APPENDIX 6.5-2

GROUNDWATER BASIN DESCRIPTION AVENAL ENERGY

APPENDIX 6.5-2

GROUNDWATER BASIN DESCRIPTION
AVENAL ENERGY

This appendix describes existing groundwater conditions in the region and vicinity of the Avenal Energy Site (Site). The primary source of water for the Avenal Energy Project (Project) will be supplied by the City of Avenal.

Under limited circumstances, the Project will utilize existing nearby agricultural wells as a back-up water supply, such as times of interrupted canal flow or events of elevated canal turbidity. Water pumped for the backup supply will be offset by conservation measures so that there will be no net increase in groundwater pumping. Achievements of groundwater conservation will be accomplished by crop rotation and by irrigation conservation measures. Reports of backup groundwater use and offsetting water conservation measures will be provided to the California Energy Commission (Commission) in the Project's Annual Report.

Because the Project will use City water as its primary water supply, and because the Project will not result in a net increase in groundwater pumping, the use of groundwater as a backup supply will have no impact on groundwater resources. This conclusion is independent of any given hydrogeologic conditions that may occur. The information in this appendix is not necessary for the determination of no impact on groundwater resources and is provided only to comprehensively address the Commission's information requirements for an Application for Certification, pursuant to California Code of Regulations, Title 20, Appendix B.

1.0 HYDROLOGIC SETTING

The Site is located near the southwest edge of the San Joaquin Valley, on a relatively featureless, gently sloping ground surface formed by coalesced alluvial fans comprised of sediments eroded from the Coast Ranges to the west. The climate is dry, and the area has no natural surface water except immediately following larger than average rainstorms. The mean annual rainfall in the Site region is between 6 and 7 inches (Williamson, et al., 1989), and the average annual pan evaporation is approximately 65 inches (Kohler, et al., 1959). Most of the surface waters that occur in the San Joaquin Valley result from the drainage of large watersheds in the Sierra Nevada

Range that bounds the east side of the valley. Surface flows from the Sierra Nevada Range provide the primary source of groundwater recharge to the San Joaquin Valley. The Coast Ranges that bound the west side of the valley have considerably lower elevations and smaller watershed areas than the Sierra Nevada Range and, consequently, provide little recharge to the valley compared to the Sierra Nevada Range.

2.0 SAN JOAQUIN VALLEY GROUNDWATER

2.1 SAN JOAQUIN VALLEY BASIN

The San Joaquin Valley is the largest groundwater basin in California. The watershed area of the valley encompasses more than 35,000 square miles, and groundwater is stored in the sedimentary basin of the valley floor, which encompasses approximately 13,500 square miles (see Figure 1). Within this area, groundwater is stored in and transmitted through the interstitial spaces between grains of the sedimentary deposits that have accumulated in the bottom of the valley over geologic time. The maximum thickness of fresh water-bearing deposits is estimated at approximately 4,400 feet. The storage capacity between the surface and a depth of 1,000 feet is estimated at more than 570 million acre-feet. Aquifers in the basin are prolific water producers, with well yields up to 3,200 gallons per minute (gpm) and averaging 1,100 gpm (DWR, 1994).

In this Application for Certification, Section 6.3 - Geologic Hazards and Resources provides a description of geologic conditions and the sequence of marine and continental deposits that occur beneath the ground surface in the Site region. The geologic materials that comprise the aquifer systems in the Site region are predominantly the Tulare Formation and overlying sediments (see Figure 2). These continental deposits have accumulated as alluvial fan, deltaic, flood plain, lake and marsh sediments, and consist predominantly of lenses of gravel, sand, silt and clay (Page, 1983). Fine-grained materials (i.e., silt, sandy silt, sandy clay and clay) constitute more than 50 percent of the aquifer systems in some areas, but most of the fine-grained lenses are not laterally extensive. A notable exception is the Corcoran Clay Member of the Tulare Formation. This clay layer encompasses an area of approximately 5,000 square miles and underlies most of the western side of the San Joaquin Valley. It ranges in thickness from zero near the margins of its occurrence to at least 160 feet, with an average thickness of 55 feet (Bertoldi, et al., 1991). In the past, investigators considered the Corcoran Clay to separate a semi-confined aquifer (upper water-bearing zone) above the clay from a confined aquifer (lower water-bearing zone) below the clay. More recently, investigators have considered the entire thickness of continental deposits as one aquifer system that has varying vertical confinement,

depending on the properties of the fine-grained lenses that occur throughout the system and on penetration by water well boreholes. The degree of confinement generally increases with depth and, below the upper few hundred feet, the aquifer is considered to be virtually confined everywhere (Bertoldi, et al., 1991; Williamson, et al., 1989). The extent of the Corcoran clay in the site vicinity is described in Section 2.2 of this appendix.

Prior to groundwater development in the San Joaquin Valley, groundwater generally moved from recharge areas at the edges of the valley toward the topographic low areas in the center of the valley. Most water was discharged as evapotranspiration in the center of the valley where the water table is shallow (Bertoldi, et al., 1991). A lesser amount of discharge occurred directly to Tulare Lake in the south end of the valley and to the San Joaquin River at the north end of the valley. Prior to construction of the existing system of canals and aqueducts, irrigation was almost entirely from thousands of large and deep irrigation wells, and conditions of groundwater overdraft, mostly from the deep regional confined aquifer, had prevailed since the 1930s (Ireland, et al., 1984). By the 1960s, water levels in the deep regional aquifer were drawn down as much as 400 feet below earlier levels in some areas (Bertoldi, et al., 1991). By the late 1980s and early 1990s, water levels had recovered to their approximate current levels. This water level recovery was the direct result of the valley-wide use of imported water.

Beneath the middle portion of the valley, a shallow, brackish, perched groundwater table occurs. The soil structure in this area includes dense clay layers of varying depth and thickness that restrict infiltration and cause unused irrigation water to collect above the clay layers. The quality of this water is poor, due to dissolution of salts from the Coast Ranges-derived alluvial soils and from evapoconcentration. The Coast Ranges-derived sediments on the west side of the valley naturally contain soluble salts and trace elements, including arsenic, boron, cadmium, copper, chromium, lead, mercury, molybdenum, selenium and zinc. When the soils are irrigated, these substances dissolve in water that percolates downward from the agricultural fields. The dissolved constituents then enter the shallow perched groundwater system. Dissolved constituent concentrations (total dissolved solids) of more than 44,000 milligrams per liter (mg/L) have been measured (Beard, et. al., 1994).

Figure 3 provides April 2001 depth contours for the shallow brackish water. As shown, groundwater occurs within 5 feet of the surface over approximately 134,000 acres of the Westlands Water District, and within 20 feet of the surface over approximately 340,000 acres of the district. The original authorization for the Westlands Water District included provisions for drainage facilities that would have removed the brackish water, but these facilities were never

completed. The salt buildup is currently managed primarily through irrigation management. In addition, land retirement and export of salt are planned to mitigate salt buildup problems in some areas of the district (Westlands Water District, 1999).

