3.0 ENVIRONMENTAL SETTING

The environmental setting is the unique combination of natural factors that can be used describe a given region. The major environmental setting factors that could potentially impact groundwater in the region of the WPCF are presented in the following sections:

3.1 Topography

3.2 Precipitation

3.3 Surface Water Resources

3.4 Soils

3.5 Geology

3.6 Groundwater Elevations and Flow

3.7 Summary Recommendations

3.1 TOPOGRAPHY

The topography in the vicinity of the WPCF has a gentle slope to the southwest. Land surface elevations range from 0 feet mean sea level (msl) near the western edge of the agricultural reuse areas to approximately 10 feet msl at the most eastern edge of the agricultural reuse area.

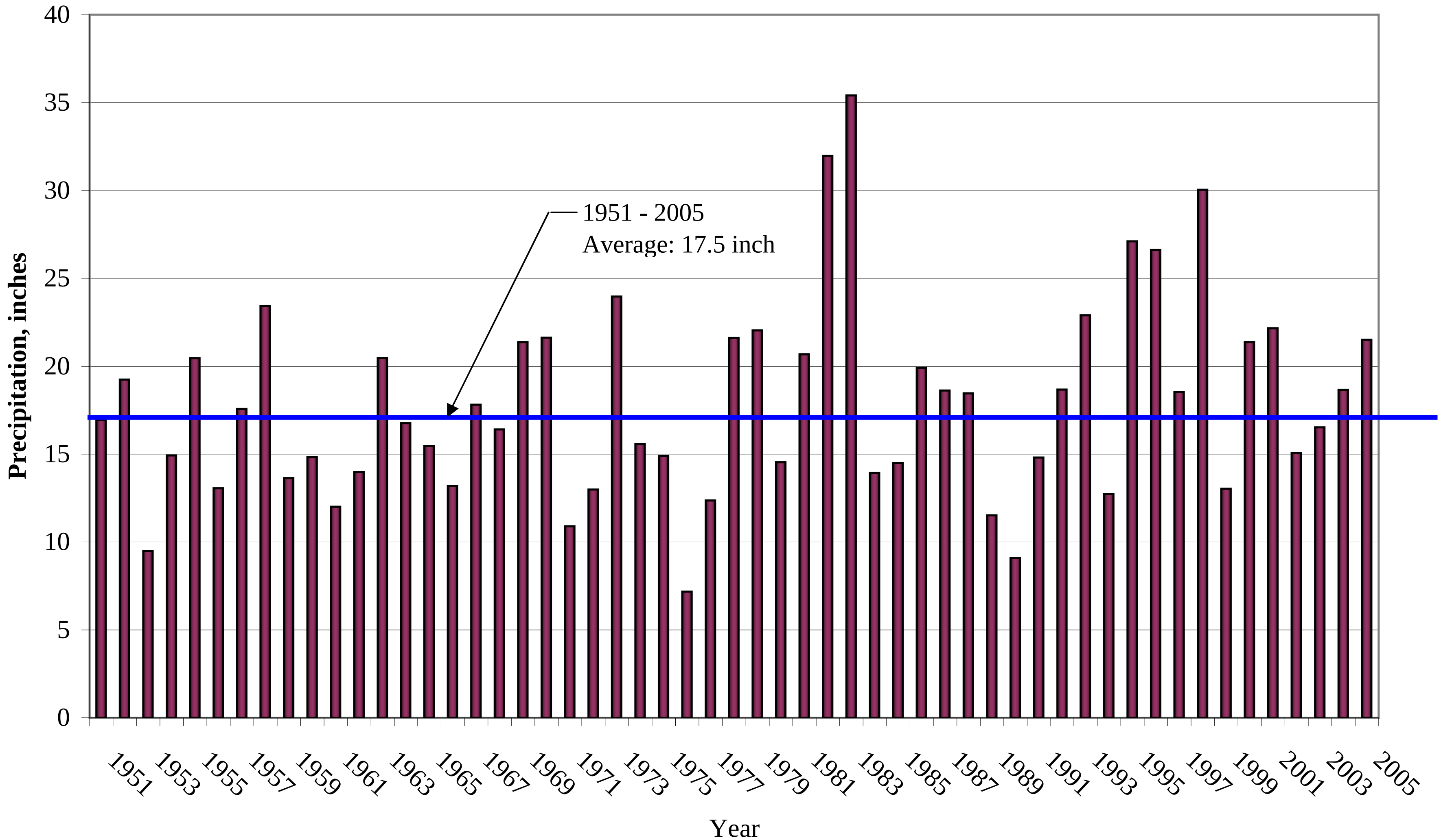
3.2 PRECIPITATION

The climate is Mediterranean, with mild, wet winters and hot, dry summers. A summary of the rainfall data collected near the WPCF (NCDC station #5032, Lodi) between 1950 and 2005 is shown in Table 3-1. Winds are predominantly from the west, with an average wind speed of approximately 4 miles per hour (1983-2000, CIMIS station #42, Lodi). A graph of the historical rainfall in the WPCF area is provided on Figure 3-1.

Table 3-1. Lodi Rainfall Data Summary

Return Period	Rainfall, inches
Average	17.5
10-Year	26.1
25-Year	31.7
100-Year	40.2

Figure 3-1. Historical Precipitation*



*Data from the NCDC #5032, Lodi.C gauging station.

3.3 SURFACE WATER RESOURCES

The major surface water features in the region of the WPCF are as follows (Figure 3-2):

- The Sacramento-San Joaquin River Delta (Delta)
- Lower Mokelumne River
- Calaveras River
- Peripheral Canal

These surface water features are further discussed below.

3.3.1 Sacramento-San Joaquin River Delta

The Delta is an approximate 700,000-acre maze of islands and both natural and man-made waterways that receive runoff from over 40 percent of the State's land area including flows from the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers.

The Delta received its first official boundary in 1959 with the passage of the Delta Protection Act (Section 12220 of the Water Code). The location of the Delta boundary and the 1-in-100 year flood zone near the WPCF is shown on Figure 3-2. As indicated, the entire WPCF property falls within the legal boundary of the Delta, and the 1-in-100 year flood zone extends through approximately half of the City's existing properties.

The Water Quality Control Plan, Fourth Edition, for the Sacramento and San Joaquin River Basin (Basin Plan) serves as the State Water Quality Control Plan applicable to the watershed draining to the Delta. The Basin Plan lists the beneficial uses of the of the Delta as municipal drinking water supply, industrial water supply, agricultural irrigation and agricultural stock watering water supply, body contact recreation, other non-body contact recreation, aesthetic enjoyment, navigation, warm freshwater aquatic habitat, cold freshwater aquatic habitat, warm fish migration habitat, cold fish migration habitat, warm spawning habitat and wildlife habitat.

The major Delta waterways located near the WPCF are Bishop Cut, White Slough, and Dredger Cut. As discussed in Section 2.4.1.2.3, there is also a small unnamed Delta channel that extends from Dredger Cut to the area south of the WPCF treatment facilities. This waterbody once was equipped with a flood gate to hold high tide flows from the Delta for irrigation of the southern portion of the City's property (prior to City ownership). During the winter months, this unnamed channel would be used to convey stormwater from the local agricultural areas to the Delta.

Since the City has purchased the WPCF property, the Delta water supplies have not been used for irrigation and the floodgate has been removed. Furthermore, stormwater and agricultural runoff from the local agricultural areas has been redirected to the City's storage ponds. Today, Delta water flowing into and out of this unnamed channel with the rising and falling tides is the primary source of water in this channel. This channel is also expected to be connected to the shallow groundwater system.

