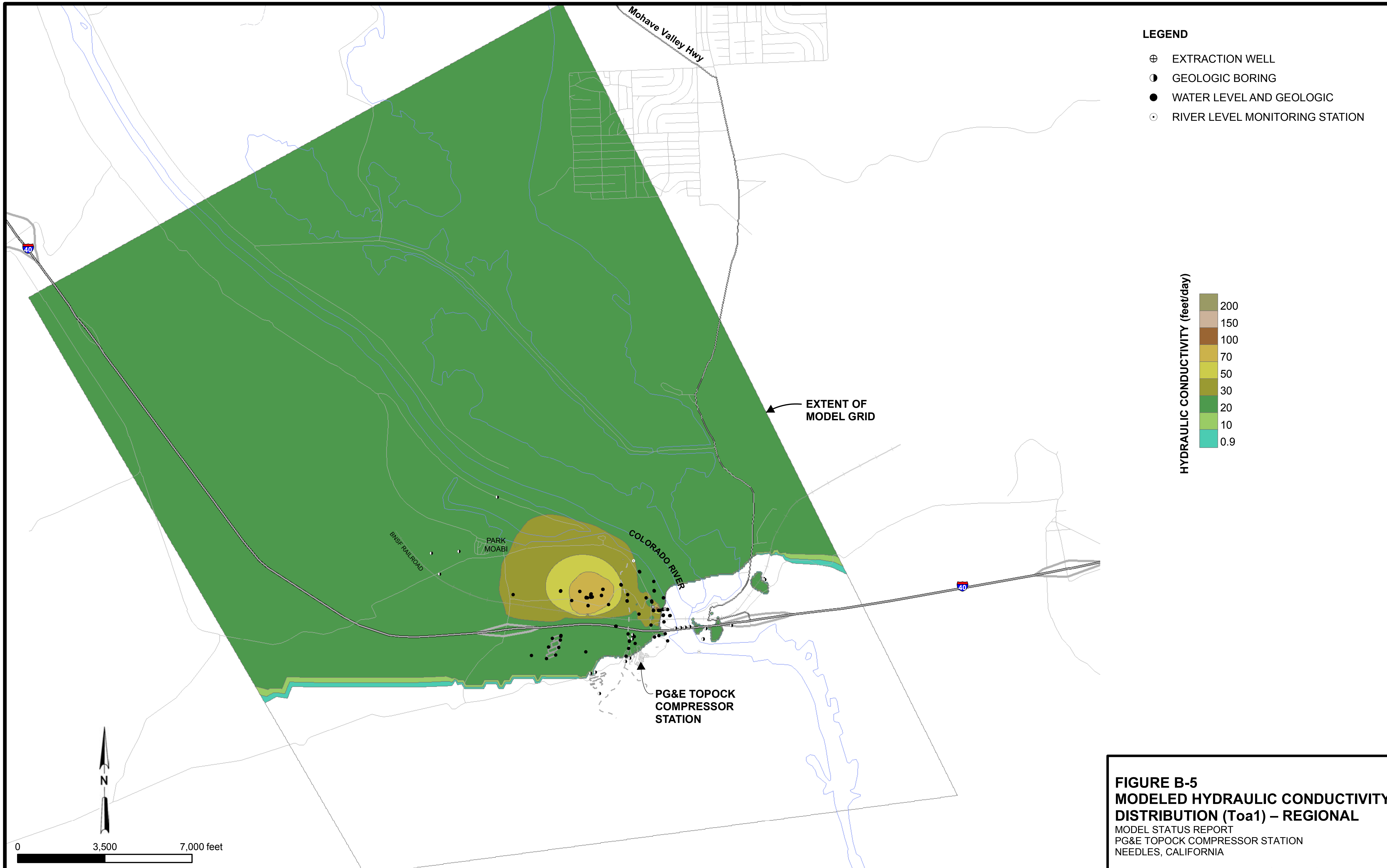

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Toa1) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_TOA1_R.MXD 0605TM_FIGB-05_TOA1_R.PDF 7/29/2005 13:59:59

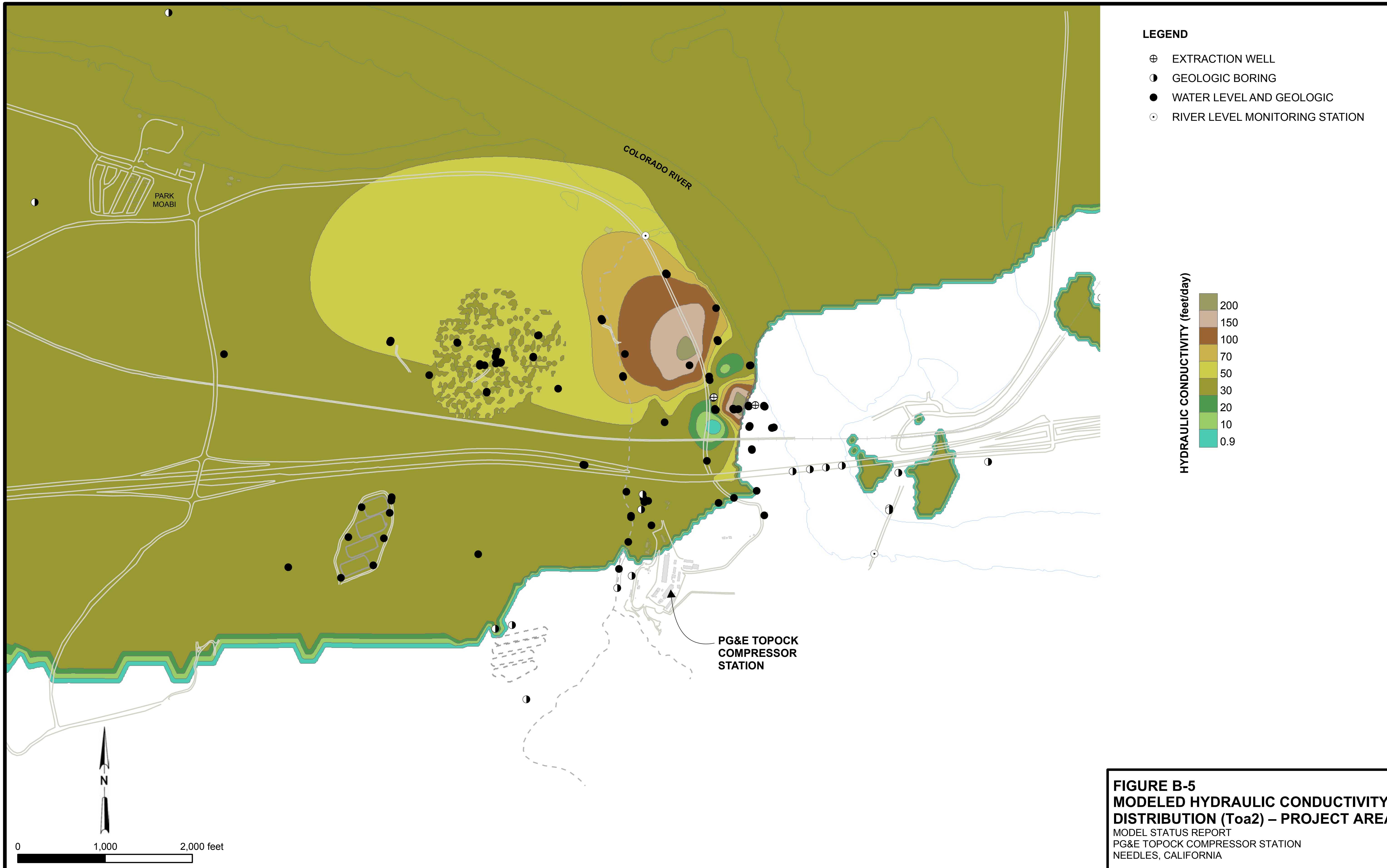

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Toa2) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

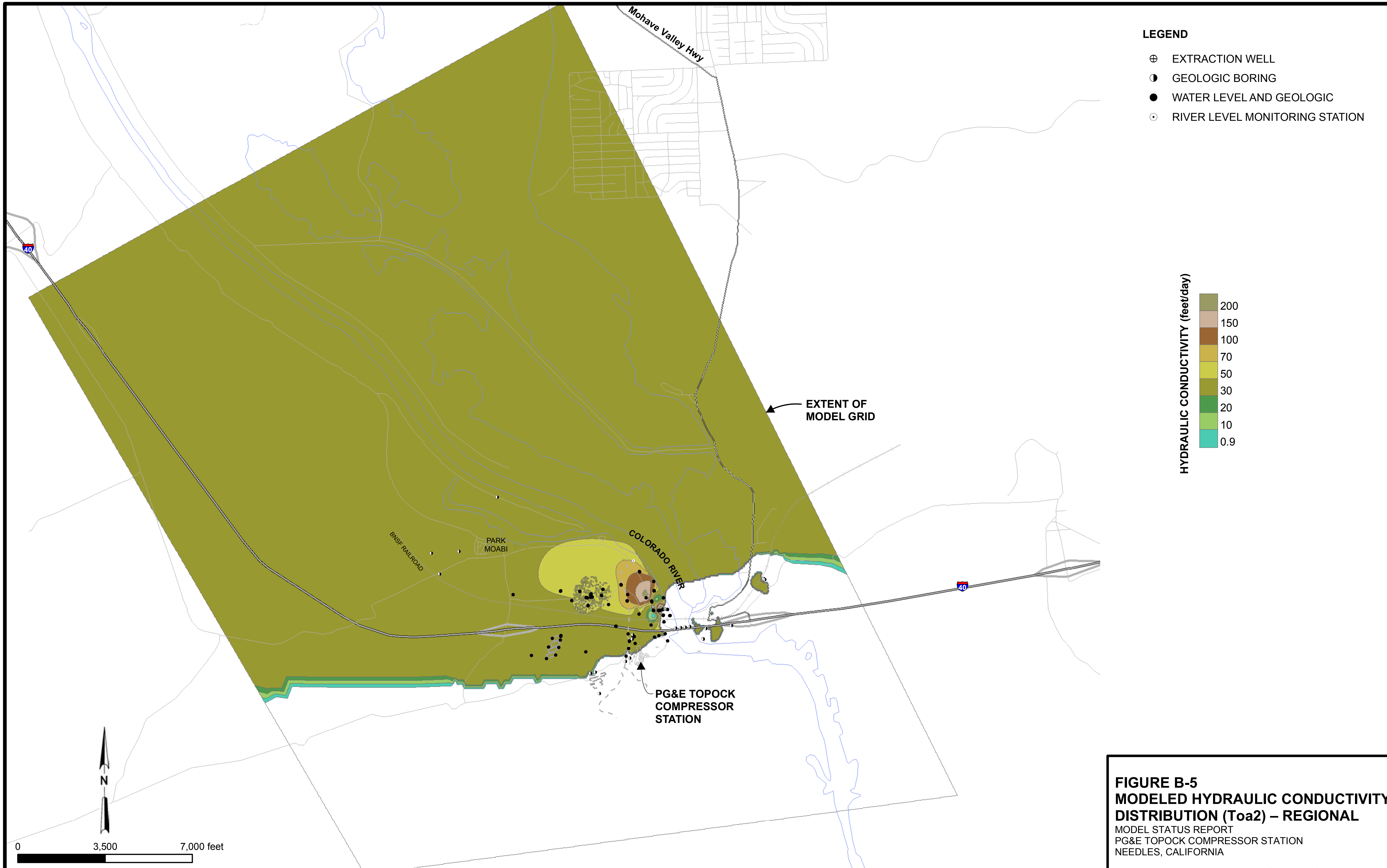

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Toa2) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_TOA2_R.MXD 0605TM_FIGB-05_TOA2_R.PDF 7/29/2005 14:01:26

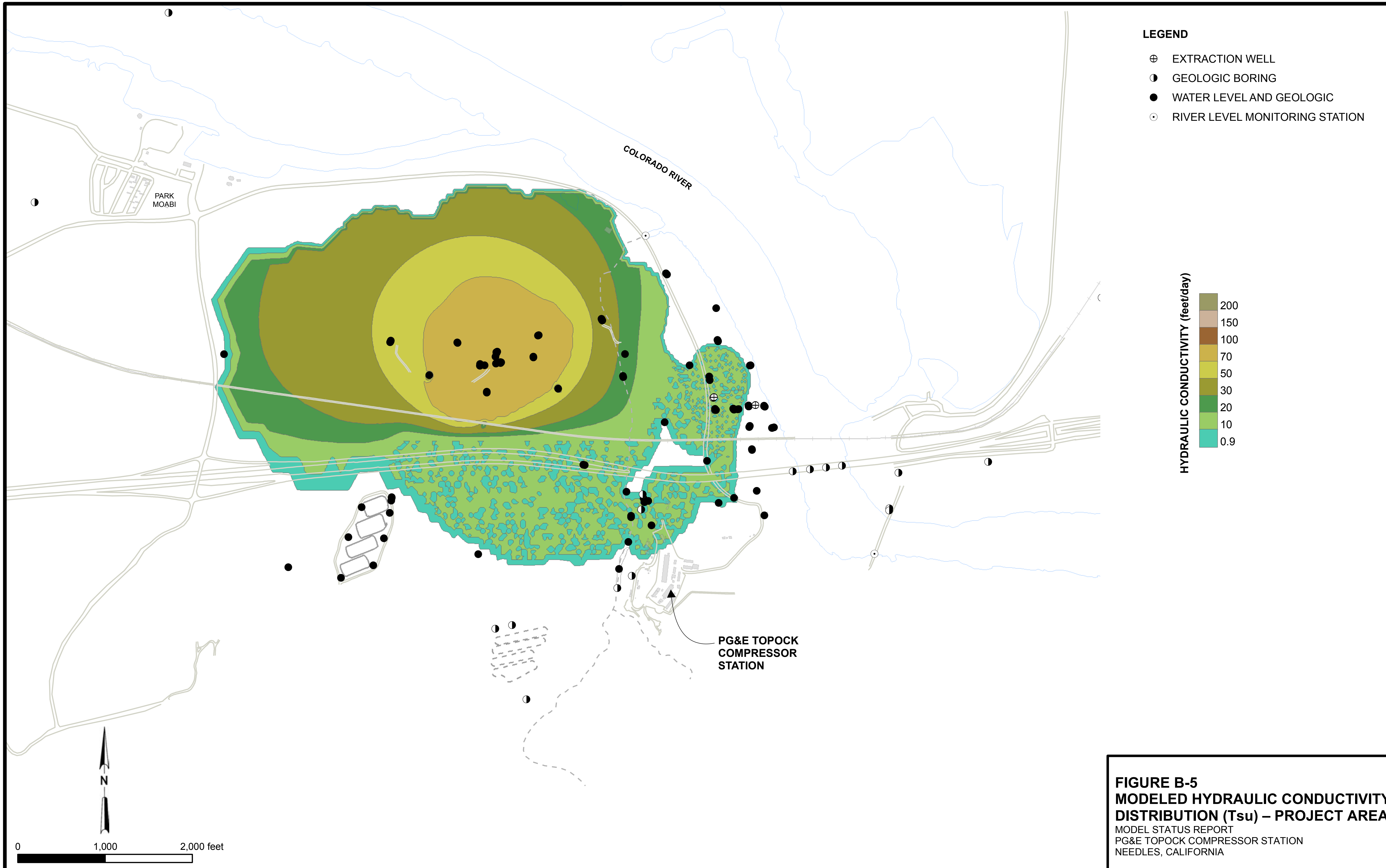

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Tsu) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