The quality of deeper groundwater (semi-confined and confined) in the valley generally has not been impacted by agricultural activity. Substantial variations in the quality of deeper groundwater occur regionally, reflecting differences in recharge sources and the geochemistry of aquifer materials. The water quality in the deeper groundwater is poorest along the west side of the valley, where dissolved constituent concentrations commonly exceed 1,500 mg/L (Bertoldi, et al., 1991). Project wells exhibit concentrations of 1,150 mg/L to 1,265 mg/L, however.

2.2 SITE REGION (WESTSIDE BASIN)

The previous section described groundwater resources of the San Joaquin Valley and provided the overall hydrogeologic setting for the following description of groundwater in the more immediate Site region. For purposes of managing groundwater data and data collections, the State Department of Water Resources (DWR) has divided the San Joaquin Valley into 15 separate basins (DWR, 1980). The Site is located in the Westside Basin, as shown in Figure 4. The Westside Basin consists mainly of lands within the Westlands Water District.

Based on Westlands Water District maps (Westlands Water District, 2001), the western edge of the Corcoran clay approximately coincides with the location of the San Luis Canal in the Site vicinity. Beneath the Site, there is regional aquifer with a piezometric surface approximately 250 feet below the ground surface. This aquifer zone extends eastward below the Corcoran Clay east of the Site; it is referred to as the Sub-Corcoran (Lower) Aquifer zone. This lower aquifer is a confined aquifer and piezometric surface contours for this aquifer zone are shown in Figures 5 and 6. Moving eastward from the San Luis Canal alignment in the Site vicinity, an upper, semiconfined regional aquifer begins to occur above the Corcoran Clay (Figures 7 and 8). East of the San Luis Canal in the Site vicinity, the piezometric surface in this upper aquifer is approximately 200 to 250 feet below the ground surface (Figure 8). The shallow perched brackish water table described in Section 2.1 of this appendix begins to occur a few miles to the east of the Site where the valley floor is at a lower elevation and irrigation water collects above shallow clay layers. Shallow perched water is not present beneath the Site.

Well yields in the Westside Basin range from 400 to more than 2,000 gpm and typically range between 800 and 1,500 gpm. Water is produced from wells as deep as 3,000 feet, with typical depths ranging between 600 and 1,200 feet. Pump lifts are typically between 200 and 800 feet.

2.3 SITE AREA GROUNDWATER

Depth to groundwater beneath the Site is on the order of 250 feet. The backup water supply will use water supply Wells 18-1, 18-4 and 24-5 (Figure 9). Characteristics of these wells are summarized in Table 1. The quality of groundwater from these wells is shown in Table 2. The existing wells are used for agricultural water for Kochergen Farms, the owner and operator of agricultural operations on the Site and contiguous lands. Under existing conditions, these wells are routinely pumped, as needed, to irrigate orchards and row crops that occur on the Site and surrounding lands.

Whenever the Project uses the backup groundwater supply, farm practices will be altered such that an equivalent amount of reduction in agricultural pumping will occur. Reductions in agricultural groundwater pumping to offset use of backup groundwater for plant operations will be achieved through crop changes, increased irrigation management or other measures that will offset the Project groundwater pumping in its entirety (Kochergen, 2001). Table 3 provides examples of measures that could be used to offset the Project backup groundwater pumping.

3.0 SUBSIDENCE AND PAST GROUNDWATER LEVELS

Large amounts of land subsidence (up to 29 feet at one location) occurred in the San Joaquin Valley in decades prior to the 1970s. The primary process responsible for subsidence in the Project region is compaction of the fine-grained clayey lenses in the aquifer system, which is caused by lowering of the hydraulic head, mostly in the lower (confined) aquifer (Williamson, et al., 1989). This compaction is slow and largely inelastic (i.e., not recoverable). If pumping slows or ceases, the compaction also will slow or cease, although with a delayed response. If pumping resumes, additional compaction will not occur until the head declines below the level of previous pumping periods (Bertoldi, et al., 1991).

In the Project area, water levels in the confined aquifer reached historic lows in the late 1960s and early 1970s, when the piezometric surface elevation of the deep aquifer was approximately 125 feet below sea level in the Site vicinity (Ireland, et al., 1984). The piezometric surface has

recovered since that time and is now approximately 50 feet above sea level (Figure 5) in the Site vicinity. The approximate 175 feet of recovery that has occurred in the area has stabilized the primary compaction mechanism.

4.0 REFERENCES

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TABLE 1

SUMMARY OF EXISTING SITE WELLS

WELL PARAMETER	WELL IDENTIFICATION		
	18-1	18-4	24-5
Depth	1,176 feet	1,140 feet	1,140 feet
Diameter	16 inches	16 inches	16 inches
Depth of Pump	510 feet	560 feet	600 feet
Production Capacity	1,275 gpm	2,320 gpm	1,100 gpm

TABLE 2

GROUNDWATER QUALITY

WELL COMPONENTS		18-1	18-4	24-5
		ppm_w as Ion	ppm_w as Ion	ppm_w as Ion
Cations				
Calcium	Ca^{++}	84.8-88	93.2-100	87.5-90
Magnesium	Mg^{++}	38.30	44.60	26.80
Sodium	Na^{+}	120.00	120.00	170.00
Potassium	K^{+}	3.70	0.90	1.90
Ammonia	NH_4^{+}	< 0.68	<0.68	<0.68
Barium	Ba^{++}	0.40	0.06	0.02
Anions				
Bicarbonate	HCO_3^{-}	106.56	101.93	73.89
Chloride	Cl^{-}	43.20	54.50	73.50
Sulfate	SO_4^{--}	410-763	460-700	420-620
Nitrate	NO_3^{-}	12.30	16.80	32.80
Fluoride	F^{-}	0.20	0.20	0.10
Phosphate (as ortho-PO_4)	PO_4^{---}	< 0.1	<0.01	<0.1
Total Phosphorous (Valance 3)	P^{---}	0.5	0.16	0.22
Borate	$B_4O_7^{--}$	1.40	6.30	6.30
Bromide	Br^{-}	0.10	0.3	0.50
Heavy Metals				
Aluminum	Al^{+++}	< 0.03	0.15	<0.03
Arsenic	As^{+++}	< 0.1	<0.01	<0.1
Boron	B^{+++}	0.40	0.50	0.50
Cadmium	Cd^{++}	0.006	<0.005	<0.005
Copper (Cupric)	Cu^{++}	ND	ND	ND
Chromium	Cr^{+++}	0.30	<0.015	<0.015
Iron (Ferrous)	Fe^{++}	ND	ND	ND
Iron (Ferric)	Fe^{+++}	ND	ND	ND
Iron Total	Fe^{++}	ND	ND	ND
Lead	Pb^{++}	ND	ND	ND
Lithium	Li^{+}	ND	ND	ND
Manganese (Manganous)	Mn^{++}	ND	ND	ND
Mercury	Hg^{++}	ND	ND	ND
Molybdenum	Mo^{++++++}	ND	ND	ND
Nickel	Ni^{++}	ND	ND	ND
Selenium	Se^{++++++}	ND	ND	ND
Silver	Ag^{+}	ND	ND	ND
Strontium	Sr^{++}	1.30	1.50	1.50
Thallium (Thallic)	Tl^{+++}	ND	ND	ND
Tin	Sn^{++}	ND	ND	ND
Titanium	Ti^{++}	ND	ND	ND
Vanadium	V++	ND	ND	ND
Zinc	Zn^{++}	< 0.1	<0.1	<0.1
Silica				
Dissolved Silica as SiO_2^{--}	ppm	13	13	13
Colloidal Silica as SiO_2^{--}	ppm	35	35	35