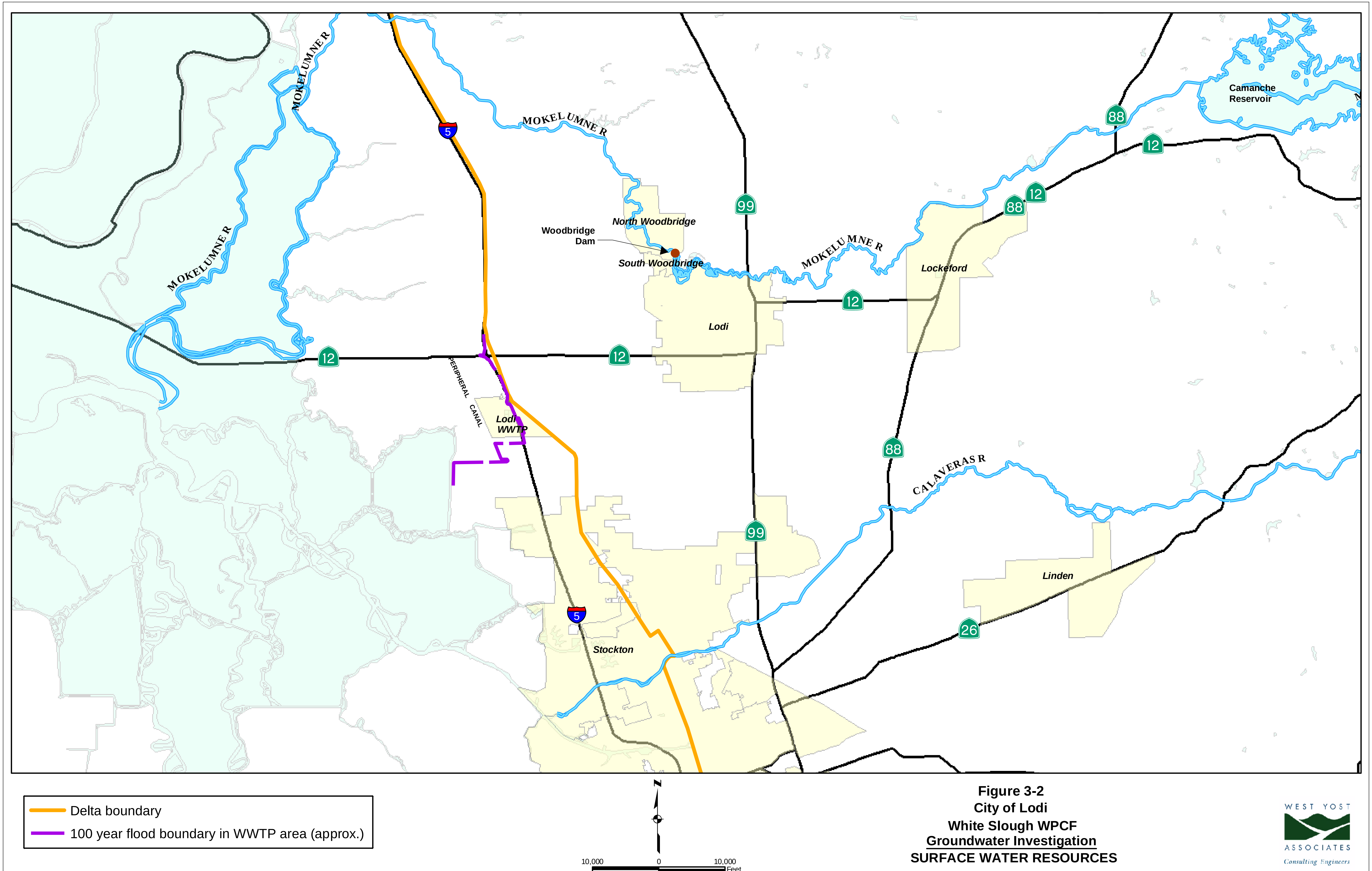


Figure 3-2
City of Lodi
White Slough WPCF
Groundwater Investigation
SURFACE WATER RESOURCES

3.3.2 Lower Mokelumne River

The Lower Mokelumne River is another major surface water feature in region, and is located to the northeast of the WPCF (Figure 3-2). The Mokelumne River drains the central western slope of the Sierra Nevada Mountains into the Delta.

Two major reservoirs, the Camanche and Pardee, are constructed on the upper reach of the Mokelumne. Both of these reservoirs are hydroelectric generating facilities and provide substantial storage capacity. The upstream Pardee Dam, completed in 1929, impounds almost 200,000 acre-feet and has a generating capacity of 28.6 megawatts. The downstream Camanche Dam, completed in 1964, impounds a reservoir of over 400,000 acre-feet and has a generating capacity of 10.7 megawatts.

Due to the presence of these reservoirs, flows are present year-round in lower reaches of the Mokelumene River. There are many seasonal diversions for irrigation from the lower Mokelumne River downstream of the Camanche Reservoir. The largest such diversion is Woodbridge Dam, which impounds Lake Lodi and is operated by the Woodbridge Irrigation District.

3.3.3 Calaveras River

The Calaveras River is located to the southeast of the WPCF (Figure 3-2). The North and South Forks of the Calaveras River originate on the western slope of the Sierra Nevada mountain range and drain to the Delta.

The upper Calaveras River above Bellota consists mainly of natural river waterways. The most prominent manmade facility is New Hogan Reservoir, which controls water flow on the Calaveras River downstream of its dam. A few small reservoirs are located upstream in the watershed and have much less of an impact on the main body of the river but may impact the tributaries on which they are located.

The Calaveras River watershed above Bellota is the water supply source for the Stockton East Water District that owns and operates the Bellota Intake and Dr. Joe Waidhofer Water Treatment Plant (WTP). The Calaveras County Water District also owns and operates two water treatment facilities in the middle and upper portions of the watershed: Jenny Lind and Sheep Ranch WTPs. The primary function of the water supply system is to supply water for municipal and irrigation purposes to communities in Calaveras and San Joaquin Counties.

The portion of the watershed below the Stockton East Water District intake at Bellota consists of several natural and manmade waterways. Two of these waterways, the Stockton Diverting Canal and Old Calaveras River Channel, join within the City of Stockton to form the lower Calaveras River.

3.3.4 Peripheral Canal

Just to the west of the WPCF properties are several open water bodies that are a portion of the partially constructed peripheral canal. This canal was originally proposed to convey Central Valley Project water around the Delta. In the course of its development the peripheral canal became very controversial and consequently was never completed. These water bodies are not connected directly to the Delta. Water levels in the canal are probably controlled by a balance between precipitation evaporation and interactions with the shallow groundwater system. Flow to and from the shallow aquifer is anticipated to be controlled by the relative levels of water in the canal and in the adjacent aquifer.

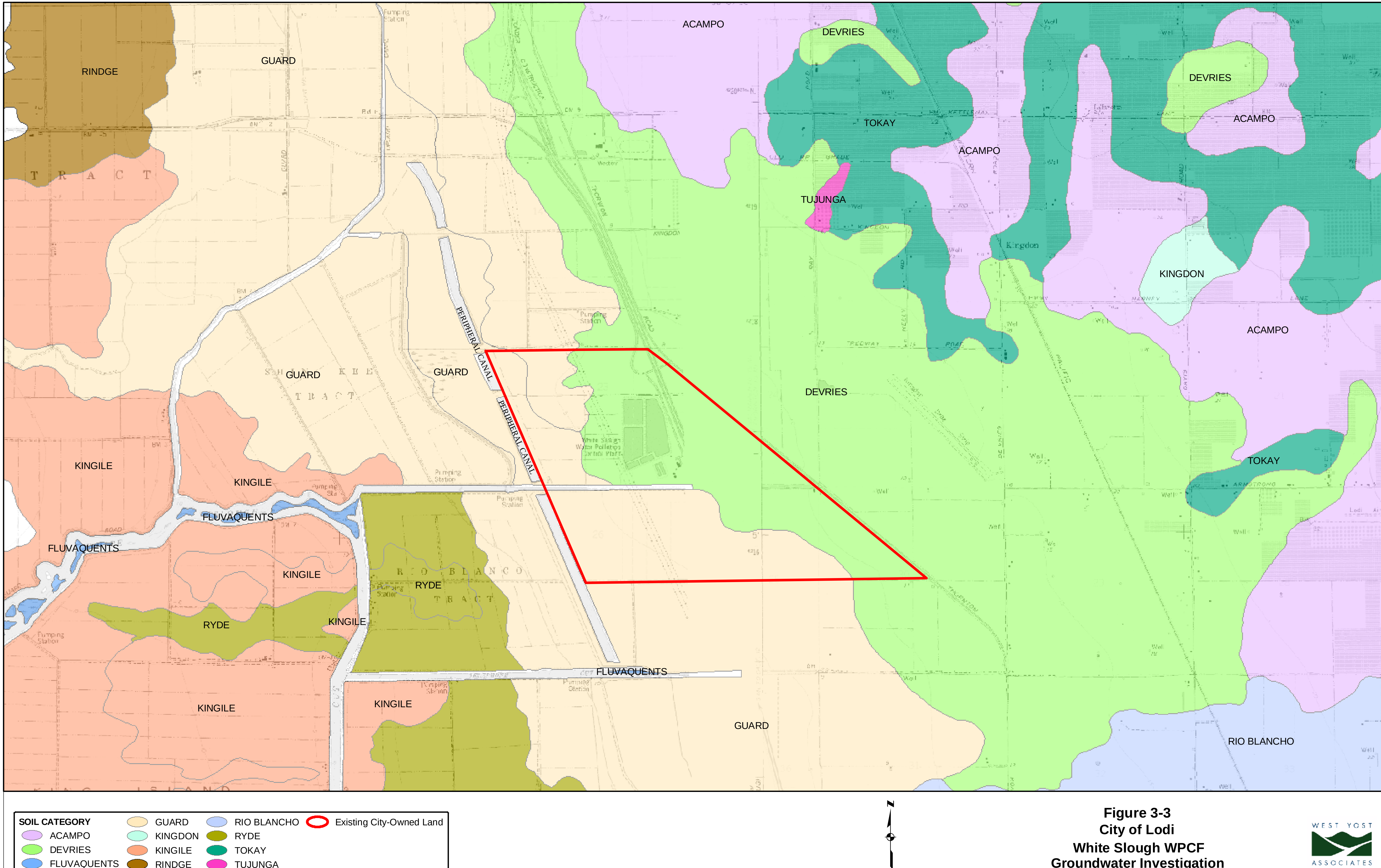
3.4 SOILS

The soils mapped in the vicinity of the White Slough WPCF are depicted on Figure 3-3. The predominant, mapped soil types in the vicinity of the WPCF and the agricultural reuse areas are the Guard and Devries soils. The distribution of these two soil types corresponds to the mapped geology of the area. The Guard and Devries soil form on the upper and lower members of the Modesto Formation, respectively (Section 3.5).