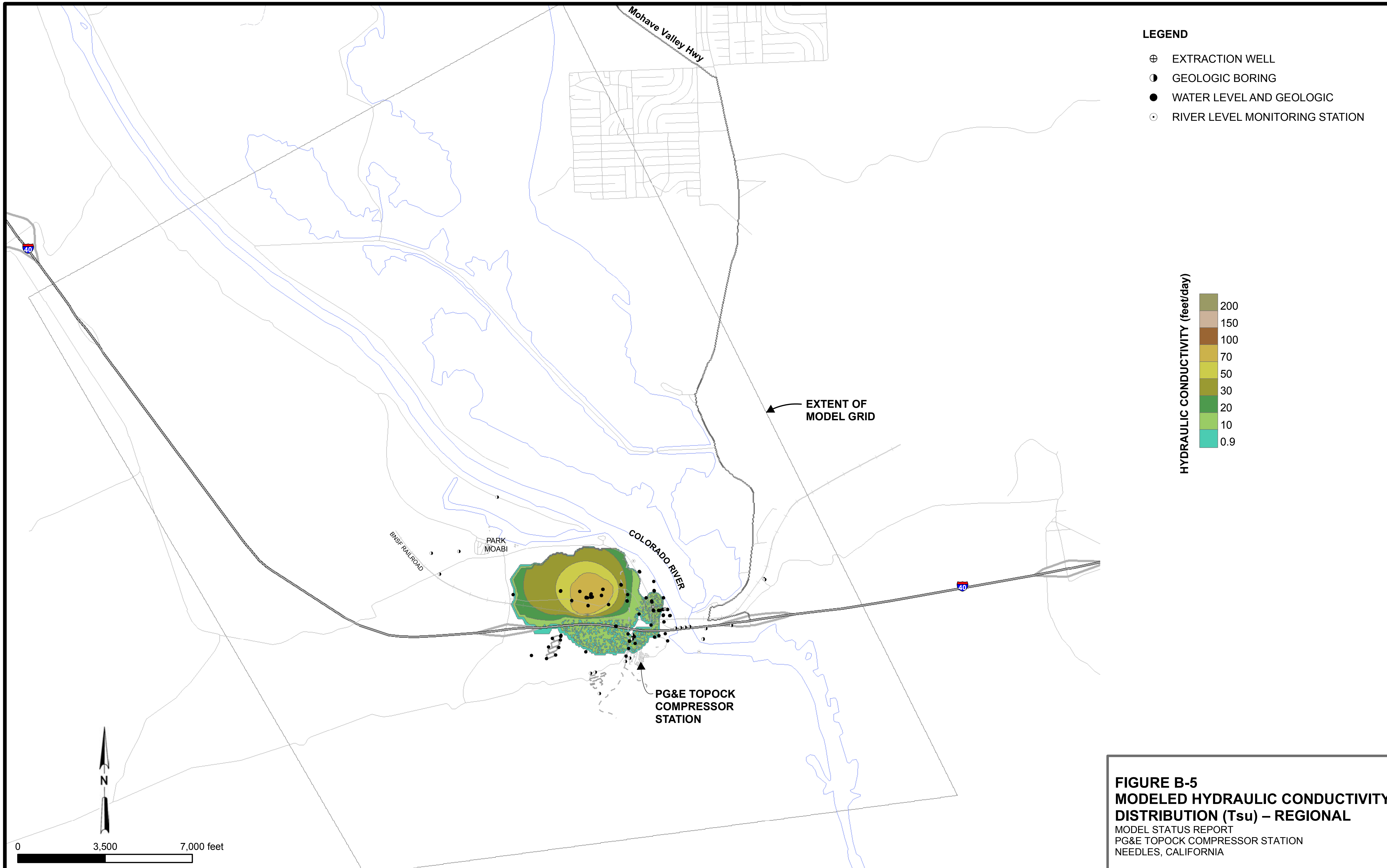

FIGURE B-5
MODELED HYDRAULIC CONDUCTIVITY DISTRIBUTION (Tsu) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPB_TSU_R.MXD 0605TM_FIGB-05_TSU_R.PDF 7/29/2005 13:58:26

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qoa) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

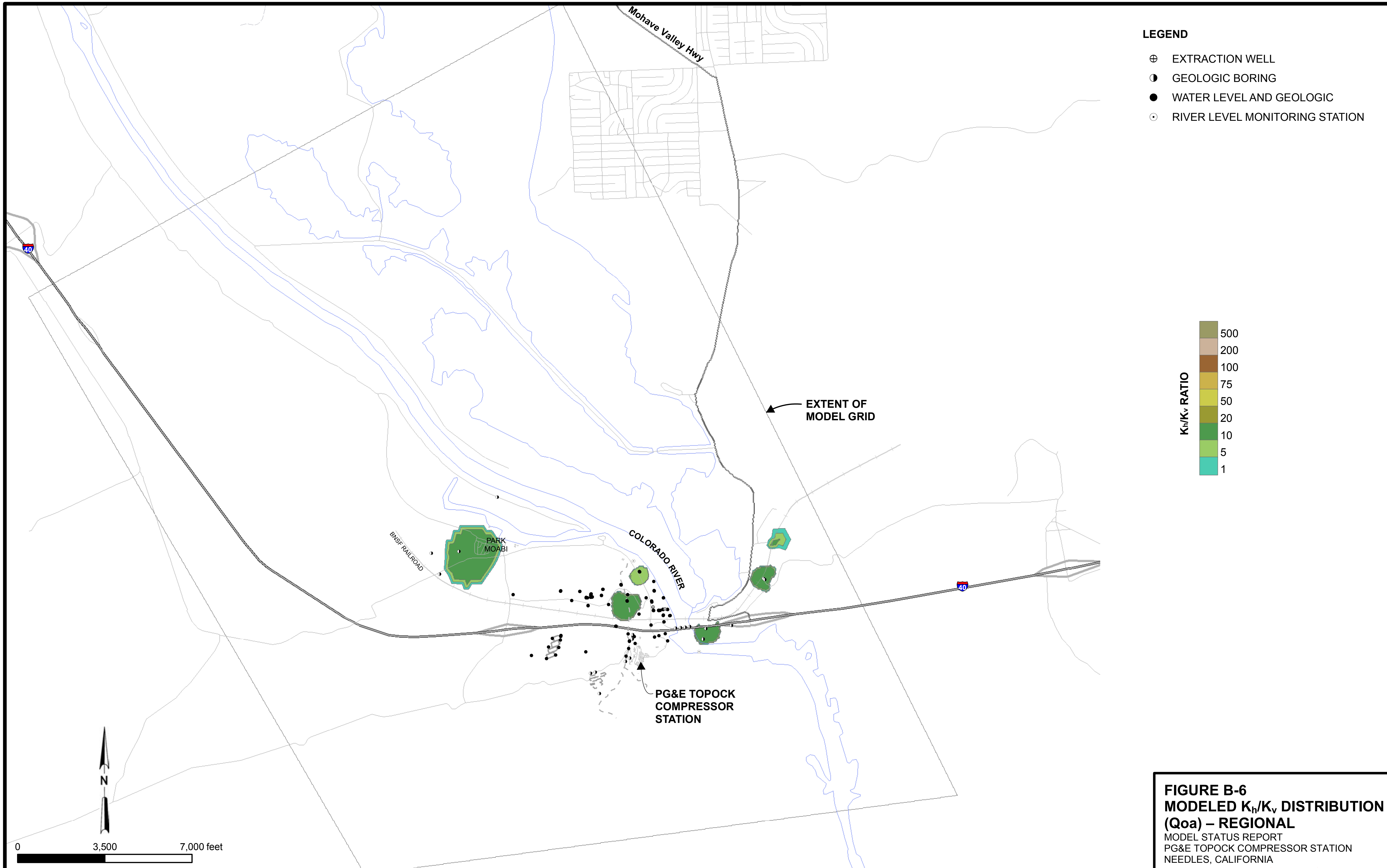

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qoa) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qr1) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_QR1_L.MXD 0605TM_FIGB-06_QR1_L.PDF 7/29/2005 17:57:20

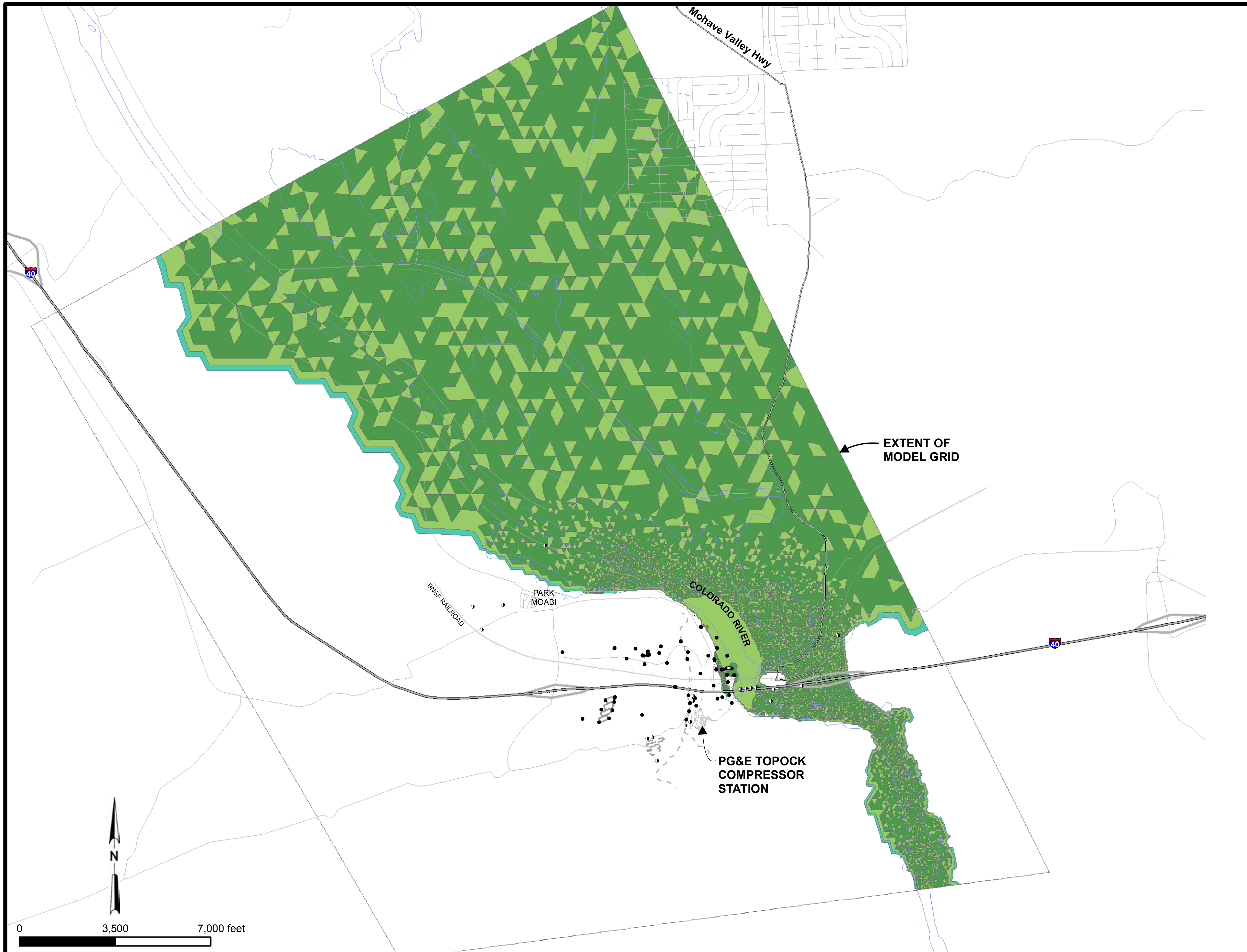

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qr1) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_QR1_R.MXD 0605TM_FIGB-06_QR1_R.PDF 7/29/2005 18:13:35