WELL COMPONENTS		18-1	18-4	24-5
		ppm_w as Ion	ppm_w as Ion	ppm_w as Ion
Water Characterization				
Specific Conductance	µ mhos/cm	1,150	1,245	1,265
Total Dissolved Solids (TDS)	ppm	920	992	954.0
Total Alkalinity as $CaCO_3$	ppm	87.4	83.6	60.6
Calcium Hardness as $CaCO_3$	ppm	210	210	240.0
Magnesium Hardness as $CaCO_3$	ppm	160	180	110.0
Carbon Dioxide CO_2	ppm	ND	ND	ND
pH	SU	8.0	7.9	7.9
Turbidity	NTU	2.0	1.15	1
Total Suspended Solids (TSS)	ppm	14	9	2.0
	ppm	ND	ND	ND
	APHA	10	10.0	10.0

ND = None detected.

(1) Wells 18-1, 18-4 and 24-5 sampled April 2001.

TABLE 3

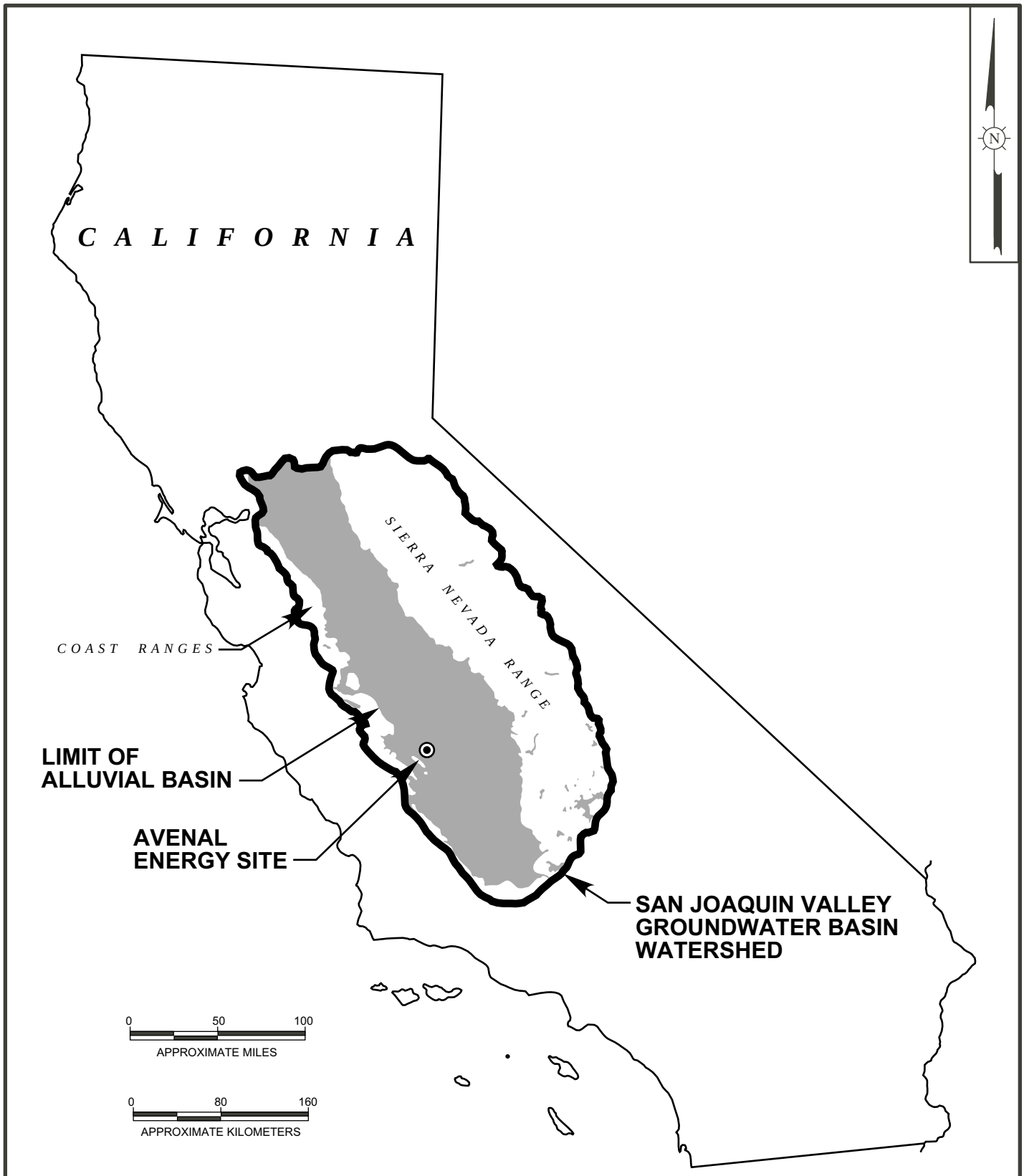
EXAMPLE WATER USE OFFSET MEASURES

CROP TYPE	TYPICAL WATER APPLICATION RATE (AF/A)	CONSERVATION MEASURE	CONSERVATION WATER USE (AF/A)	CONSERVATION WATER SAVINGS (AF/A)
Row Crop	3.0	Shift to Wheat or Barley	1.0	2.0
Almonds(1)	3.25	Drip or Fan Jet Irrigation	2.75	0.5
Row Crop	3.0	Subirrigation	2.0	1.0

AF/A = Acre feet per year per acre of land.

(1) This example measure has been implemented on some areas of Kochergen Farms to save water for Project needs.