Tables 3-2 and 3-3 provide general characterization data of Guard and Devries soil series. Major physical property differences between the two soil series include 1) texture, 2) permeability, and 3) subsoil. The Guard soil is fine-textured (clay loam), while the Devries is coarse textured (sandy loam). Consequently, the water permeability class for the Guard is slow and the Devries is moderately rapid. The Guard soil has a calcareous-silica subsoil (Bkq horizon), while the Devries series has a duripan (a hard, subsurface horizon, cemented by silica or other materials such as iron oxides or calcium carbonate that are always brittle, even after prolonged wetting) that is also calcareous (Bkqm). The native subsoil pHs of about 8.0, which are controlled by the presence of free calcium carbonate.

The Guard soil series is taxonomically classified as fine-loamy, mixed, superactive, calcareous, thermic Duric Endoaquolls, while the Devries is classified as coarse-loamy, mixed, superactive, thermic Typic Duraquolls (USDA-NRCS, 1992). Both soils are on the basin rims of the San Joaquin Delta ranging from about -5 to 10 feet mean elevation for the Guard and about 5 to 15 feet mean elevation for the Devries. The parent materials for these soils are alluvium from mixed sources.

Table 3-4 indicates quantitatively the extent of the agricultural reuse areas occupied by the Guard and Devries soil series. Note in the table that there are two soil phases of Guard series and one phase of Devries mapped for this area (USDA-NRCS, 1992). An important distinction between the two Guard soil phases listed is that the effective rooting depth for the Guard clay loam, 0-2% slopes, is limited to 18 to 36 inches because of a perched water table; and the effective rooting depth of the Guard clay loam, drained, 0-2% slopes, is generally greater than 60 inches. Finally, the effective rooting depth of the Devries sandy loam, drained, 0-2% slopes, is limited to 20-40 inches because of the duripan discussed above.



Note: Soils data based on Soil Survey Geographic (SSURGO) database, developed by the National Resources Conservation Service.

Figure 3-3
City of Lodi
White Slough WPCF
Groundwater Investigation
SOILS MAP

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Table 3-2. Soil Characterization of Guard Soil Series (from USDA-NRCS soil survey).

Horizon	Depth, inches	Texture	Structure	Free Lime	pH	Water permeability class	Saturated hydraulic conductivity, in/hr
Ap	0-5	clay loam	sub-angular blocky	yes	8.0	Slow	0.2-0.6
A	5-15	clay loam	sub-angular blocky	yes	8.0		0.2-0.6
Bkq1	15-27	clay loam	massive	yes	8.0		0.06-0.2
Bkq2	27-72	clay loam	massive, weakly cemented	yes	8.0		0.06-0.2

Reference: USDA – NRCS (1992).

Table 3-3. Soil Characterization of Devries Soil Series (from USDA-NRCS soil survey).

Horizon	Depth, inches	Texture	Structure	Free Lime	pH	Water permeability class	Saturated hydraulic conductivity, in/hr
A1	0-4	sandy loam	angular blocky	no	7.0	Moderately rapid	2.0-6.0
A2	4-13	sandy loam	angular blocky	no	7.5		2.0-6.0
Bt	13-28	sandy loam	angular blocky	yes	8.0		2.0-6.0
Bkqm	28-80	cemented	massive, duripan	yes	8.0		—

Reference: USDA – NRCS (1992).

Table 3-4. Agricultural Reuse Area Breakdown by Soil Phase.

Soil Phase	Field	Extent	Field Acres	Acres	Total	Percent of Total
Guard Clay Loam 0-2% slopes (0.2% of all San Joaquin County Soils)	1A	1.00	11	11.0		
	1C	1.00	9	9.0		
	2A - W side	0.25	36	9.0		
	2B	1.00	32	32.0		
	2C	1.00	20	20.0		
	3D - SW side	0.20	17	3.4	84.4	9.5
Guard Clay Loam drained 0-2% slopes (1.6% of all San Joaquin County Soils)	1B - W side	0.33	37	12.2		
	1D - W side	0.33	55	18.2		
	2A - E side	0.75	36	27.0		
	5A	1.00	37	37.0		
	5B	1.00	43	43.0		
	5C	1.00	43	43.0		
	5D	1.00	35	35.0		
	5E	1.00	35	35.0		
	5F	1.00	30	30.0		
	6A - S side	0.60	45	27.0		
	6B - S side	0.50	45	22.5		
	6C - S side	0.50	45	22.5		
	6D - S side	0.33	45	14.9		
	6E - S side	0.20	40	8.0	375.2	42.4
Devries Sandy Loam drained 0-2% (1.1% of all San Joaquin County Soils)	1B - E side	0.67	37	24.8		
	1D - E side	0.67	55	36.9		
	3A	1.00	11	11.0		
	3B	1.00	13	13.0		
	3C	1.00	16	16.0		
	3D - NW side	0.80	17	13.6		
	4A	1.00	12	12.0		
	4B	1.00	13	13.0		
	4C	1.00	22	22.0		
	4D	1.00	34	34.0		
	4E	1.00	49	49.0		
	6A - N side	0.50	45	22.5		
	6B - N side	0.50	45	22.5		
	6C - N side	0.50	45	22.5		
	6D - N side	0.67	45	30.2		
	6E - N side	0.80	40	32.0		
	6F	1.00	35	35.0		
	6G	1.00	15	15.0	424.9	48.0
				TOTAL ACREAGE	884.5	100

USDA-NRCS. 1992. Soil Survey of the San Joaquin County, California. USDA-Natural Resource Conservation Service. Washington, D.C.

The USDA Land Capability Classification is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time. Class 2 (II) soils have moderate limitations that reduce the choice of plants or require moderate conservation practices, Class 3 (III) soils have severe limitations that reduce the choice of plants or require special conservation practices (or both), and Class 4 (IV) soils have very severe limitations that restrict the choice of plants or require very careful management (or both). Subclass w is made up of soils for which excess water is the dominant hazard or limitation affecting their use. Poor soil drainage, wetness, a high water table, and overflow are the factors that affect soils in this subclass.

Because of the perched water table depth, the Guard CL, 0-2% slopes, is classified as IIIw and the Guard CL, drained, 0-2% slopes is IIw. For the Devries soils, water may be perched above the duripan after a heavy rain or irrigation; therefore, this series is classified as IVw.

3.5 Geology

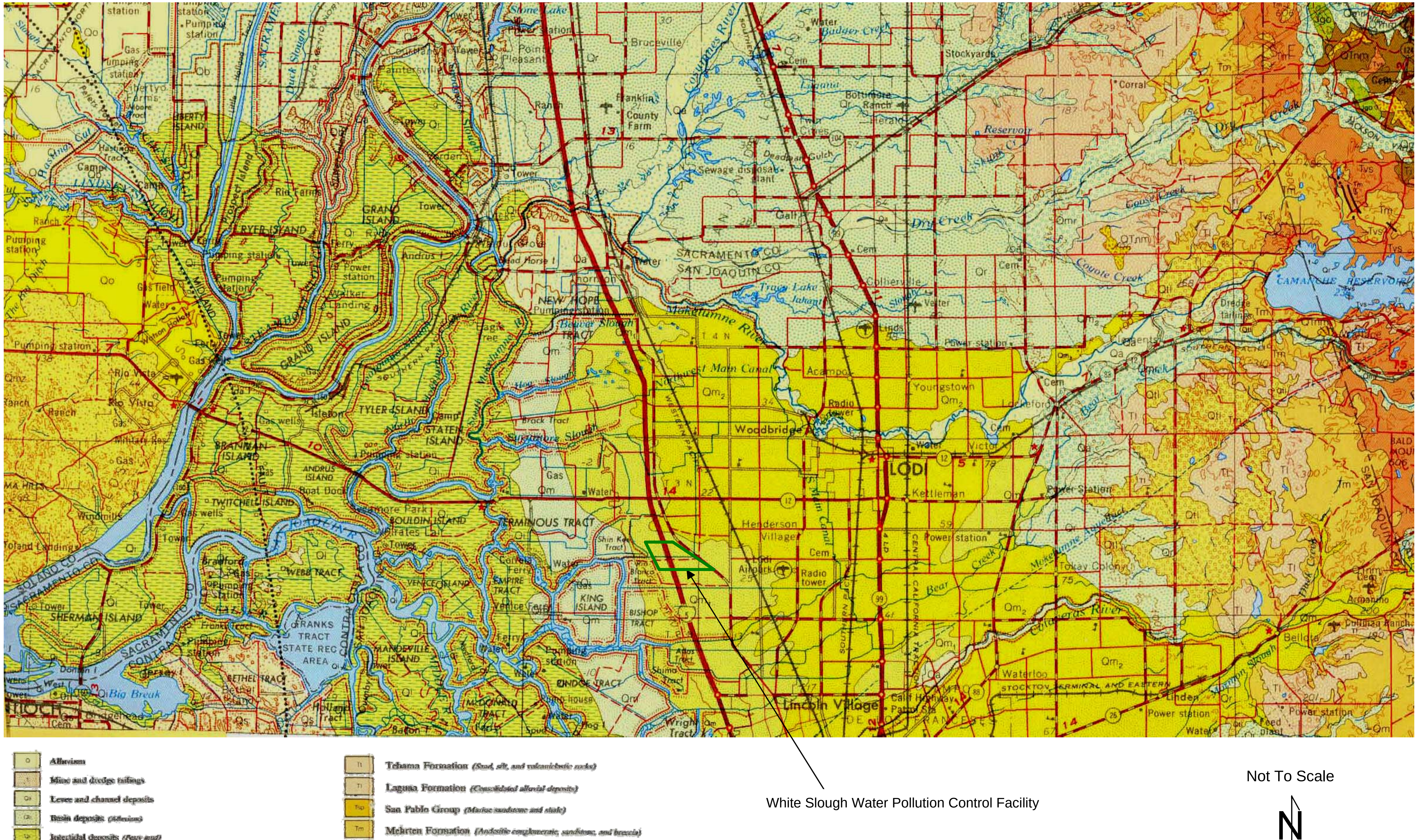
Following the nomenclature of DWR Bulletin 118, the WPCF lies within the Eastern San Joaquin Subbasin of the San Joaquin Valley Groundwater Basin (DWR, 2003 and 2006). The DWR subbasin designation is 5-22.01. DWR's description of the Eastern San Joaquin Subbasin can be found at http://www.groundwater.water.ca.gov/bulletin118.