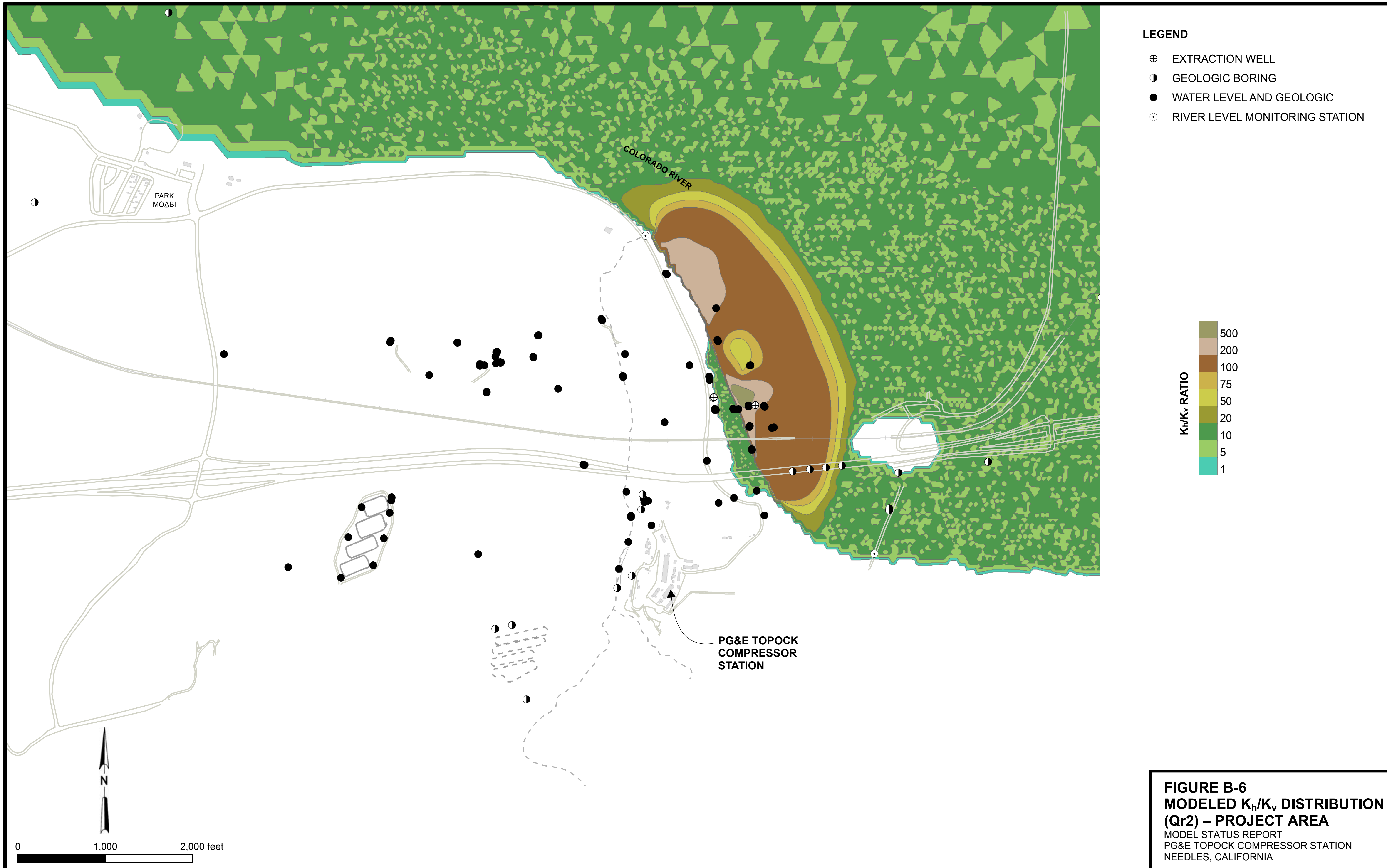

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qr2) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_QR2_L.MXD 0605TM_FIGB-06_QR2_L.PDF 7/29/2005 17:58:53

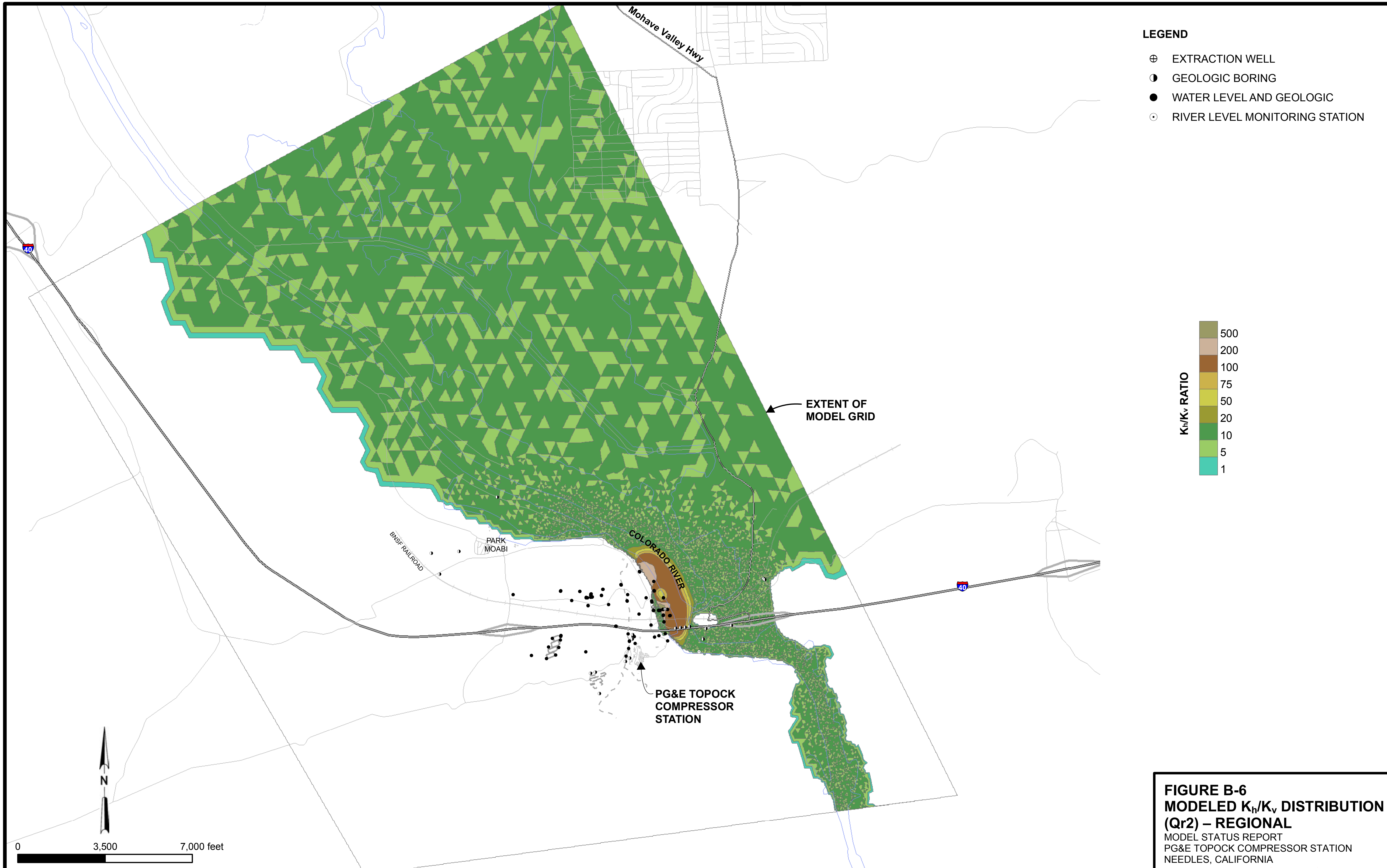

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qr2) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_QR2_R.MXD 0605TM_FIGB-06_QR2_R.PDF 7/29/2005 18:15:06

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qr3) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_QR3_L.MXD 0605TM_FIGB-06_QR3_L.PDF 7/29/2005 18:00:35

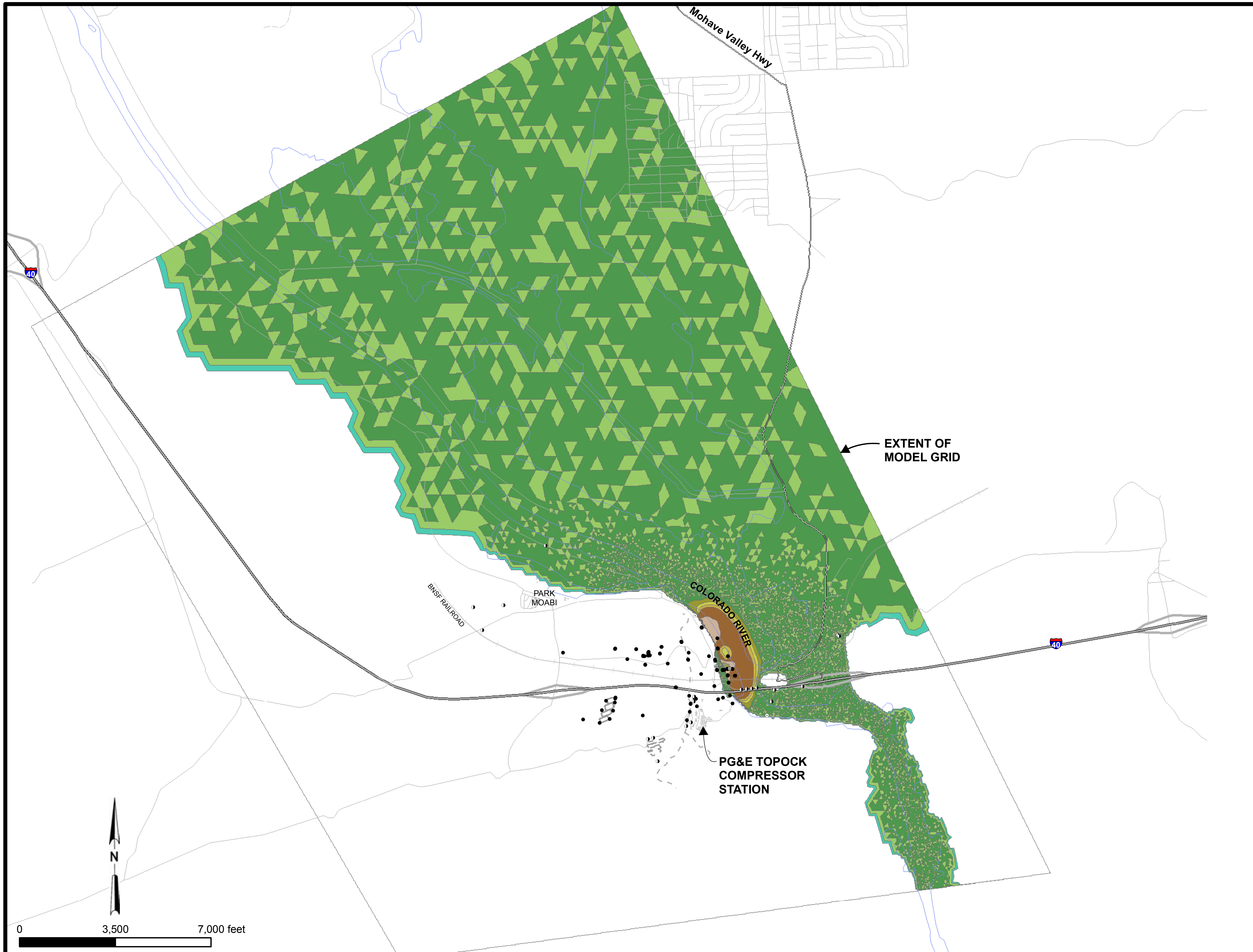

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Qr3) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_QR3_R.MXD 0605TM_FIGB-06_QR3_R.PDF 7/29/2005 18:16:38

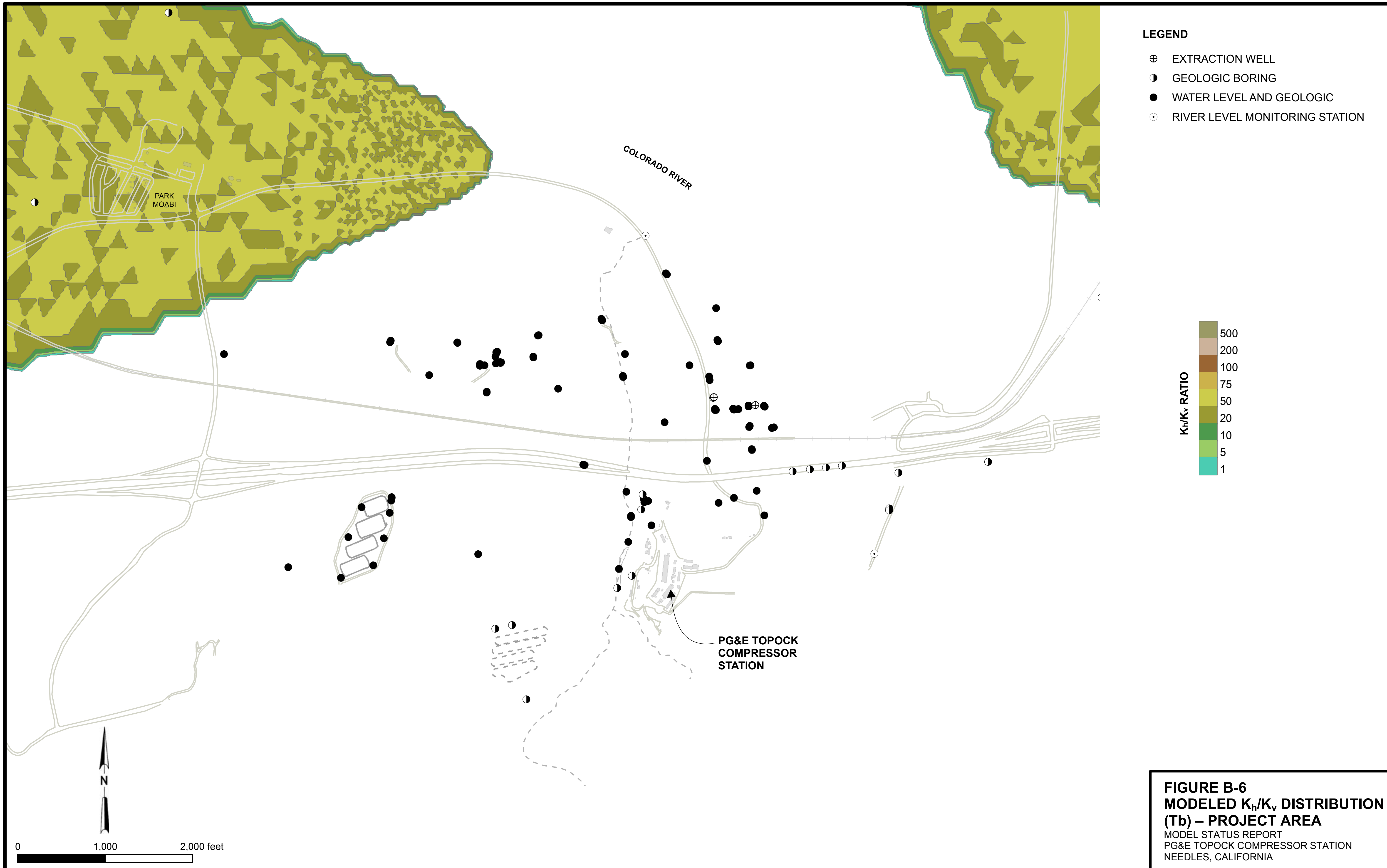

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Tb) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_TB_L.MXD 0605TM_FIGB-06_TB_L.PDF 7/29/2005 17:55:06