125155-AFC-GW-FIG1.CNV REV. 11/21/07



SAN JOAQUIN VALLEY WATERSHED AND ALLUVIAL BASIN

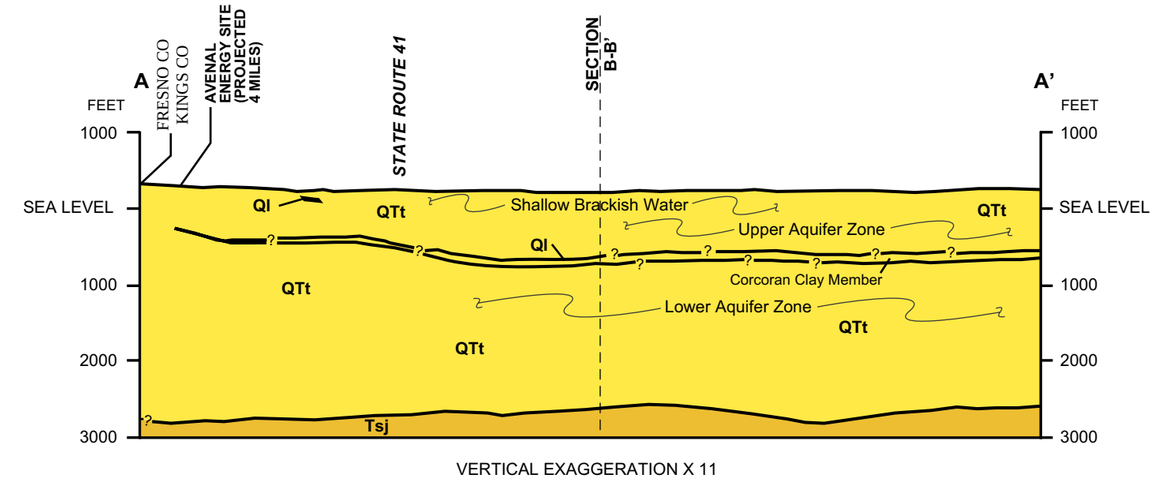
FEDERAL POWER AVENAL, LLC

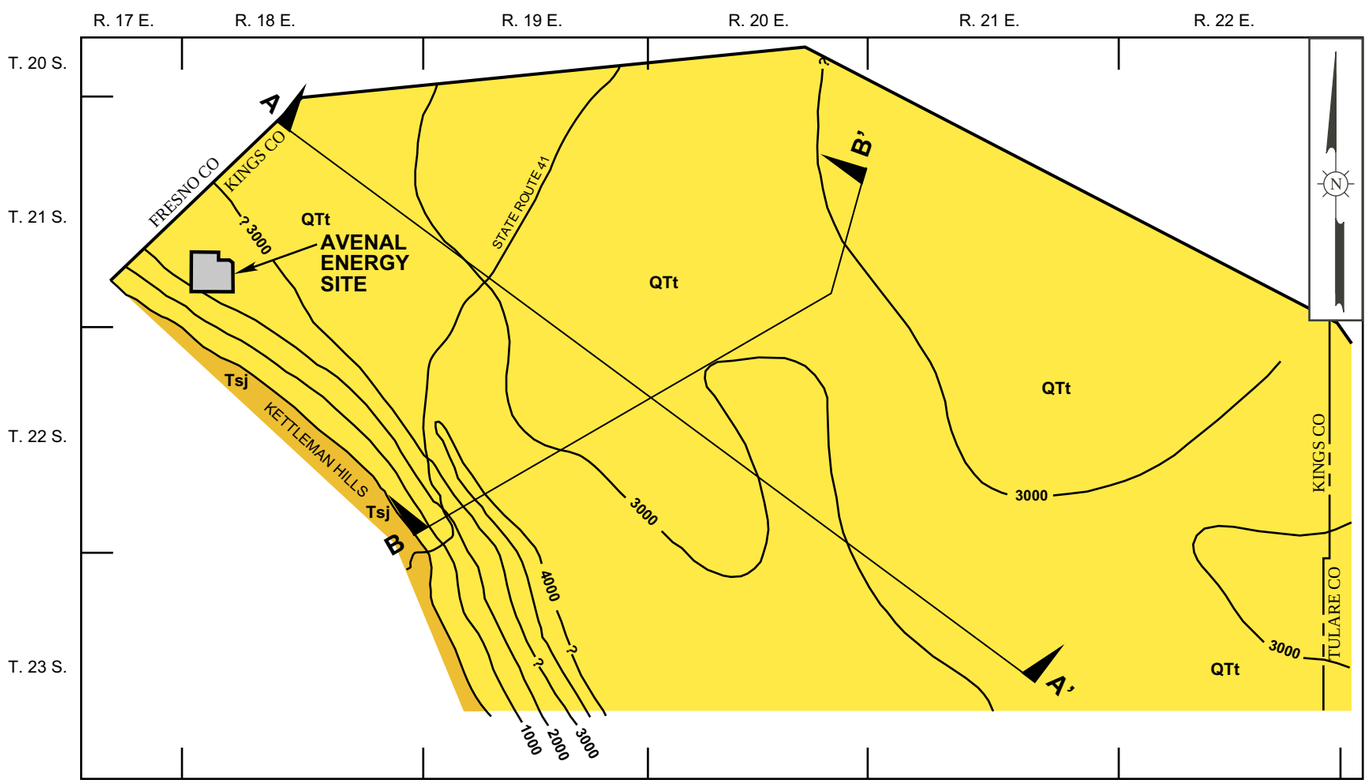
AVENAL ENERGY	**FIGURE 1**

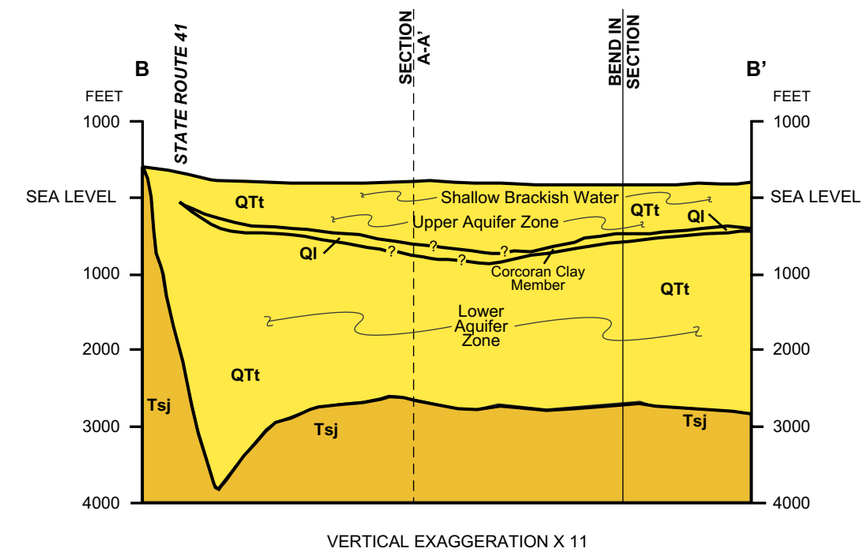
125155-AFC-GW-FIG2.CNV REV.11/21/07

LEGEND

- **QTt** — TULARE FORMATION AND OTHER CONTINENTAL DEPOSITS (HOLOCENE TO PLIOCENE)
- **Ql** — LACUSTRINE AND MARSH DEPOSITS (PLEISTOCENE AND HOLOCENE)
- **Tsj** — SAN JOAQUIN FORMATION (PLIOCENE)
- **A A'** — LINE OF GEOLOGIC SECTION
- **3000** — LINE OF EQUAL DEPTH AND THICKNESS OF TULARE FORMATION AND OTHER CONTINENTAL DEPOSITS
  Approximately located; queried where data are inconclusive.
  Datum is land surface.