3.5.1 Geologic Setting

The surficial geology in the vicinity of the WPCF from the "Geologic Map of the Sacramento Quadrangle" California Geological Survey [CGS], 1987) is shown on Figure 3-4. As shown, The WPCF lies on a westward thickening and dipping sequence of sedimentary rock and unconsolidated sediment that underlies the eastern flank of the Central Valley. The sequence overlies Jurassic-Cretaceous igneous and metamorphic basement rock.

These sediments were eroded and transported in association with the tectonic uplift of the Sierra Nevada and were deposited into the subsiding structural trough of the Central Valley. This sedimentary sequence consists of Late Cretaceous to Eocene marine and continental sedimentary rock overlain by Late Tertiary to Quaternary unconsolidated alluvial and fluvial sediments. The Late Cretaceous to Eocene rocks contain saline water. The Late Tertiary to Quaternary unconsolidated alluvial and fluvial sediments comprise the potable groundwater aquifer. The geologic units of interest in the White Slough WPCF area are (from oldest to youngest):

- Mehrten Formation from the Late Miocene to early Pliocene age
- Laguna Formation from the Late Pliocene to Early Pleistocene age
- Turlock Lake Formation from the Pleistocene age
- Riverbank and Modesto Formations from the Pleistocene age



Alluvium
Mine and dredge tailings
Levee and channel deposits
Basin deposits *(Alluvium)*
Intertidal deposits *(Peaty mud)*
Dune sand
Lake deposits
Older alluvium
Glacial deposits
Modesto Formation *(Alluvium)* — Upper and lower members
Riverbank Formation *(Alluvium)*
Modesto-Riverbank Formations *(Arkosic alluvium)*
Montezuma Formation *(Poorly consolidated, clayey sand)*
Turlock Lake Formation *(Sand, silt, and gravel)*
Red Bluff Formation *(Gravel in reddish, silty or sandy matrix)*
North Merced Gravel *(Thin pediment veneer)*
Tehama Formation *(Sand, silt, and volcaniclastic rocks)*
Laguna Formation *(Consolidated alluvial deposits)*
San Pablo Group *(Marine sandstone and shale)*
Mehrten Formation *(Andesitic conglomerate, sandstone, and breccia)*

References:
California Geological Survey, 1981, Geologic Map of the Sacramento Quadrangle, compiled by D.L. Wagner, C.W. Jennings, T.L. Bedrossian and E.J. Bortungno, 1:250,000, second printing 1987.

Figure 3-4
City of Lodi
White Slough WPCF
Groundwater Investigation
GEOLOGIC MAP

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3.5.1.1 Mehrten Formation

The Mehrten Formation consists of conglomerate, sandstone, siltstone and claystone derived from andesitic (igneous, volcanic rock) source material laid down by southwesterly trending streams carrying andesitic debris from the central and northern Sierra Nevada (Marchand and Alldwardt, 1981). The upper part of the Mehrten Formation contains numerous weakly to moderately developed paleosols (a former soil preserved underneath sedimentary bedrock such as alluvium). The uppermost Mehrten Formation also includes light colored or reddish gravel and sand beds easily confused with the overlying Laguna Formation (Marchand and Alldwardt, 1981). The Mehrten Formation outcrops about 18 miles east of the WPCF and is thought to have a regional slope of approximately 0.02 to the southwest (Marchand and Alldwardt, 1981; CGS, 1987). Based on the locations of the surface outcrops of the Mehrten Formation and the southwesterly regional slope of its upper surface, the top of the Mehrten Formation is expected to occur at a depth between roughly 800 and 1,000 feet below land surface (bls) in the vicinity of the WPCF.

3.5.1.2 Laguna Formation

The Laguna Formation overlies the Mehrten Formation and consists of alluvial gravels, sand and silt. Pebbles and cobbles of quartz and metamorphic fragments dominate the gravelly units. The matrix of the gravel and the finer grained units of the Laguna are arkosic (derived from the disintegration of granite or gneiss), in contrast to the andesitic deposits of the underlying Mehrten Formation (Marchand and Alldwardt, 1981). The Laguna Formation outcrops approximately 18 miles east of the WPCF (Figure 3-4). Based on the locations of outcrops and the southwesterly regional dip of the formation, the top of the Laguna Formation is anticipated to occur at depths ranging from roughly 100 to 200 feet beneath the White Slough WPCF.

3.5.1.3 Turlock Lake Formation

The Pleistocene Turlock Lake Formation consists predominately of partially consolidated gravel, sand and silt derived mainly from Sierran granitic and metamorphic rocks (CGS, 1987). The formation is in unconformable (not lying in a parallel position) contact with the underlying Laguna Formation and overlying Riverbank and Modesto Formations (Marchand and Alldwardt, 1981). The formation is difficult to distinguish from the Laguna Formation, but is significantly younger at slightly less than one million years.

3.5.1.4 Riverbank and Modesto Formations

The Mehrten, Laguna and Turlock Lake Formations are unconformably overlain by the Pleistocene age Riverbank and Modesto Formations. These formations consist of up to 200 feet of loose to moderately compacted silt, silty clay, sand and gravel deposited in alluvial depositional environments during periods of world-wide glaciation (Lettis, 1988; Weissmann, et. al., 2002; DWR, 2006). The formations were deposited in response to Sierra Nevadan glacial activity and the accompanying changes in base levels and increased precipitation during the glacial cycles. The increased precipitation and lower base level resulted in greater stream discharge and competency than at the present time. The greater competency of the streams led to scouring of stream channels in pre-existing geologic deposits, such as the Mehrten and Laguna

Formation, followed by transport, deposition and burial of sands and gravels in the channels as the glacial cycles progressed.

The age of the Riverbank Formation ranges from 0.13 to 0.45 million years and corresponds to the Illinoisan and older glacial stages. The age of the Modesto Formation ranges from approximately 0.01 to 0.042 million years and correlates to the Wisconsin glacial stage. These ages are significantly younger than the roughly one million year age of the Turlock Lake Formation and the 3 to 4 million year age of the Laguna Formation, which are the next youngest geologic formation in the vicinity of the WPCF.

The Modesto Formation is divided into upper and lower members, which are both present at the land surface at the WPCF. These are designated Qm1 and Qm2, respectively, on Figure 3-4. As noted in the preceding discussion of soils, the Guard soils have formed on the upper member and Devries soils have formed on the lower member.

3.5.2 Site-Specific Geology

This section presents a discussion of the following information related to the site-specific groundwater conditions near the WPCF:

- Geologic Cross-sections
- Sand Thickness

Information presented in this section was developed from the logs of test borings and 19 monitoring wells installed by the City to monitor groundwater levels and quality near the WPCF. All of the monitoring wells and borings were drilled in the lower member of the Modesto Formation (Figure 3-4). The locations of these borings and monitoring wells are shown on Figure 3-5, along with the cross-sections that were developed for this report.