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Tb) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_TB_R.MXD 0605TM_FIGB-06_TB_R.PDF 7/29/2005 18:09:42

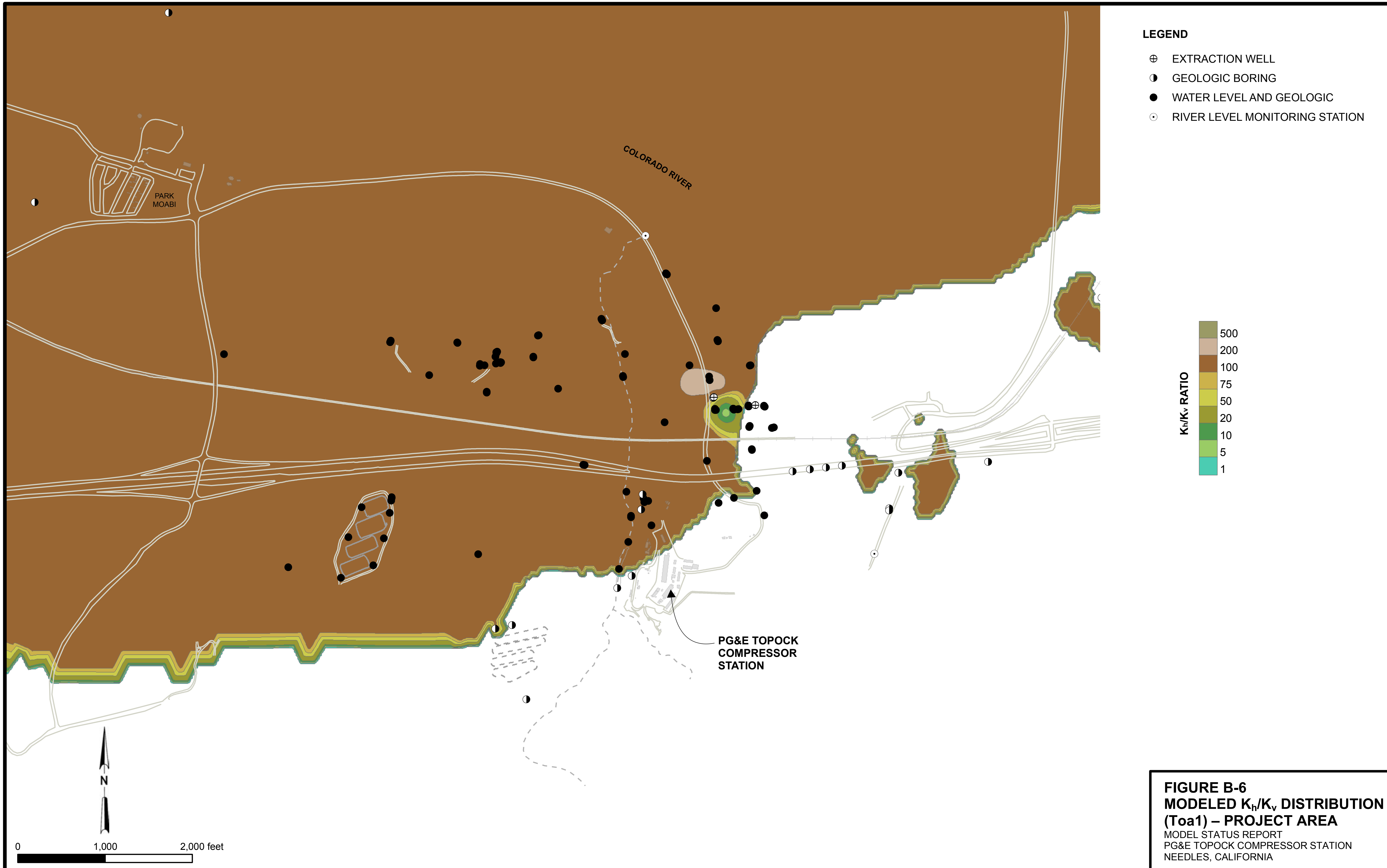

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Toa1) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_TOA1_L.MXD 0605TM_FIGB-06_TOA1_L.PDF 7/29/2005 17:53:00

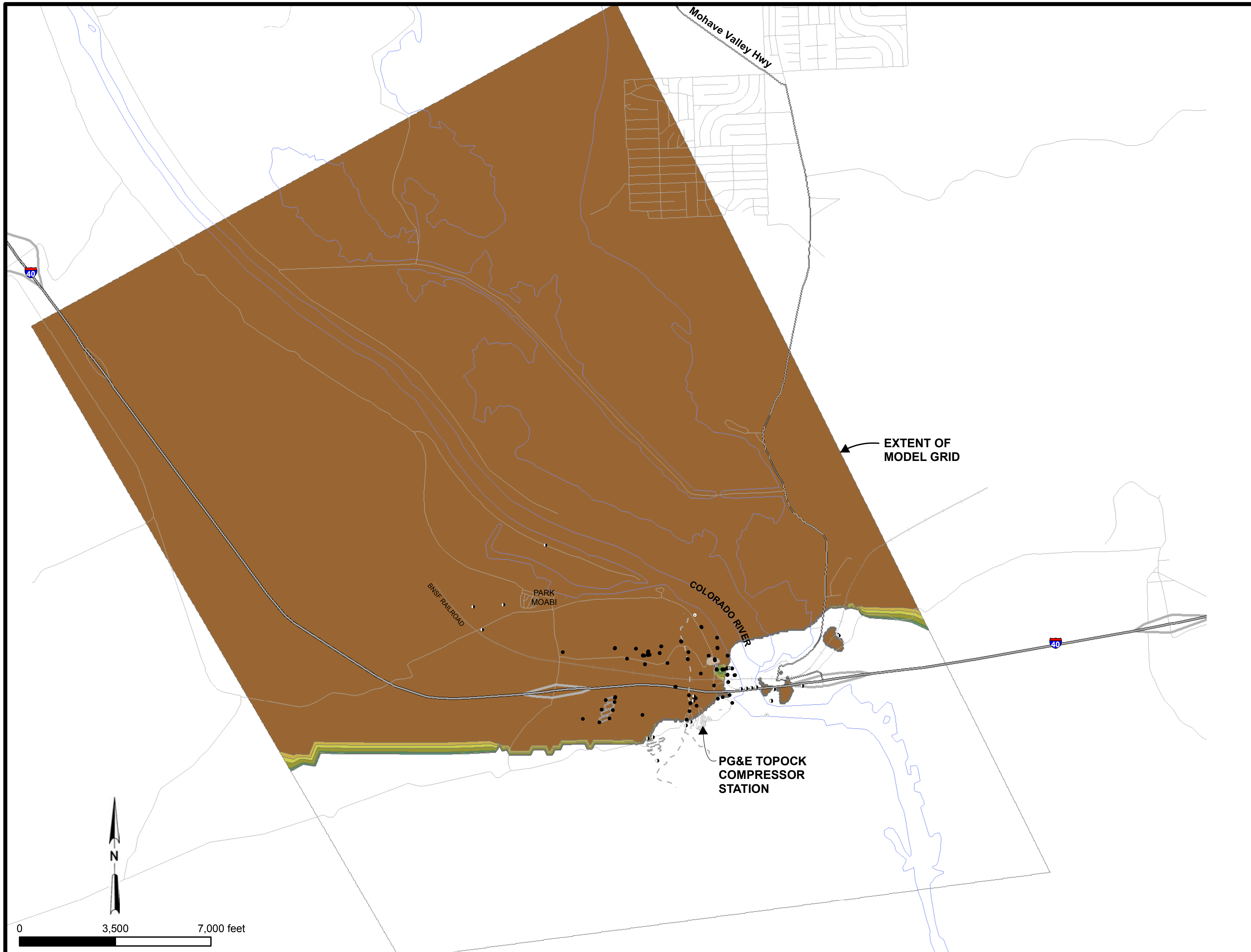

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Toa1) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

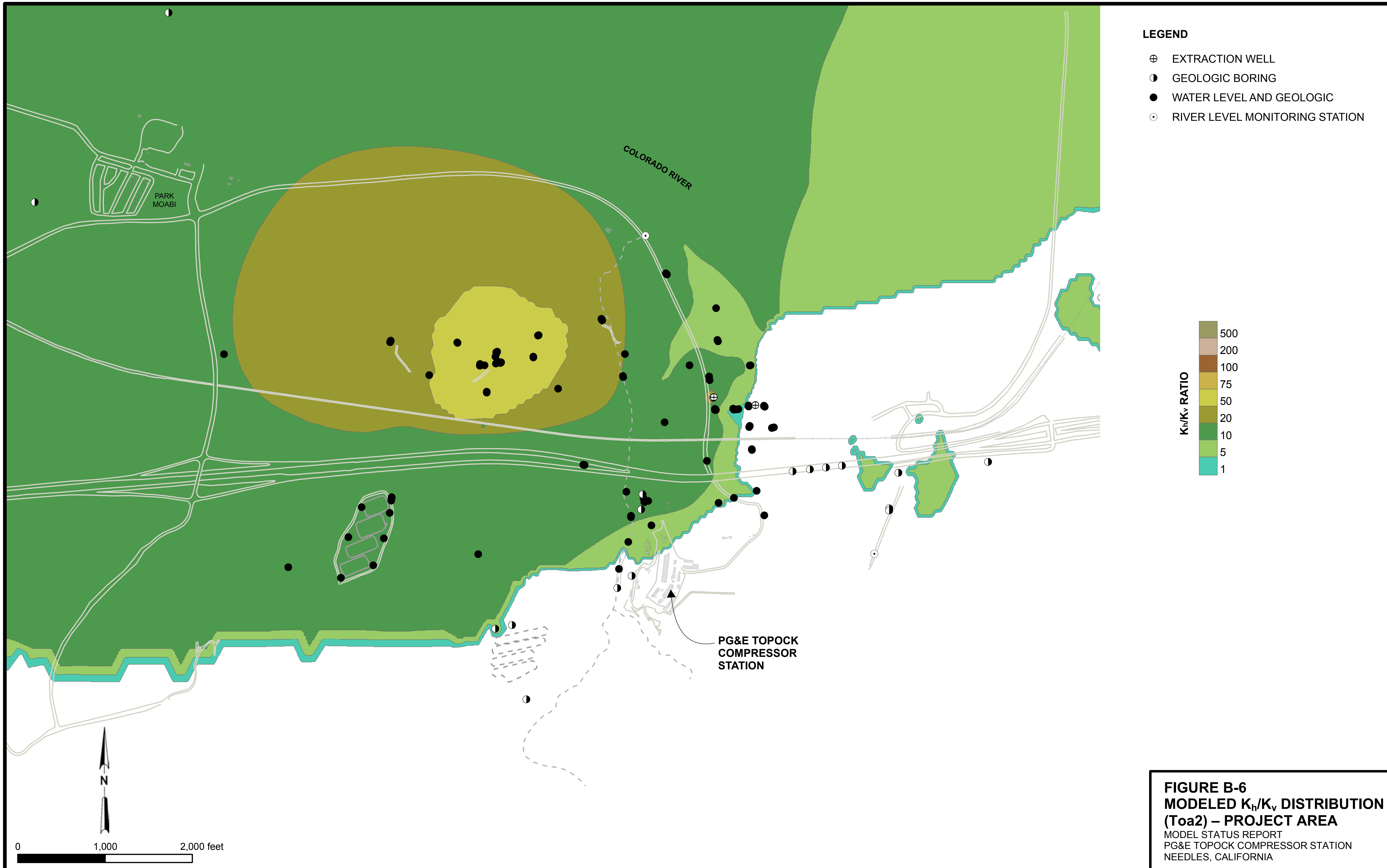

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Toa2) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_TOA2_L.MXD 0605TM_FIGB-06_TOA2_L.PDF 7/29/2005 17:53:49