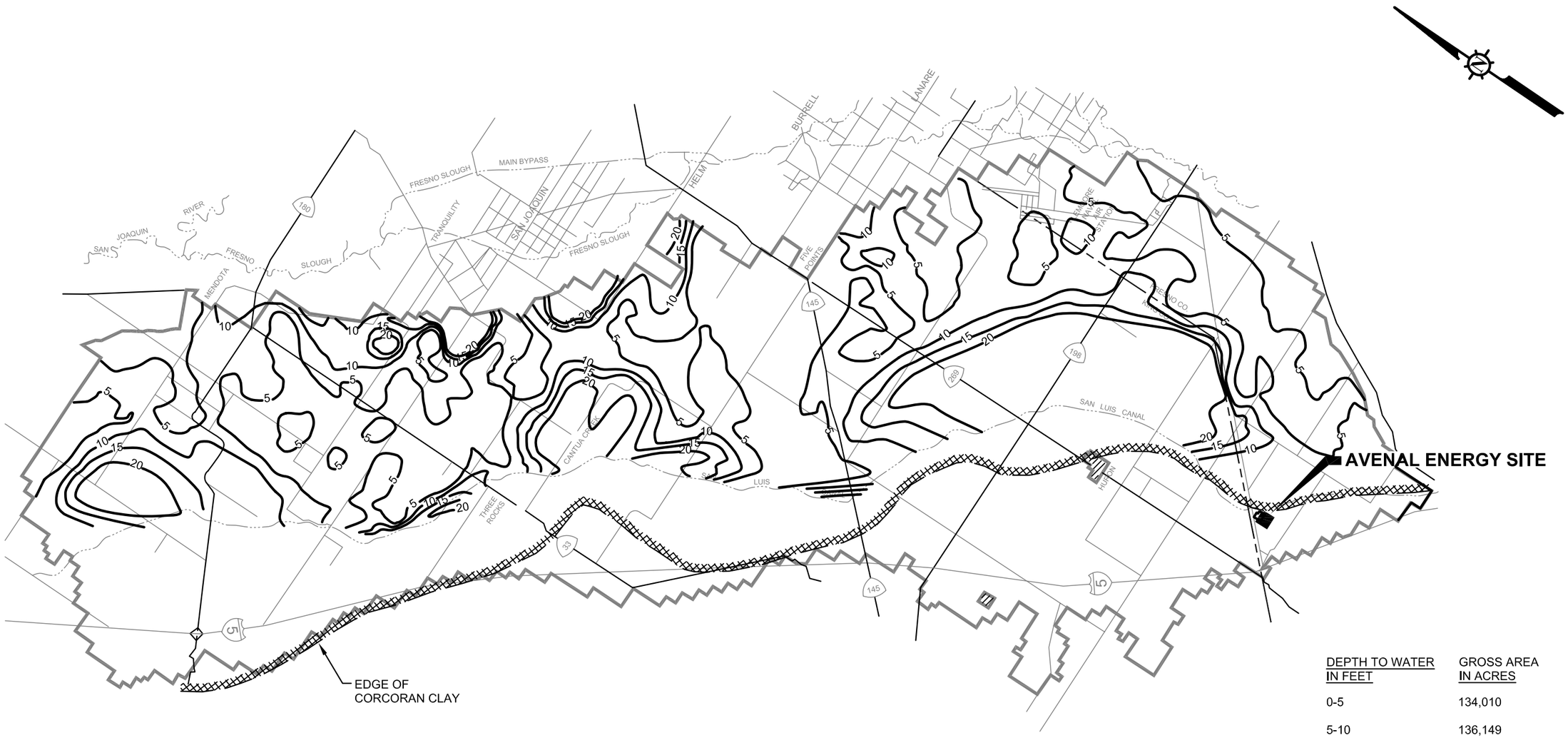
0 4 8 MILES
HORIZONTAL SCALE

REFERENCE: ADAPTED FROM PAGE, R.W., 1983.

REGIONAL AQUIFERS CROSS-SECTIONS

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 2**



DEPTH TO WATER IN FEET	GROSS AREA IN ACRES
0-5	134,010
5-10	136,149
10-20	67,075
0-20	337,234

LEGEND:

- LINES OF EQUAL DEPTH IN FEET TO SHALLOW GROUNDWATER- DASHED WHERE APPROXIMATELY LOCATED
- WESTLANDS WATER DISTRICT BOUNDARY
- INTERSTATE HIGHWAY
- INTERCHANGE
- EDGE OF CORCORAN CLAY
- STATE HIGHWAY
- PAVED ROAD
- WATERWAY
- COUNTY LINE
- NOT IN DISTRICT

0 5 10 MILES
SCALE

GENERALIZED DEPTH TO SHALLOW BRACKISH GROUNDWATER (APRIL 2001)

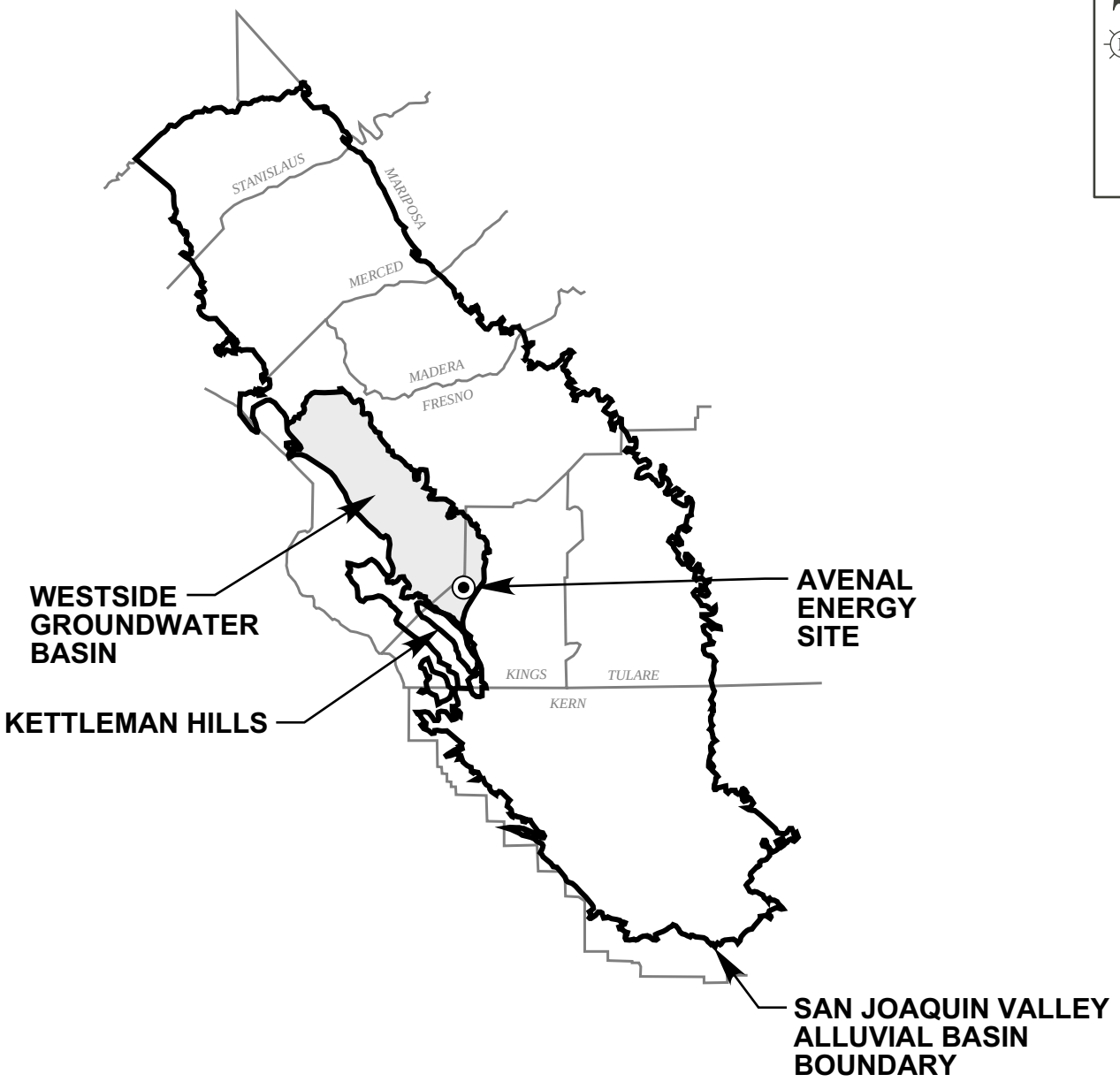
FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 3**