3.5.2.1 Geologic Cross-Sections

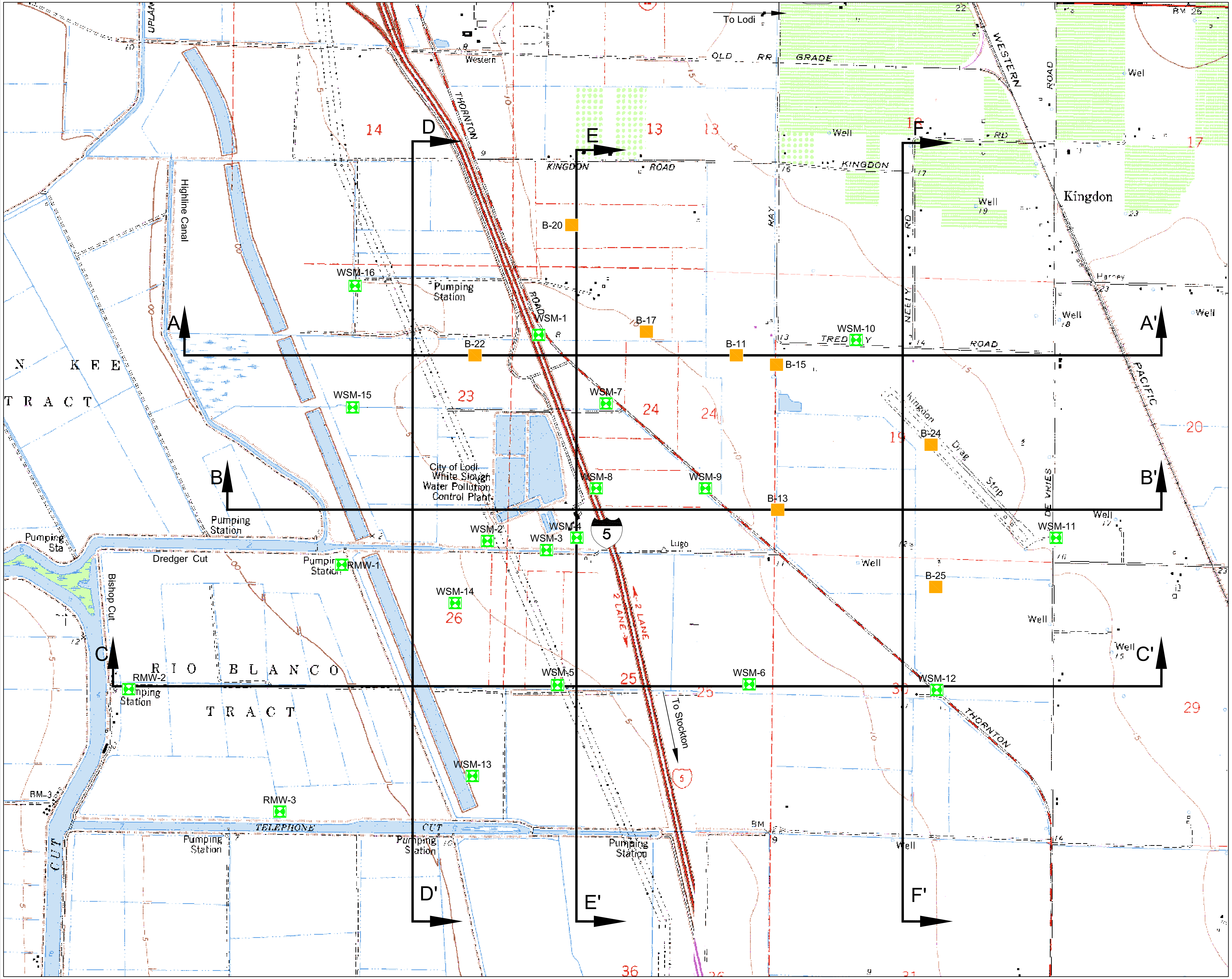
The geologic cross-sections are shown on Figures 3-6 through 3-11. As shown on these figures, the completion depths of the monitoring wells increase from approximately 10 to 50 feet bls from west to east with increasing depth to groundwater.

The sediments encountered during drilling are predominately fine-grained, ranging from silts and clays to silty fine sands. Actual hydraulic conductivity values have not been assessed at the WPCF. Typical hydraulic conductivity values for these materials range from roughly 0.001 to 10 feet per day (Freeze and Cherry, 1976).

Several of the wells penetrate coarser grained layers without appreciable fine grained material intermixed. These clean sand layers were composed of fine to coarse grained sands with occasional fine gravel. Typical hydraulic conductivity values for these materials range from roughly 10 to 1,000 feet per day (Freeze and Cherry, 1976).

Although not recorded in the drilling logs, observations made by WYA and facilities staff indicate that cemented and hard pan zones are present within the sediments at depths of six to ten feet. These zones would tend to lower the hydraulic conductivity of the sediments and impede the vertical flow of groundwater.

Figure 3-5
City of Lodi
White Slough WPCF
Groundwater Investigation
CROSS SECTION LOCATION MAP



LEGEND:

WSM-1 CITY MONITORING WELL

B-1 CITY BORING (COMPLETED IN 1999)

CROSS SECTION LOCATION

N

0 900 1800
SCALE IN FEET

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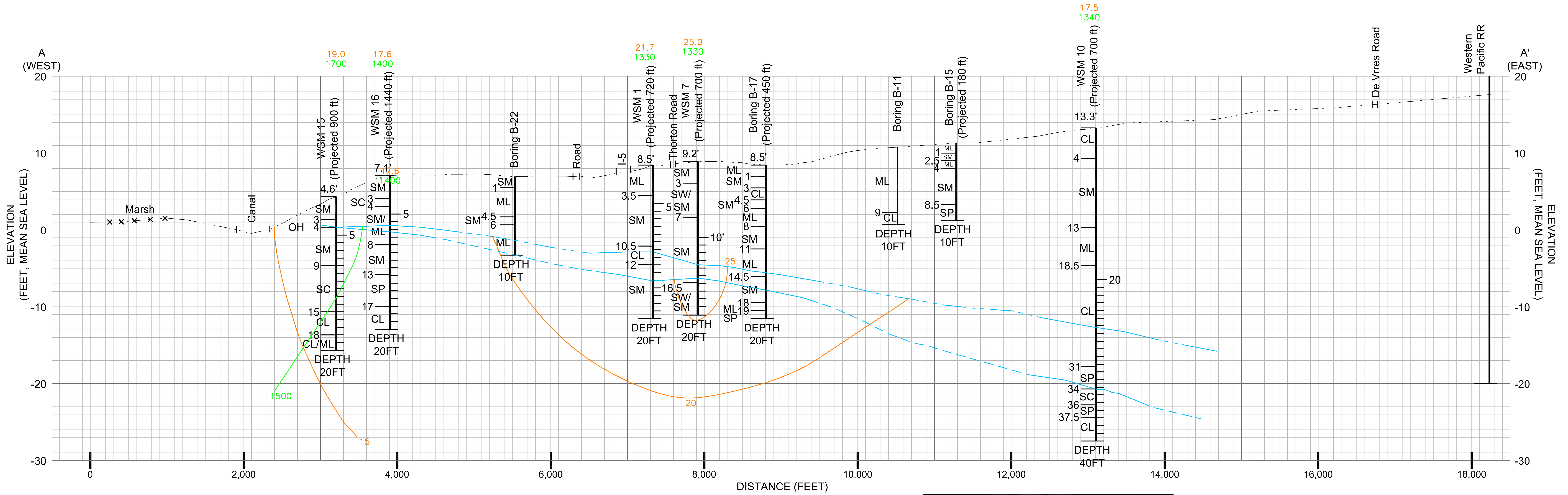

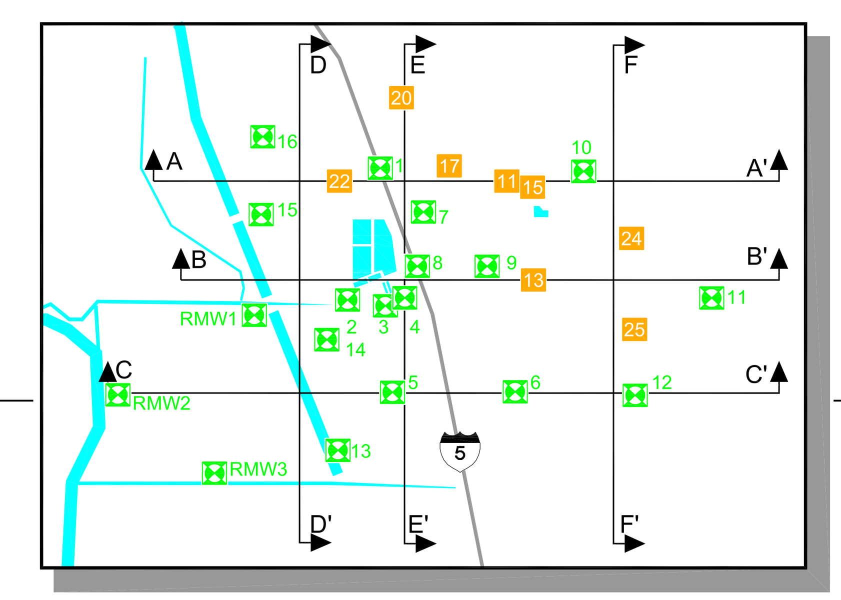

LOCATION MAP LEGEND:
MONITORING WELL, WSM -SERIES UNLESS NOTED
SOIL BORING

LEGEND:
EXISTING GRADE
GROUNDWATER ELEVATION, SEPTEMBER 2003
GROUNDWATER ELEVATION, MARCH 2004
DASHED WHERE APPROXIMATE
MEDIAN NITRATE CONCENTRATION CONTOUR IN mg/L, CONTOUR INTERVAL: 5 mg/L
MEDIAN ELECTRICAL CONDUCTANCE CONTOUR IN umhos/cm, CONTOUR INTERVAL: 250 umhos/cm

HORIZ. SCALE 1" = 1,000'
VERT. SCALE: 1" = 10'

Note:
Median Nitrate and Electrical Conductivity Data Collected Between August 2001 and November 2005.