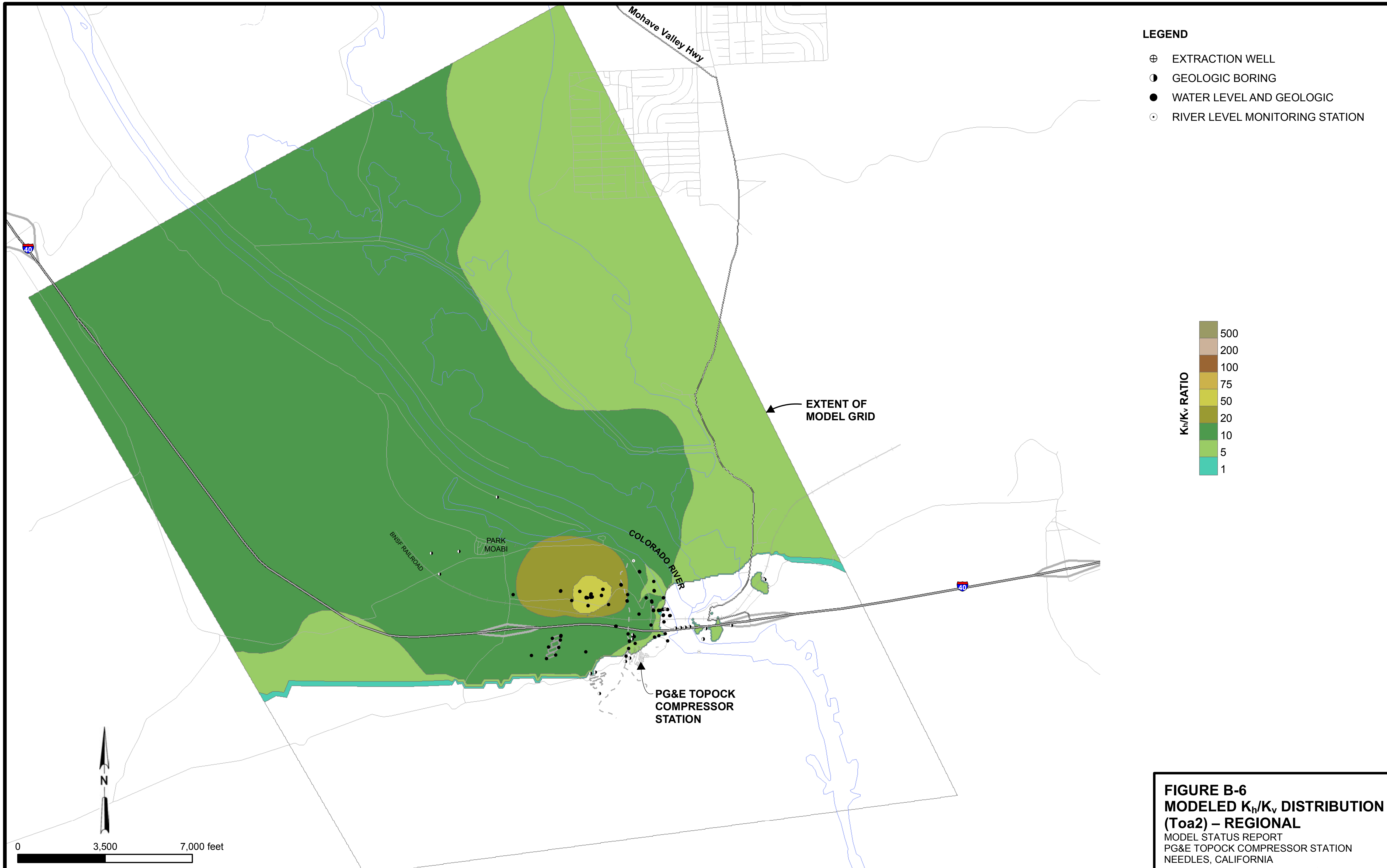

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Toa2) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Tsu) – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_QOA_L.MXD 0605TM_FIGB-06_TSU_L.PDF 7/29/2005 17:51:33

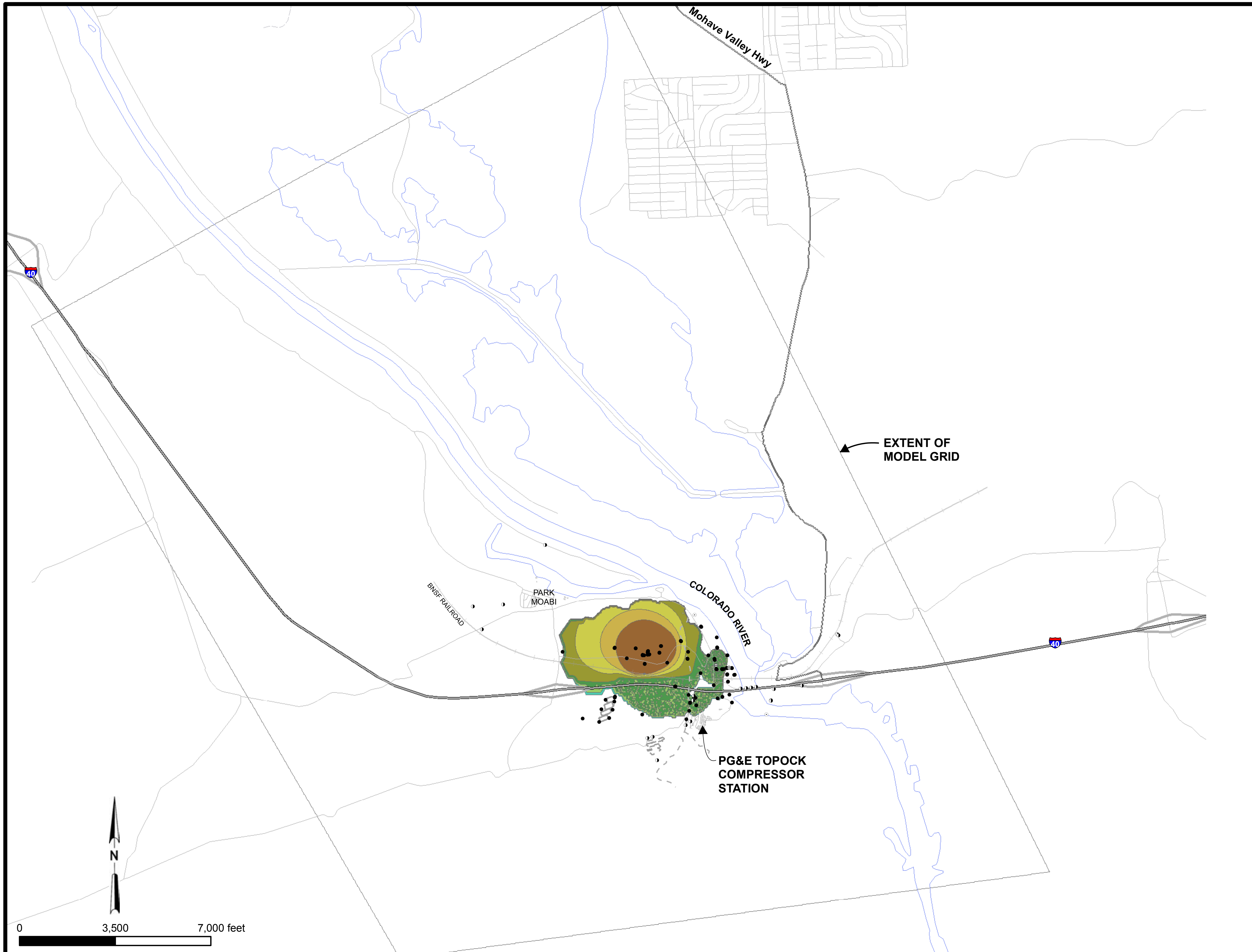

FIGURE B-6
MODELED K_h/K_v DISTRIBUTION (Tsu) – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBKVKH_TSU_R.MXD 0605TM_FIGB-06_TSU_R.PDF 7/29/2005 14:37:51

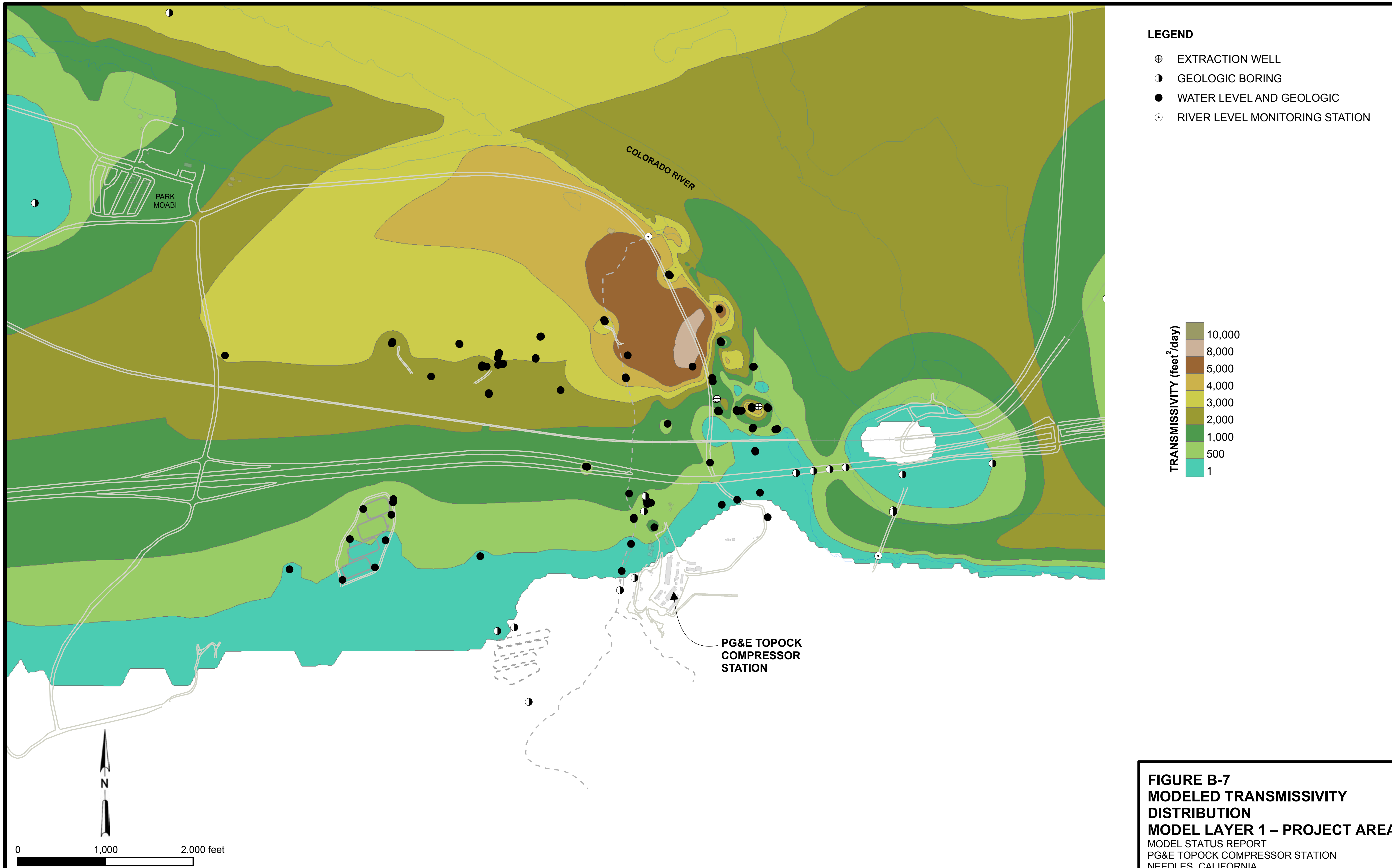

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 1 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBT_L1_L.MXD 0605TM_FIGB-07_T1_L.PDF 7/29/2005 15:13:03

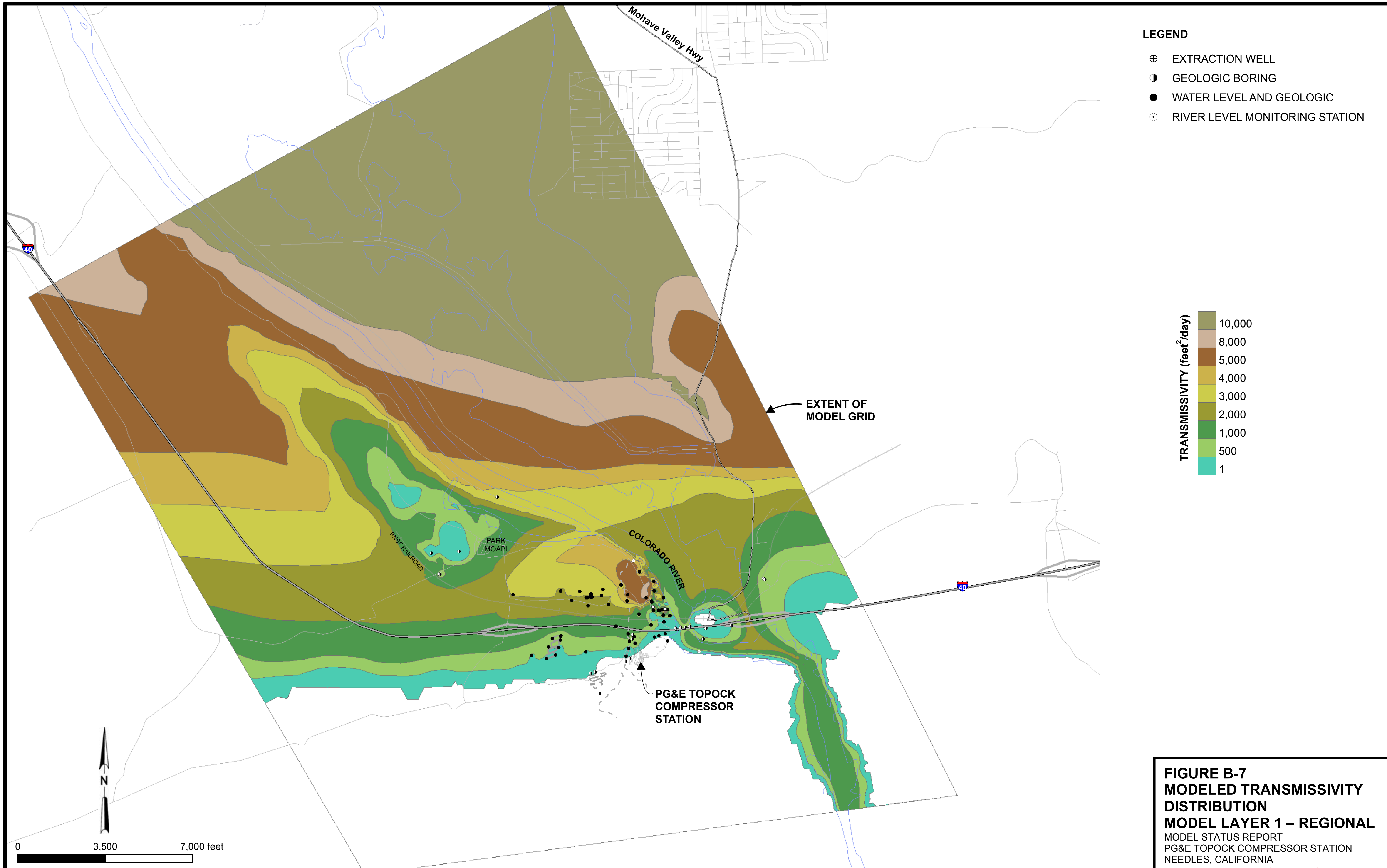

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 1 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