Reference: Westland Water District, July 2001.
<http://www.westlandswater.org/Maps/SGWMapSel.htm>

I:\DUKE\125155\Appendix 6.5-3\125155-AFC-GW-FIG3.dwg Nov 21, 2007 - 12:32pm rcollins

125155-AFC-GW-FIG4.CNV REV. 11/21/07



0 40 80 MILES

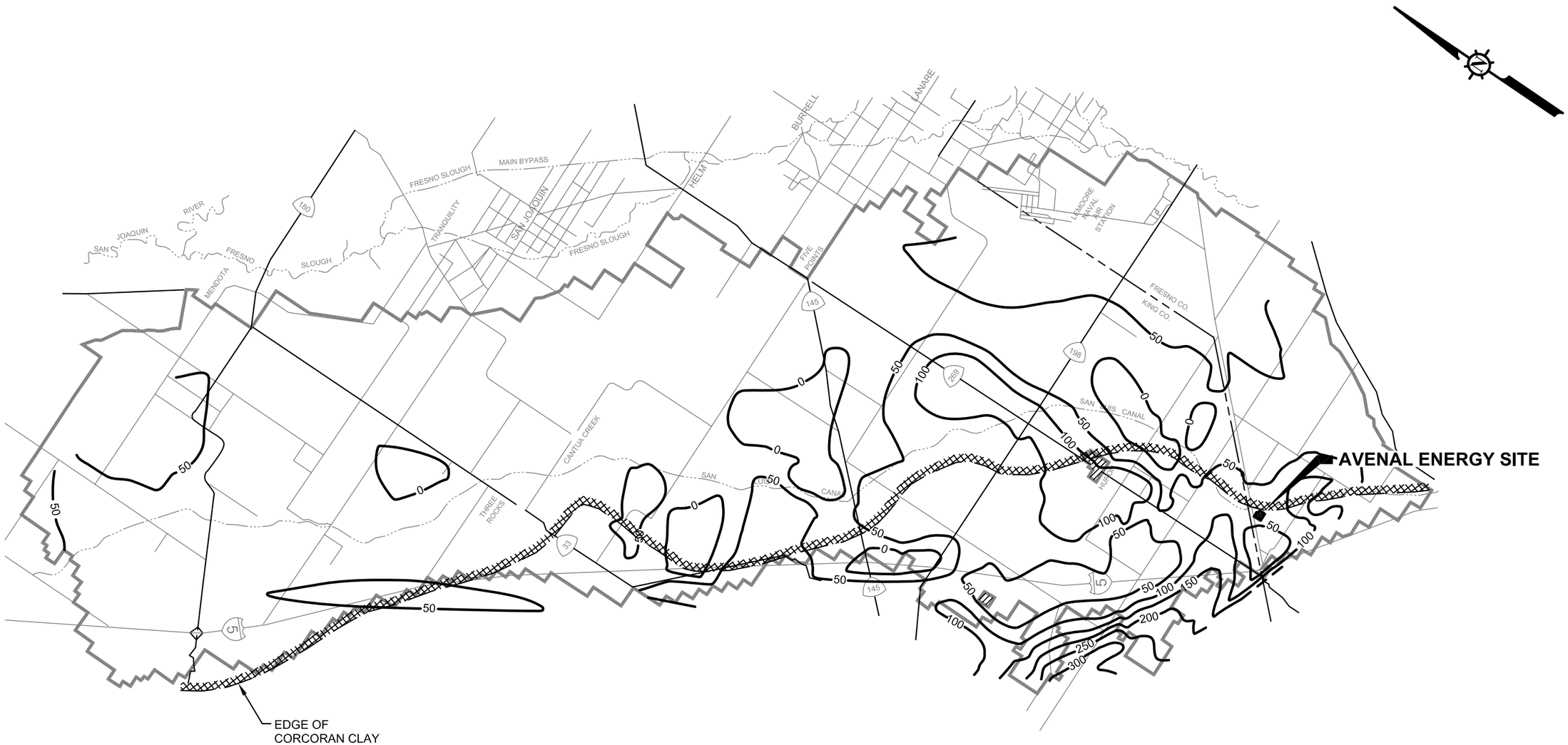
SCALE

REFERENCE:
DWR, 2001.
<http://wwwdpla.water.ca.gov/sjd/groundwater/basinmap.html> (1/23/01)

WESTSIDE GROUNDWATER BASIN

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 4**



0 5 10 MILES
SCALE

LEGEND:

- WESTLANDS WATER DISTRICT BOUNDARY
- INTERSTATE HIGHWAY
- INTERCHANGE
- EDGE OF CORCORAN CLAY
- STATE HIGHWAY
- PAVED ROAD
- WATERWAY
- COUNTY LINE
- NOT IN DISTRICT

Reference: Westland Water District, July 2001.
<http://www.westlandswater.org/Maps/SGWMapSel.htm>

GENERALIZED ELEVATION OF SUB-CORCORAN (LOWER AQUIFER ZONE) PIEZOMETRIC GROUNDWATER SURFACE (DECEMBER 2000)

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 5**

I:\DUKE\125155\Appendix 6.5-3\125155-AFC-GW-FIG5.dwg Nov 21, 2007 - 12:33pm rcollins