Figure 3-6
City of Lodi
White Slough WCPF
Groundwater Investigation
GEOLOGIC CROSS SECTION A-A'

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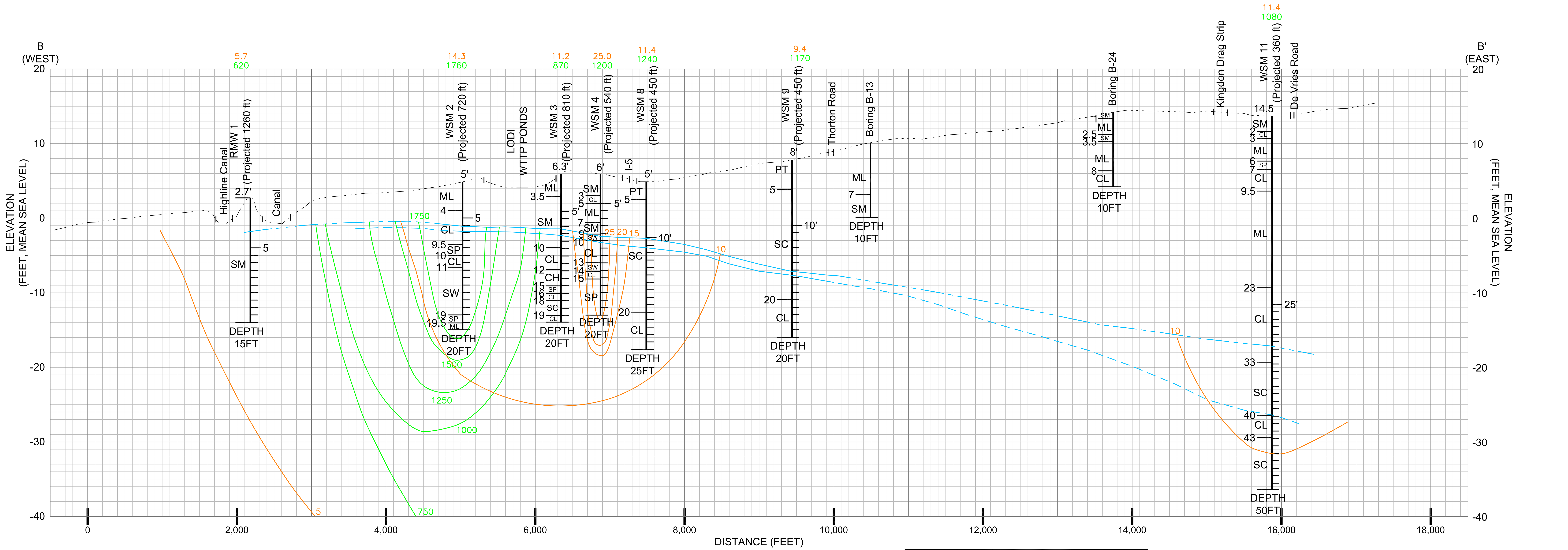
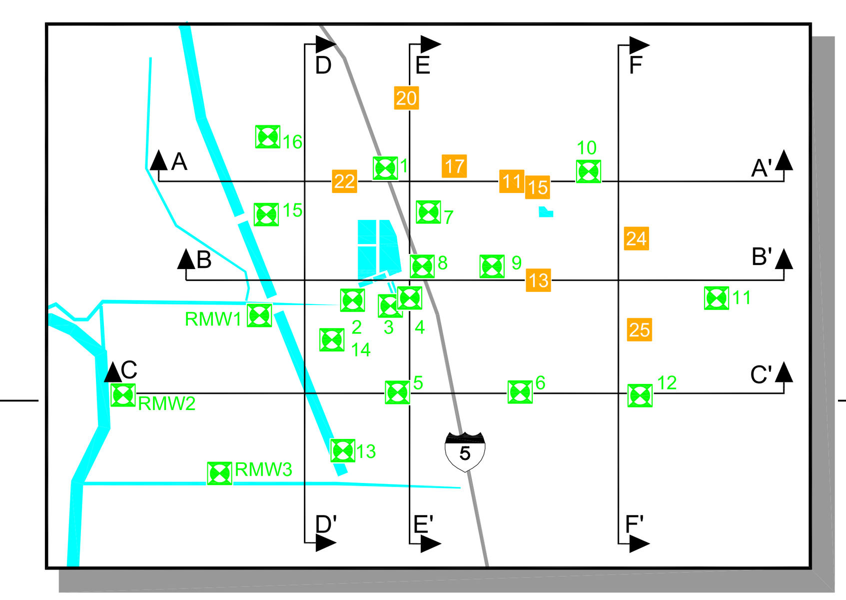


LEGEND:

- EXISTING GRADE
- GROUNDWATER ELEVATION, SEPTEMBER 2003 } DASHED WHERE APPROXIMATE
- GROUNDWATER ELEVATION, MARCH 2004
- MEDIAN NITRATE CONCENTRATION CONTOUR IN mg/L, CONTOUR INTERVAL: 5 mg/L
- MEDIAN ELECTRICAL CONDUCTANCE CONTOUR IN umhos/cm, CONTOUR INTERVAL: 250 umhos/cm

Note:
Median Nitrate and Electrical Conductivity Data Collected Between August 2001 and November 2005.

HORIZ. SCALE 1" = 1,000'
VERT. SCALE: 1" = 10'



LOCATION MAP LEGEND:
MONITORING WELL, WSM -SERIES UNLESS NOTED
SOIL BORING

Figure 3-7
City of Lodi
White Slough WCPF
Groundwater Investigation
GEOLOGIC CROSS SECTION B-B'

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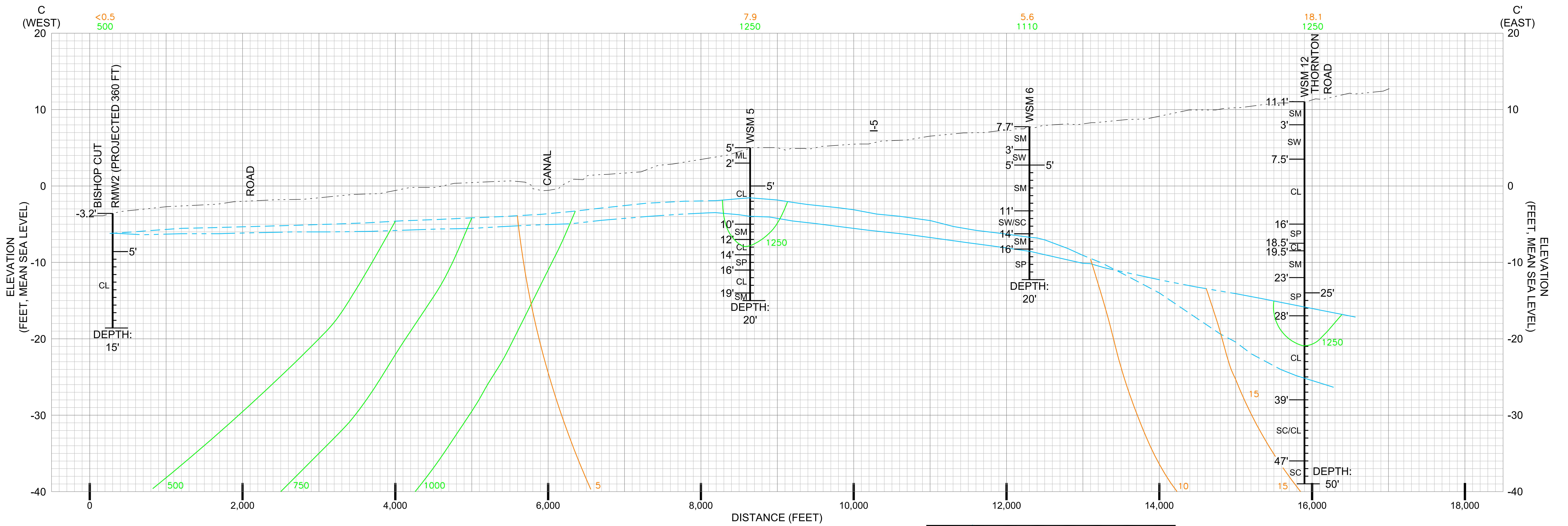

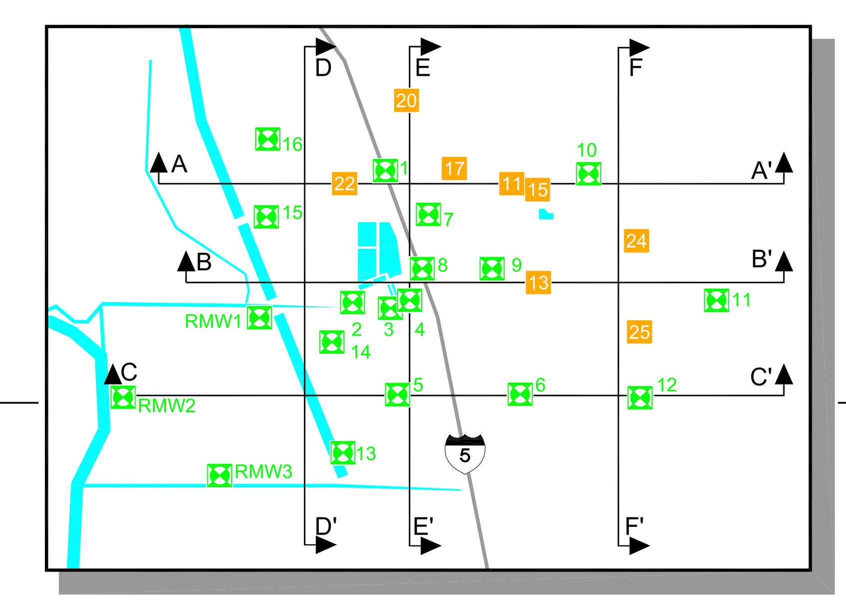

LOCATION MAP LEGEND:
MONITORING WELL, WSM -SERIES UNLESS NOTED
SOIL BORING

LEGEND:
EXISTING GRADE
GROUNDWATER ELEVATION, SEPTEMBER 2003
GROUNDWATER ELEVATION, MARCH 2004
DASHED WHERE APPROXIMATE
MEDIAN NITRATE CONCENTRATION CONTOUR IN mg/L, CONTOUR INTERVAL: 5 mg/L
MEDIAN ELECTRICAL CONDUCTANCE CONTOUR IN umhos/cm, CONTOUR INTERVAL 250 umhos/cm

Note:
Median Nitrate and Electrical Conductivity Data Collected Between August 2001 and November 2005.