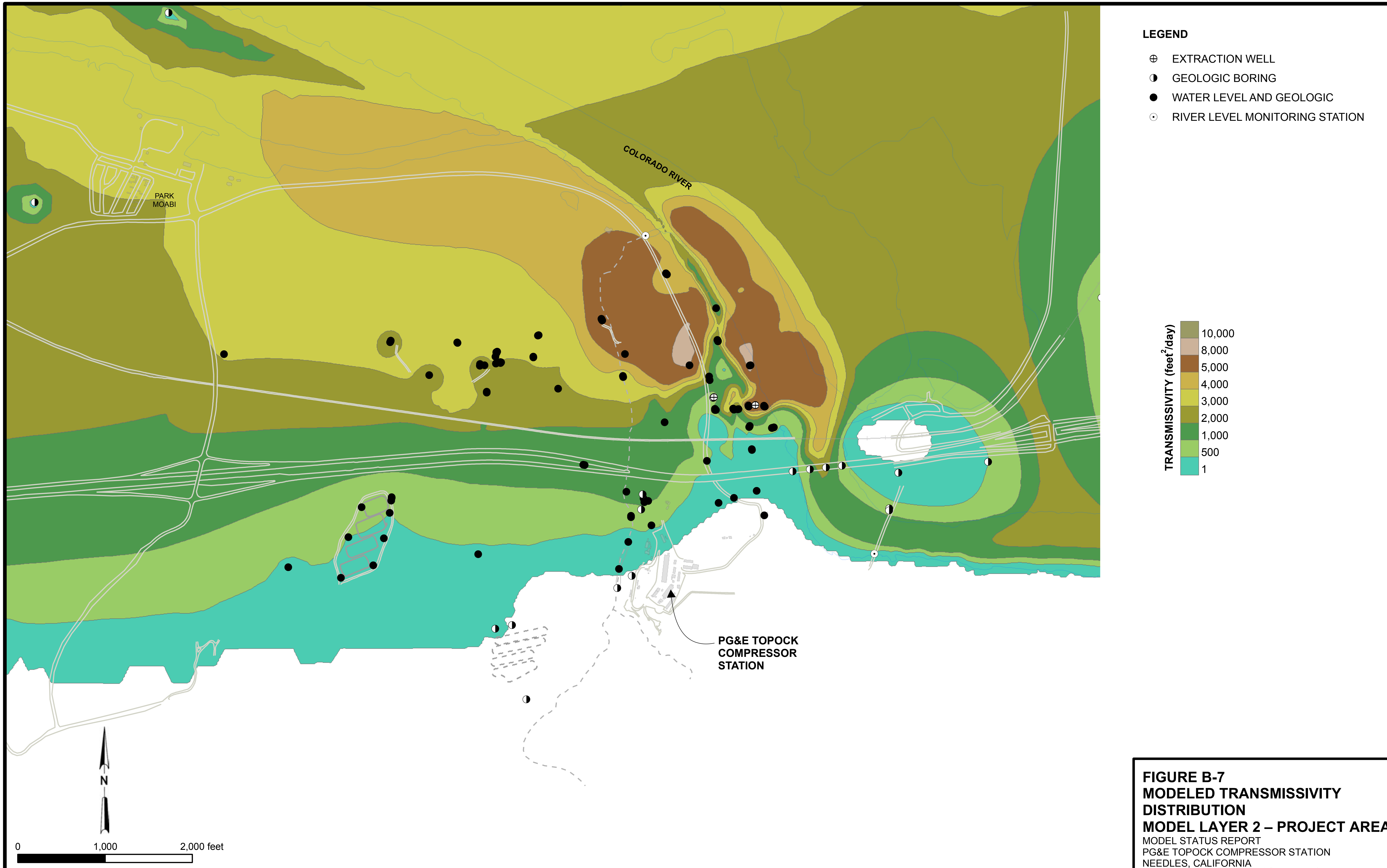

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 2 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBT_L2_L.MXD 0605TM_FIGB-07_T2_L.PDF 7/29/2005 18:22:28

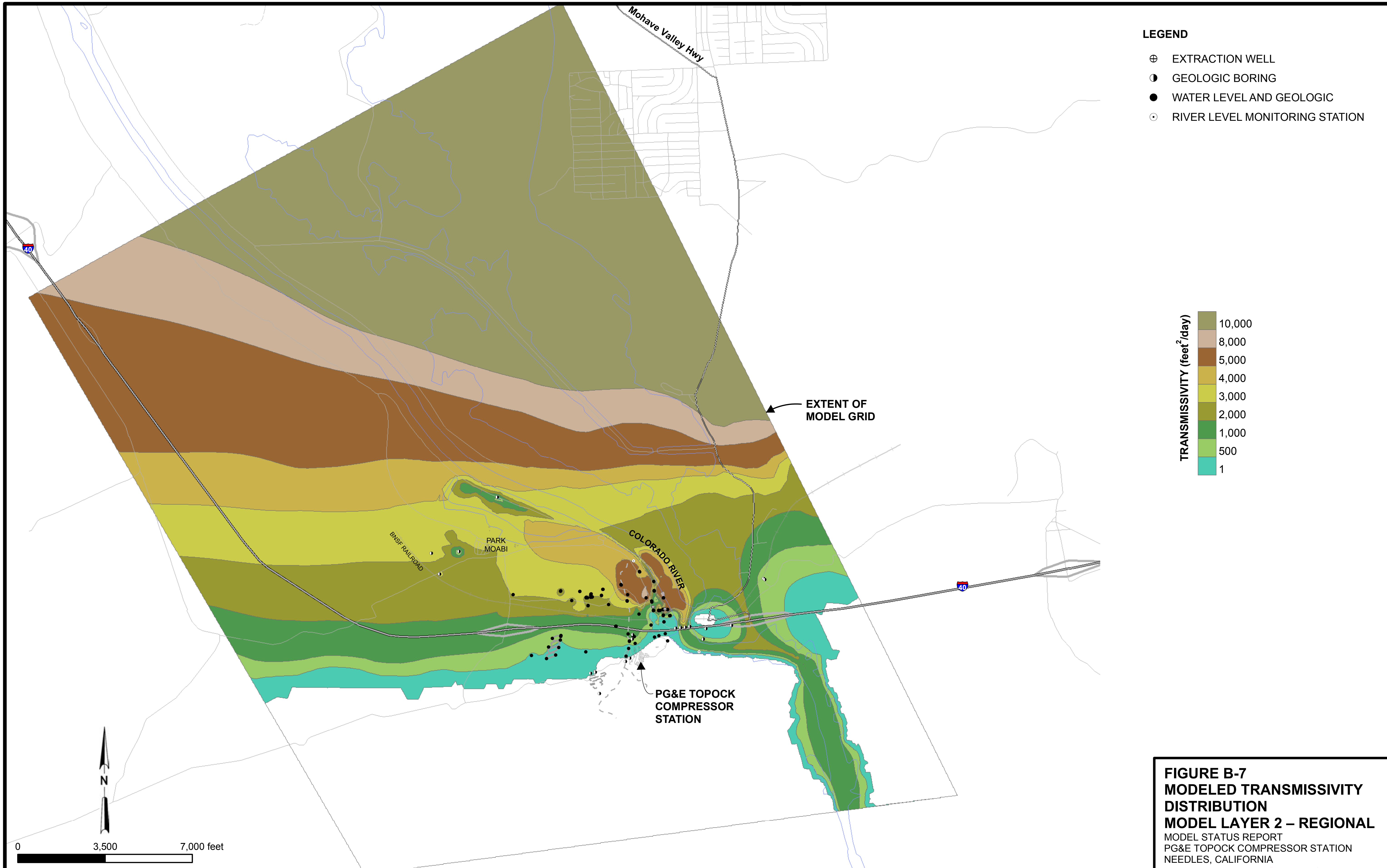

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 2 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBT_L2_R.MXD 0605TM_FIGB-07_T2_L.PDF 7/29/2005 18:39:33

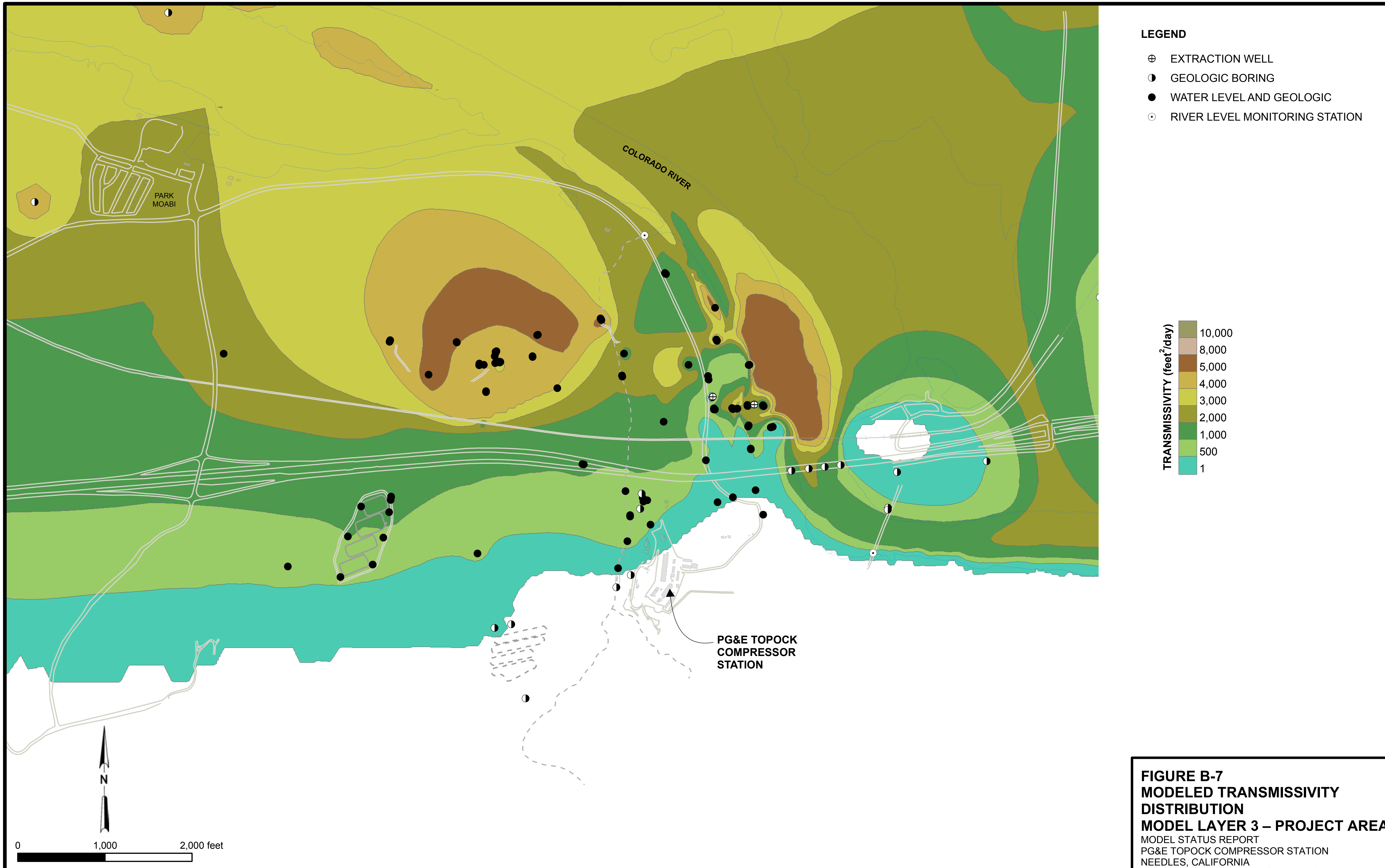

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 3 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBT_L3_L.MXD 0605TM_FIGB-07_T3_L.PDF 7/29/2005 18:23:27