0 5 10 MILES
SCALE

LEGEND:

- WESTLANDS WATER DISTRICT BOUNDARY
- INTERSTATE HIGHWAY
- INTERCHANGE
- EDGE OF CORCORAN CLAY
- STATE HIGHWAY
- PAVED ROAD
- WATERWAY
- COUNTY LINE
- NOT IN DISTRICT

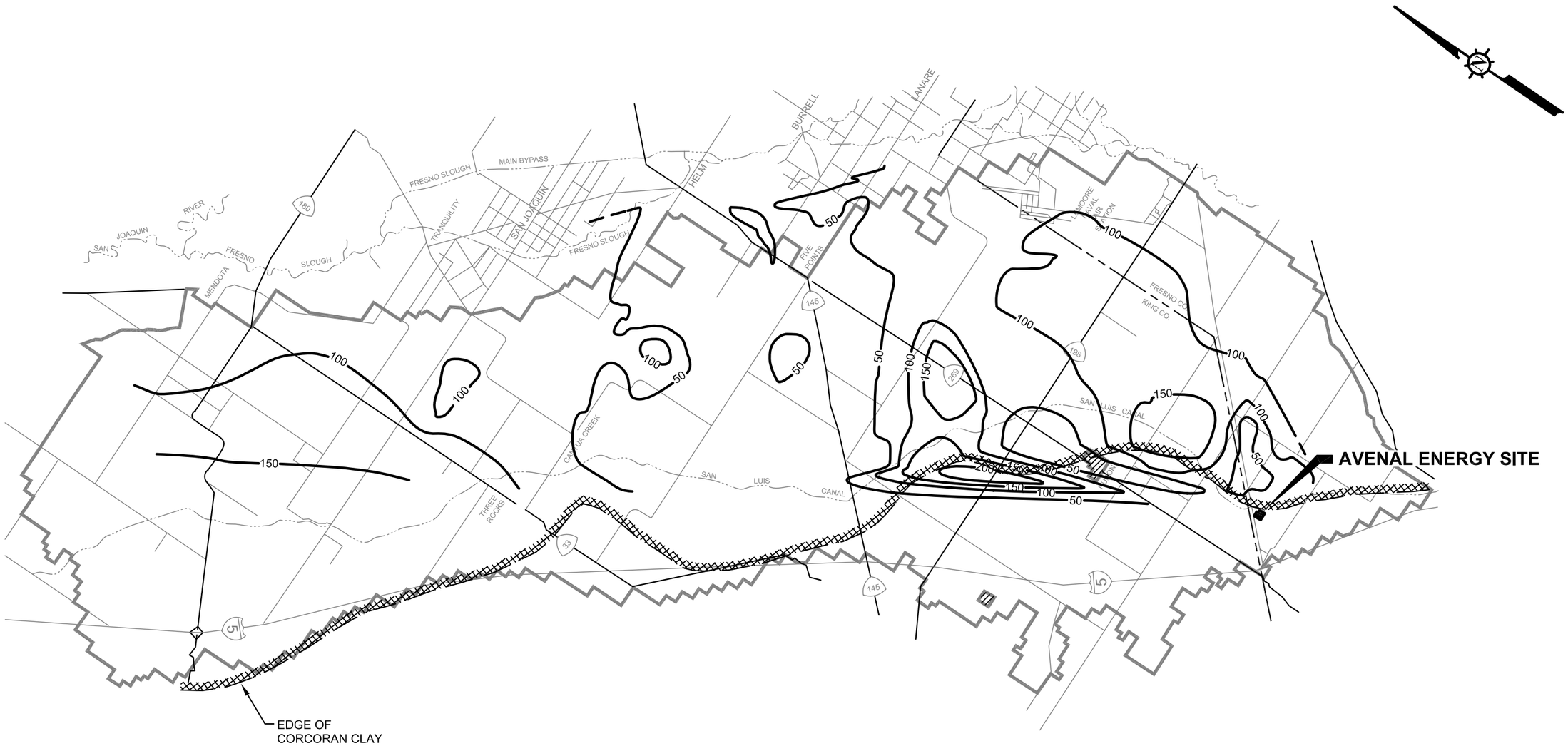
Reference: Westland Water District, July 2001.
<http://www.westlandswater.org/Maps/SGWMapSel.htm>

GENERALIZED DEPTH TO SUB-CORCORAN (LOWER AQUIFER ZONE) PIEZOMETRIC GROUNDWATER SURFACE (DECEMBER 2000)

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 6**

I:\DUKE\125155\Appendix 6.5-3\125155-AFC-GW-FIG6.dwg Nov 21, 2007 - 12:34pm rcollins



0 5 10 MILES
SCALE

LEGEND:

- WESTLANDS WATER DISTRICT BOUNDARY
- INTERSTATE HIGHWAY
- INTERCHANGE
- EDGE OF CORCORAN CLAY
- STATE HIGHWAY
- PAVED ROAD
- WATERWAY
- COUNTY LINE
- NOT IN DISTRICT

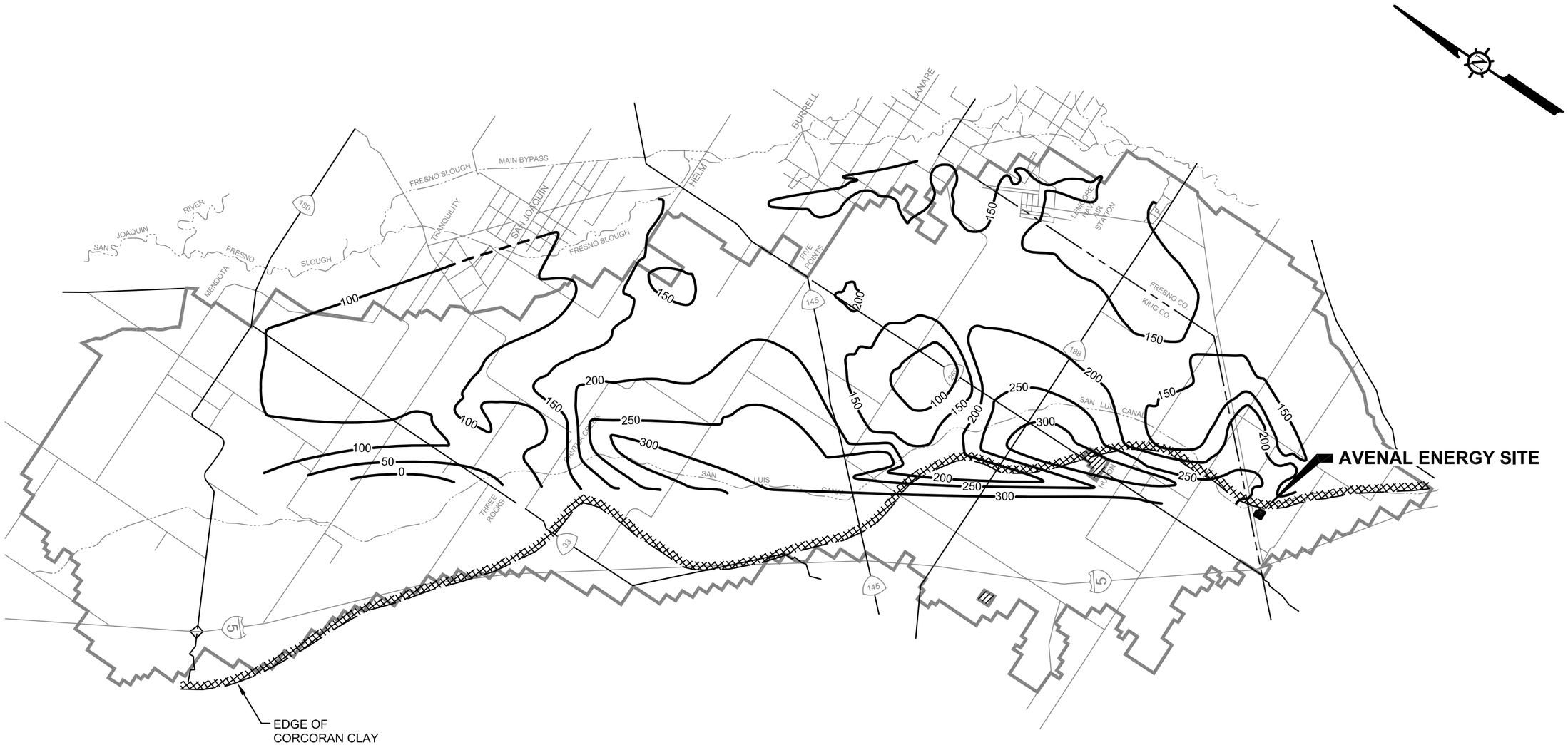
GENERALIZED ELEVATION OF GROUNDWATER IN THE UPPER AQUIFER ZONE (DECEMBER 2000)