HORIZ. SCALE 1" = 1,000'
VERT. SCALE: 1" = 10'

Figure 3-8
City of Lodi
White Slough WCPF
Groundwater Investigation
GEOLOGIC CROSS SECTION C-C'

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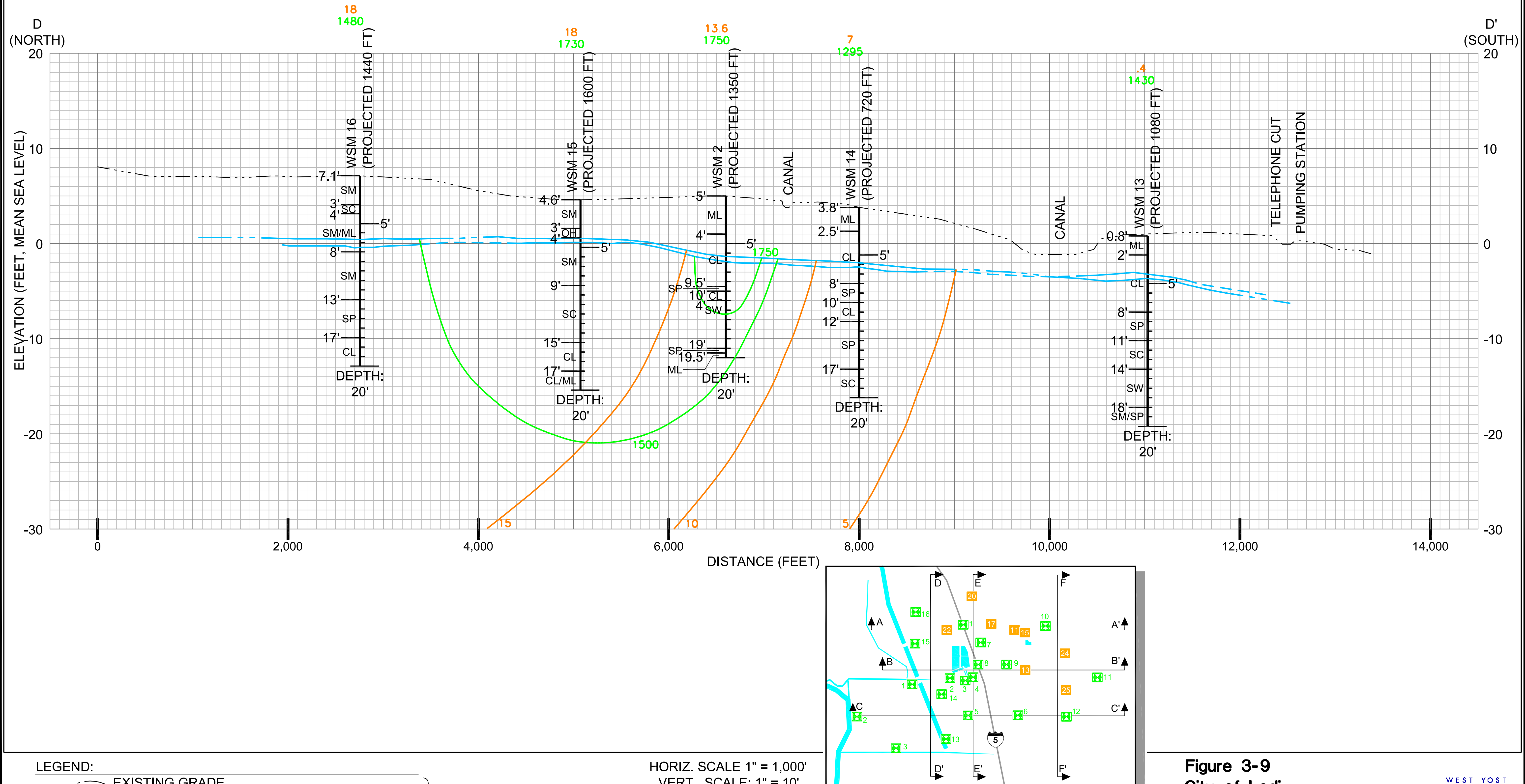


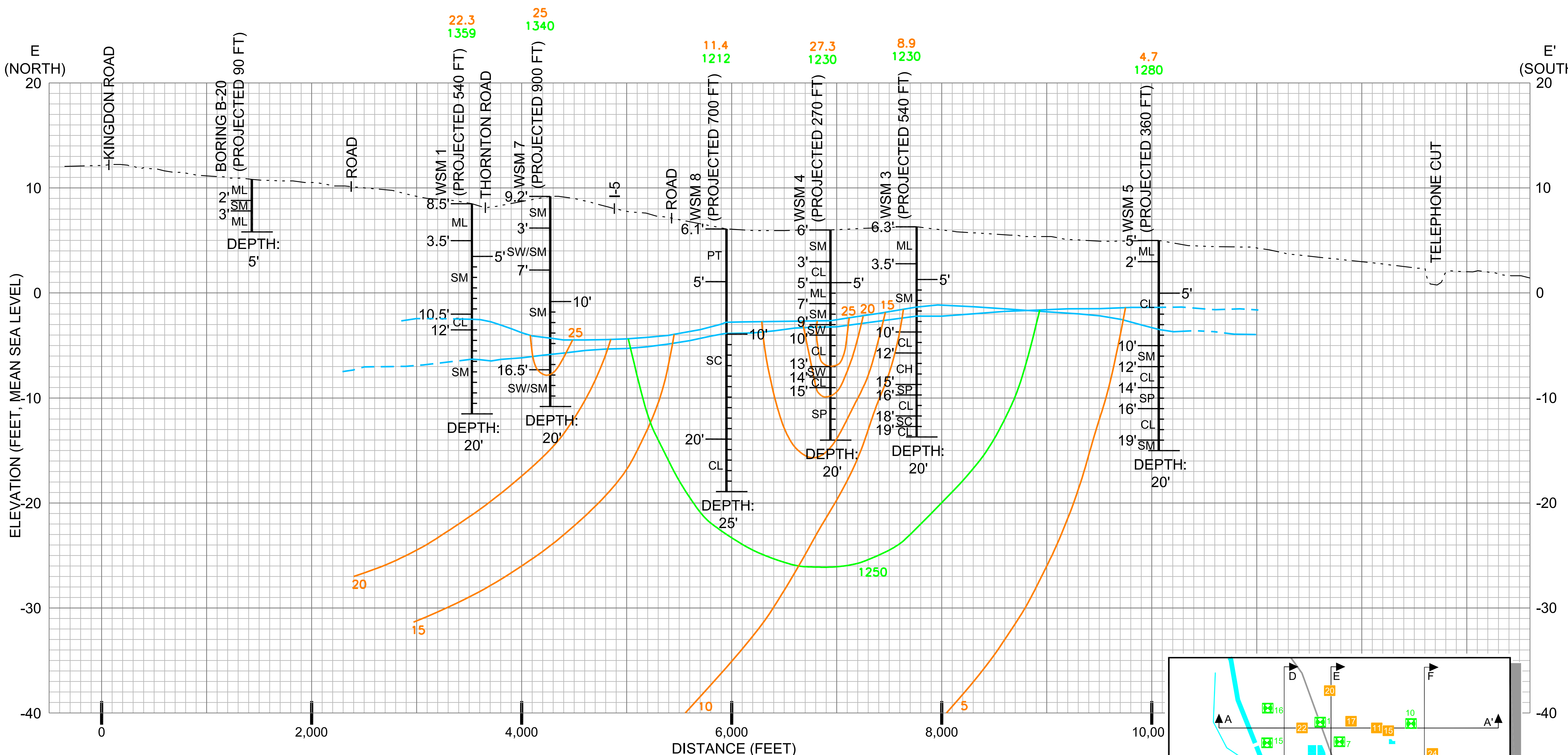
LEGEND:
- EXISTING GRADE
- GROUNDWATER ELEVATION, SEPTEMBER 2003 } DASHED WHERE APPROXIMATE
- GROUNDWATER ELEVATION, MARCH 2004 } DASHED WHERE APPROXIMATE
- 20 MEDIAN NITRATE CONCENTRATION CONTOUR IN mg/L, CONTOUR INTERVAL: 5 mg/L
- 1500 MEDIAN ELECTRICAL CONDUCTANCE CONTOUR IN umhos/cm, CONTOUR INTERVAL 250 umhos/cm