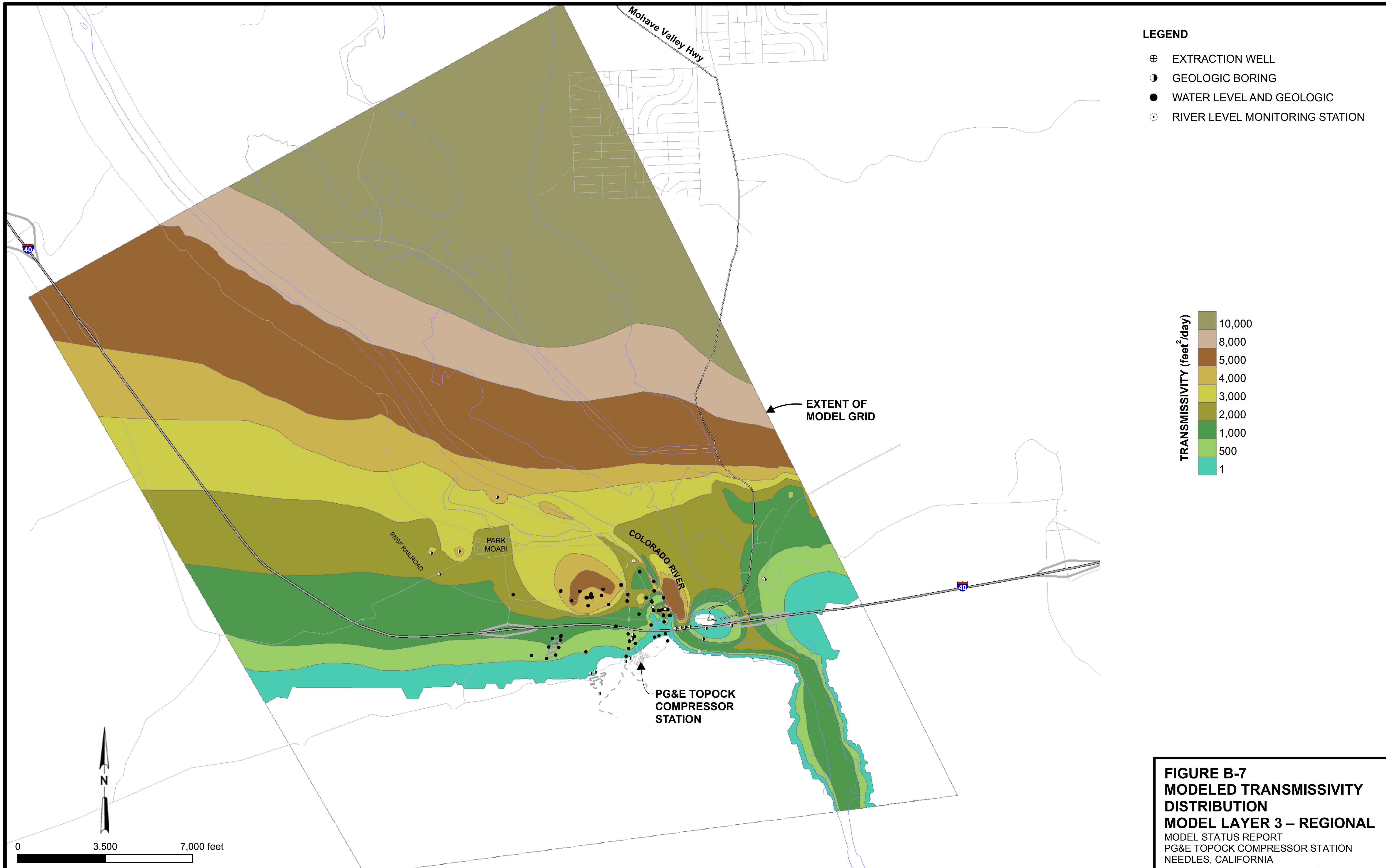

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 3 – REGIONAL

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

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBT_L3_R.MXD 0605TM_FIGB-07_T3_L.PDF 7/29/2005 15:25:37

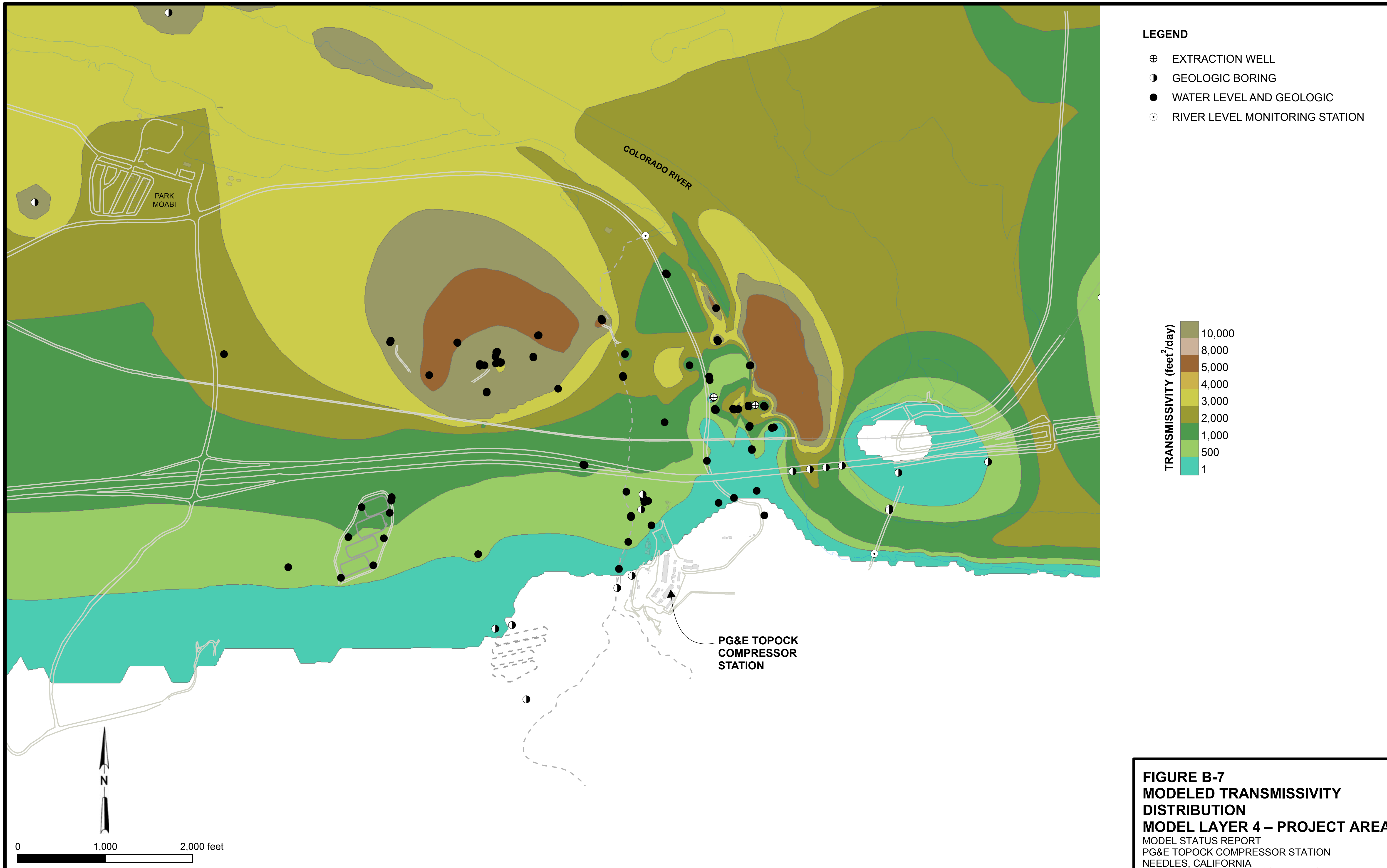

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 4 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBT_L4_L.MXD 0605TM_FIGB-07_T4_L.PDF 7/29/2005 18:24:13

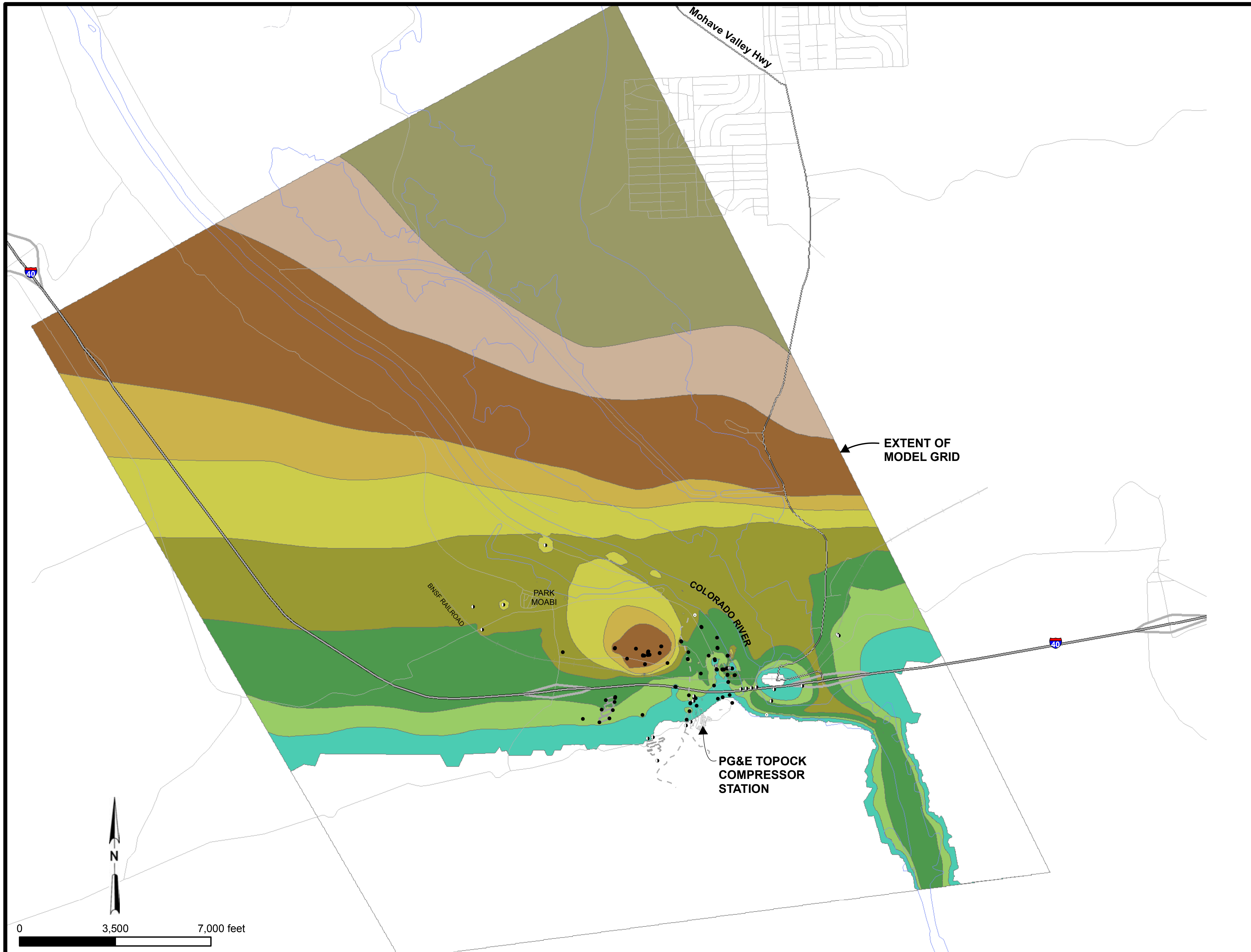

FIGURE B-7
MODELED TRANSMISSIVITY DISTRIBUTION
MODEL LAYER 4 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBT_L4_R.MXD 0605TM_FIGB-07_T4_L.PDF 7/29/2005 18:40:28

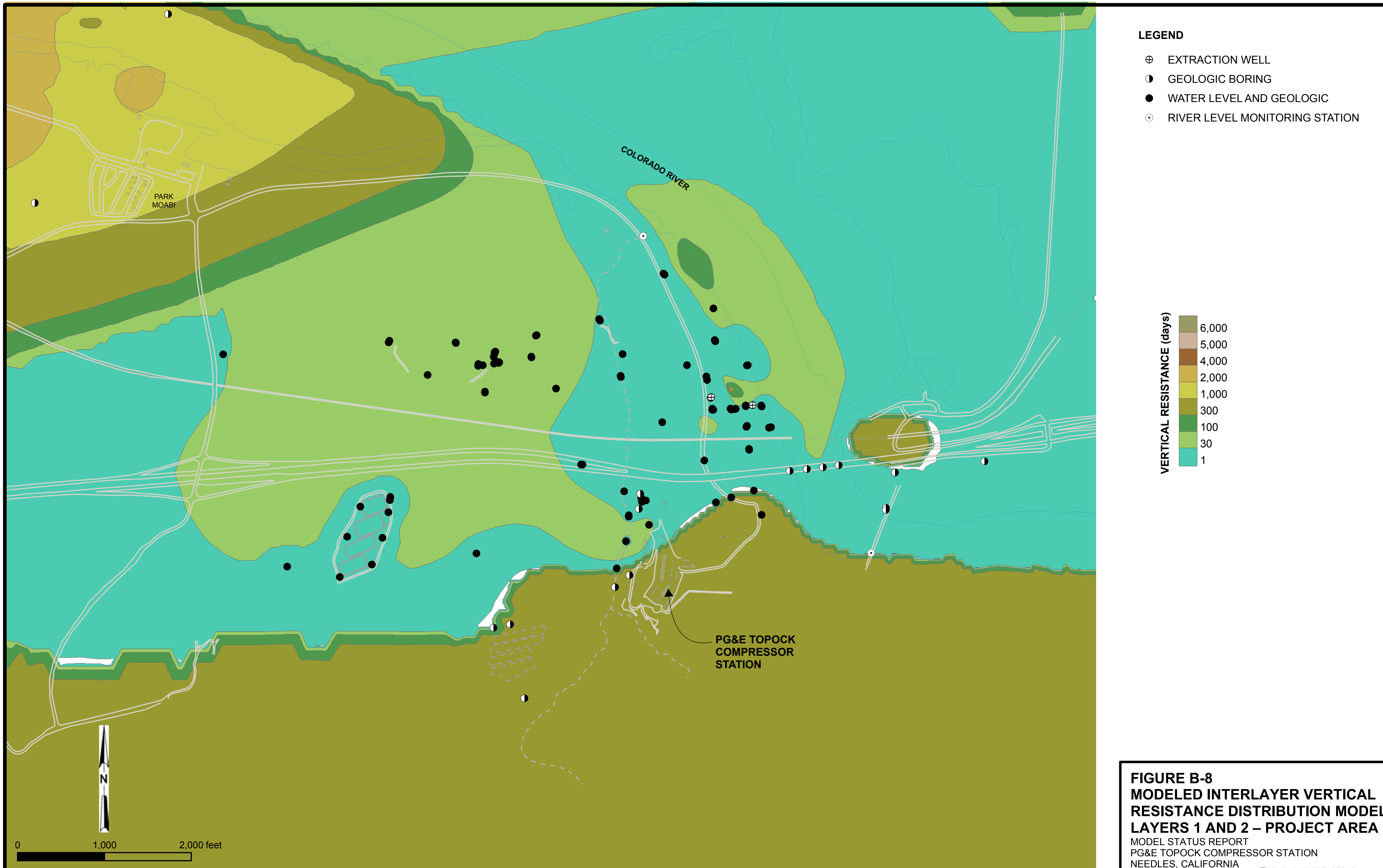

FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 1 AND 2 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBVR_L1-2_L.MXD 0605TM_FIGB-08_VR1_2_L.PDF 7/25/2005 14:03:54