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 7**

Reference: Westland Water District, July 2001.
<http://www.westlandswater.org/Maps/SGWMapSel.htm>

I:\DUKE\125155\Appendix 6.5-3\125155-AFC-GW-FIG7.dwg Nov 21, 2007 - 12:35pm rcollins



0 5 10 MILES
SCALE

LEGEND:

- WESTLANDS WATER DISTRICT BOUNDARY
- INTERSTATE HIGHWAY
- INTERCHANGE
- EDGE OF CORCORAN CLAY
- STATE HIGHWAY
- PAVED ROAD
- WATERWAY
- COUNTY LINE
- NOT IN DISTRICT

Reference: Westland Water District, July 2001.
<http://www.westlandswater.org/Maps/SGWMapSel.htm>

GENERALIZED DEPTH TO GROUNDWATER IN THE UPPER AQUIFER ZONE (DECEMBER 2000)

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 8**

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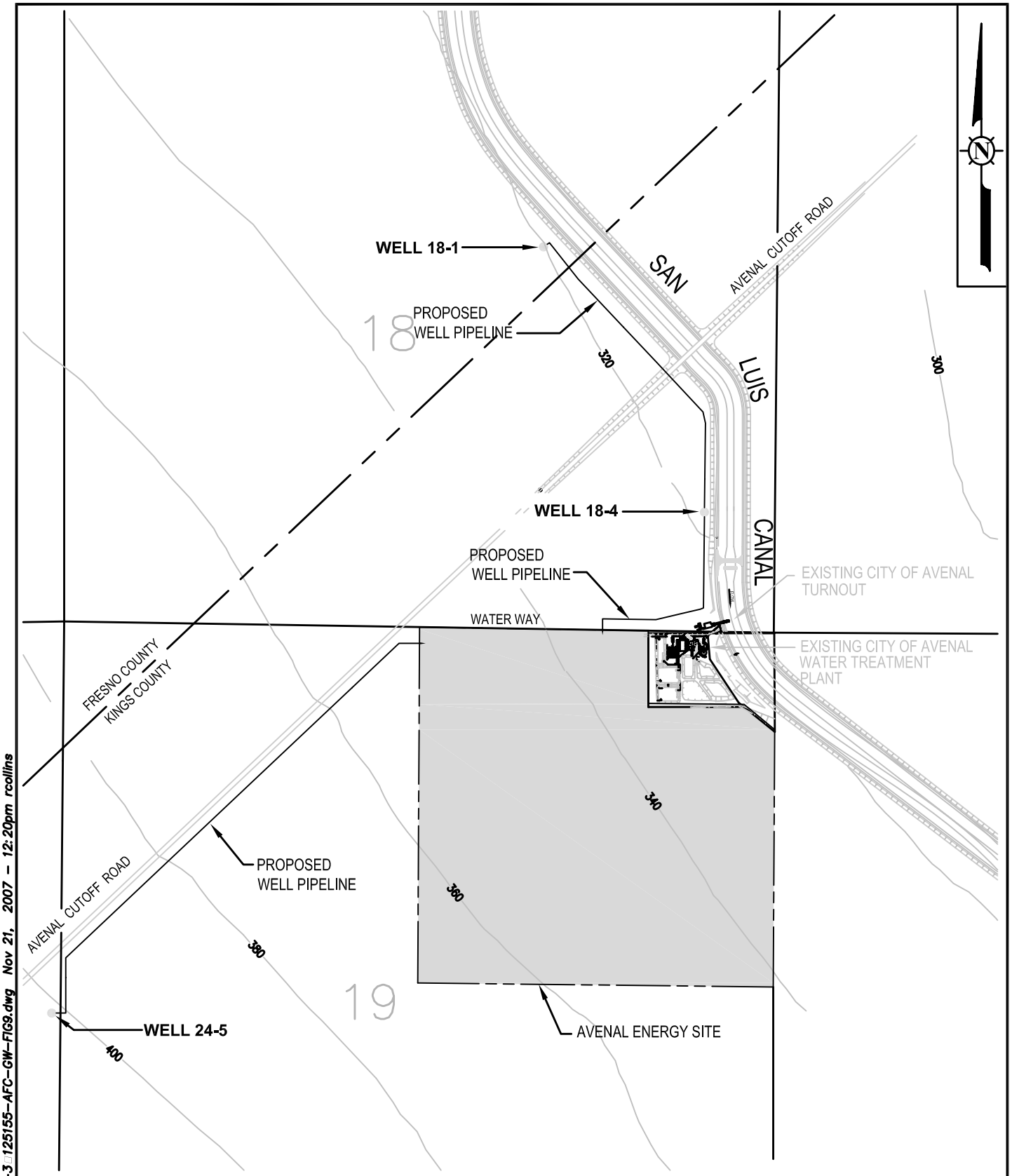

REFERENCE: SUMMERS ENGINEERING, INC., LOCATION MAP, WATER SUPPLY AND TREATMENT FACILITIES WITH OPTION B, PRELIMINARY, MARCH 7, 2001.

0 1,000 2,000 FEET
SCALE

BACKUP WATER SUPPLY WELLS

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 9**

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