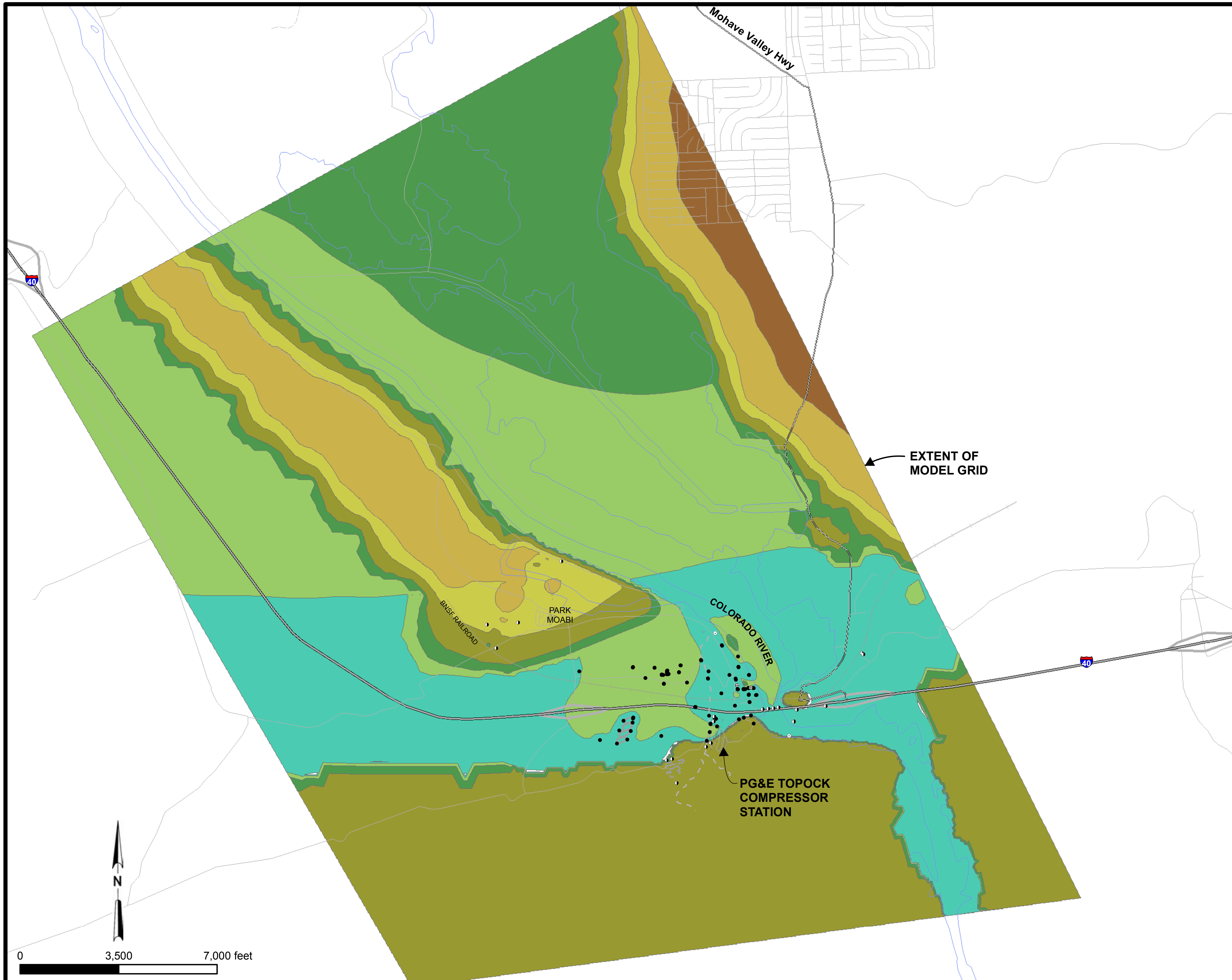

FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 1 AND 2 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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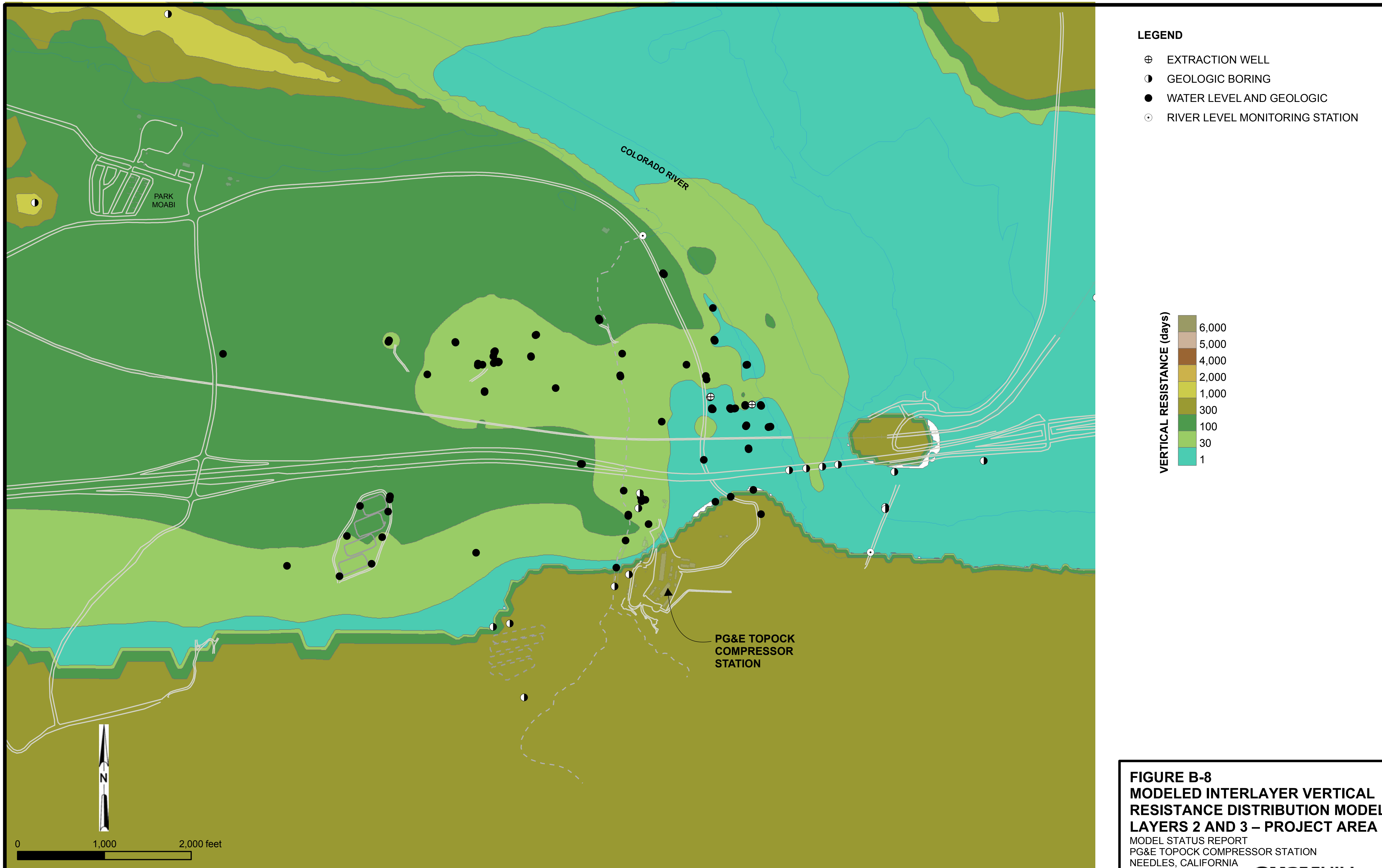

FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 2 AND 3 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 2 AND 3 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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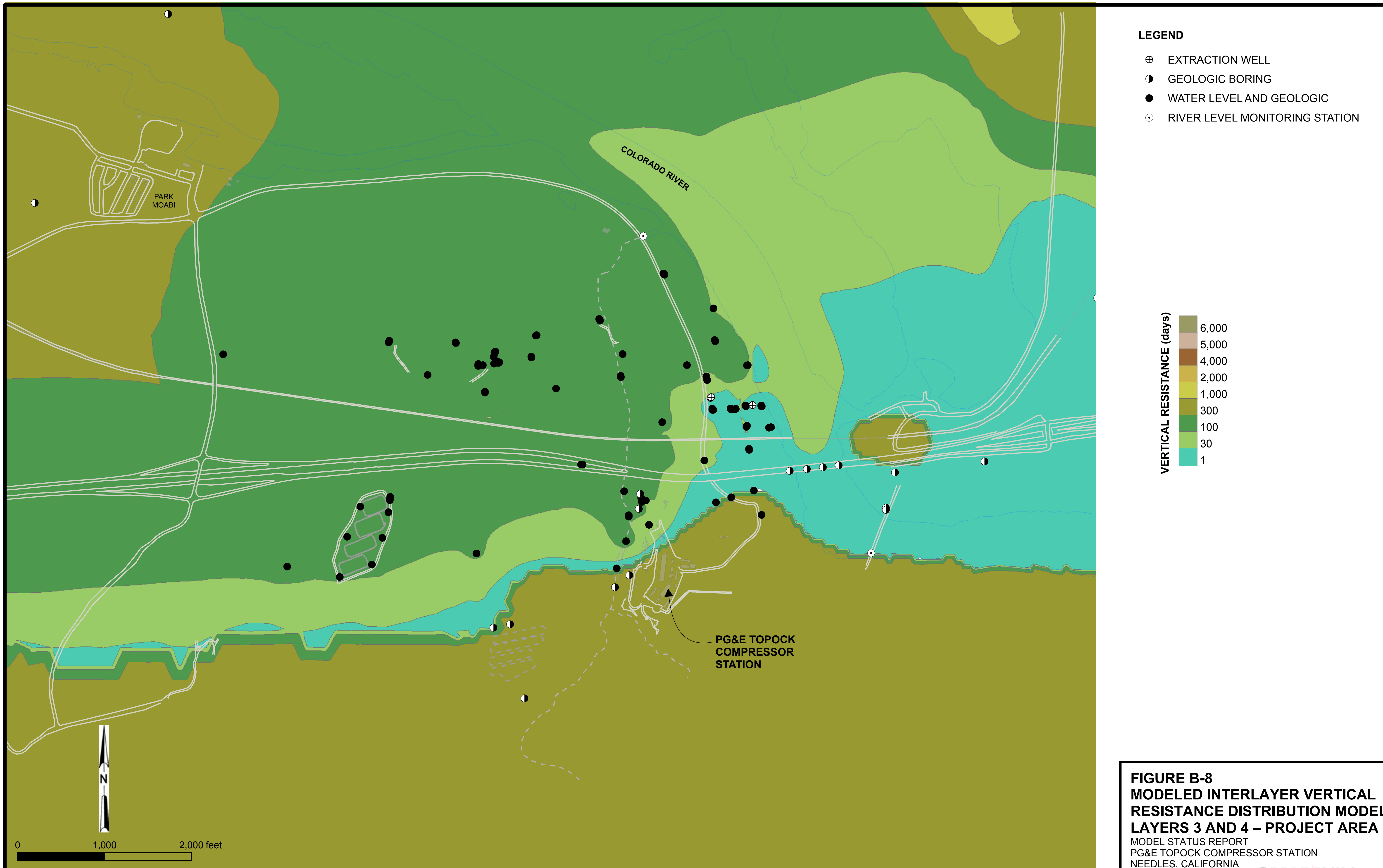

FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 3 AND 4 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 3 AND 4 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 4 AND 5 – PROJECT AREA
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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RDD \\ODIN\PROJ\TOPOCK\FIGURES\MXD\0605TM_APPBVR_L1-2_L.MXD 0605TM_FIGB-08_VR1_2_L.PDF 7/25/2005 14:03:54

FIGURE B-8
MODELED INTERLAYER VERTICAL RESISTANCE DISTRIBUTION MODEL LAYERS 4 AND 5 – REGIONAL
MODEL STATUS REPORT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

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