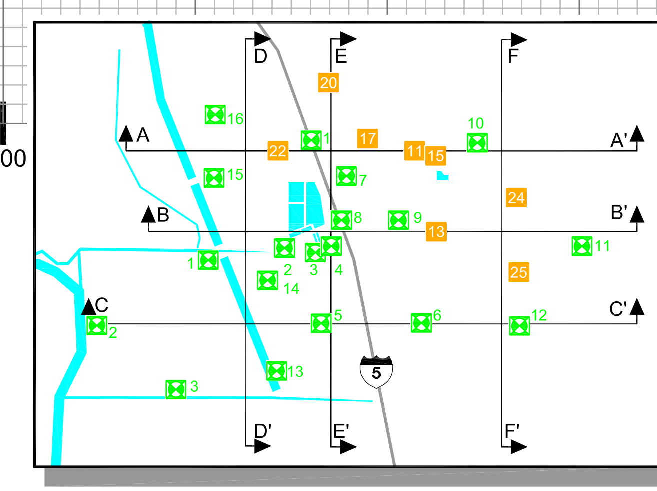
HORIZ. SCALE 1" = 1,000'
VERT. SCALE: 1" = 10'

Reference:
Nitrate and Electrical Conductance data from Saracino, Kirby, Snow (2003) Median of samples collected between July 2001 and June 2003

Figure 3-9
City of Lodi
White Slough WCPF
Groundwater Investigation
GEOLOGIC CROSS SECTION D-D'

WEST YOST ASSOCIATES
Consulting Engineers





LEGEND:

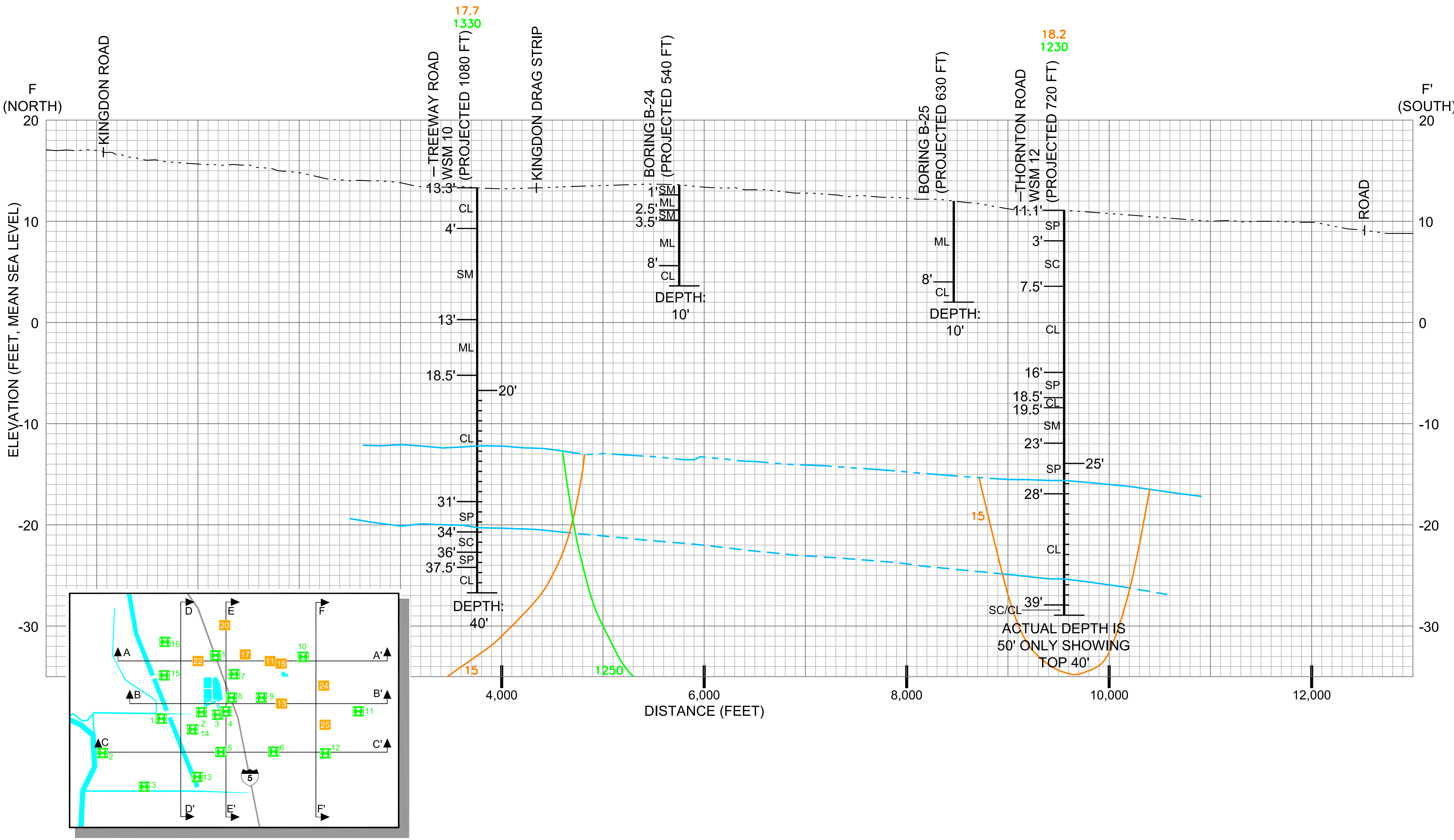
- EXISTING GRADE
- GROUNDWATER ELEVATION, SEPTEMBER 2003 } DASHED WHERE APPROXIMATE
- GROUNDWATER ELEVATION, MARCH 2004
- 20 MEDIAN NITRATE CONCENTRATION CONTOUR IN mg/L, CONTOUR INTERVAL: 5 mg/L
- 1500 MEDIAN ELECTRICAL CONDUCTANCE CONTOUR IN umhos/cm, CONTOUR INTERVAL: 250 umhos/cm

HORIZ. SCALE 1" = 1,000'
VERT. SCALE: 1" = 10'

Reference:
Nitrate and Electrical Conductance data from Saracino, Kirby, Snow (2003)
Median of samples collected between July 2001 and June 2003

Figure 3-10
City of Lodi
White Slough WCPF
Groundwater Investigation
GEOLOGIC CROSS SECTION E-E'

WEST YOST ASSOCIATES
Consulting Engineers



LEGEND:
EXISTING GRADE
GROUNDWATER ELEVATION, SEPTEMBER 2003 } DASHED WHERE APPROXIMATE
GROUNDWATER ELEVATION, MARCH 2004
20 MEDIAN NITRATE CONCENTRATION CONTOUR IN mg/L, CONTOUR INTERVAL: 5 mg/L
1500 MEDIAN ELECTRICAL CONDUCTANCE CONTOUR IN umhos/cm, CONTOUR INTERVAL: 250 umhos/cm

HORIZ. SCALE 1" = 1,000'
VERT. SCALE: 1" = 10'

Reference:
Nitrate and Electrical Conductance data from Saracino, Kirby, Snow (2003)
Median of samples collected between July 2001 and June 2003

Figure 3-11
City of Lodi
White Slough WCPF
Groundwater Investigation
GEOLOGIC CROSS SECTION F-F'

WEST YOST ASSOCIATES
Consulting Engineers

3.5.2.2 Sand Thickness

The cross-sections were used to estimate the thickness of clean sands within the saturated zone penetrated by the wells. For purposes of this analysis, clean sands were defined as those containing less than 5 percent of silt and clay sized particles as noted by the unified soil classification system (USCS) designations indicated on the monitoring well driller's logs. This included the poorly graded sand (SP) and well graded sand (SW) USCS categories. The contours of saturated sand thickness are shown on Figure 3-12. This information can be used to show areas of higher hydraulic conductivity beneath the WPCF site. The sands encountered in the saturated zone beneath the WPCF site are probably channel deposits formed by streams, but the wells are spaced too far apart to identify the orientation and lateral continuity of the sands. The sands are part of the lower member of the Modesto Formation, which is a geologically young formation that was probably deposited on a terrain similar to today's terrain.

The sand thickness ranged from zero feet in the wells west of the peripheral canal and wells WSM-1, WSM-8, WSM-9, WSM-11 and WSM-15 to more than five feet in wells WSM-2, WSM-4, WSM-13, and WSM-14. As shown on Figures 3-2 and 3-4, the dominant orientation of most streams and drainage in the area is west-southwesterly, although significant variations from this trend exist locally. A thick section of saturated sand was encountered along a southwesterly-northeasterly trending zone extending through WSM-13, WSM-14, WSM-2, and WSM-7 (Figure 3-12). If continuous from well to well, this sand may represent a stream channel sequence underlying the main WPCF treatment and storage facilities.

A relatively thick section of sand was also encountered at WSM-4, but the available information suggests that this sand may be distinct from the sand body discussed in the preceding paragraph. As shown on Figure 3-12, the thick sands encountered in wells WSM-2 and WSM-4 are separated by an area of significantly reduced sand thickness, as encountered in wells WSM-3, WSM-8 and WSM-9.

Wells WSM-2, WSM-3, WSM-4 and WSM-8 are the most closely spaced of any of the wells at the WPCF. The higher variability in sand thickness encountered in these wells is an indication that the width of the sand bodies beneath the area is less than the typical spacing of the other wells. This means that the contours shown on Figure 3-12 may be an over-estimate of the width and continuity of the sands. The sands comprise a small percentage of the aquifer encountered during drilling at the WPCF. The aquifer is composed mostly of fine grained sediments enclosing discontinuous lenses of coarser grained materials.

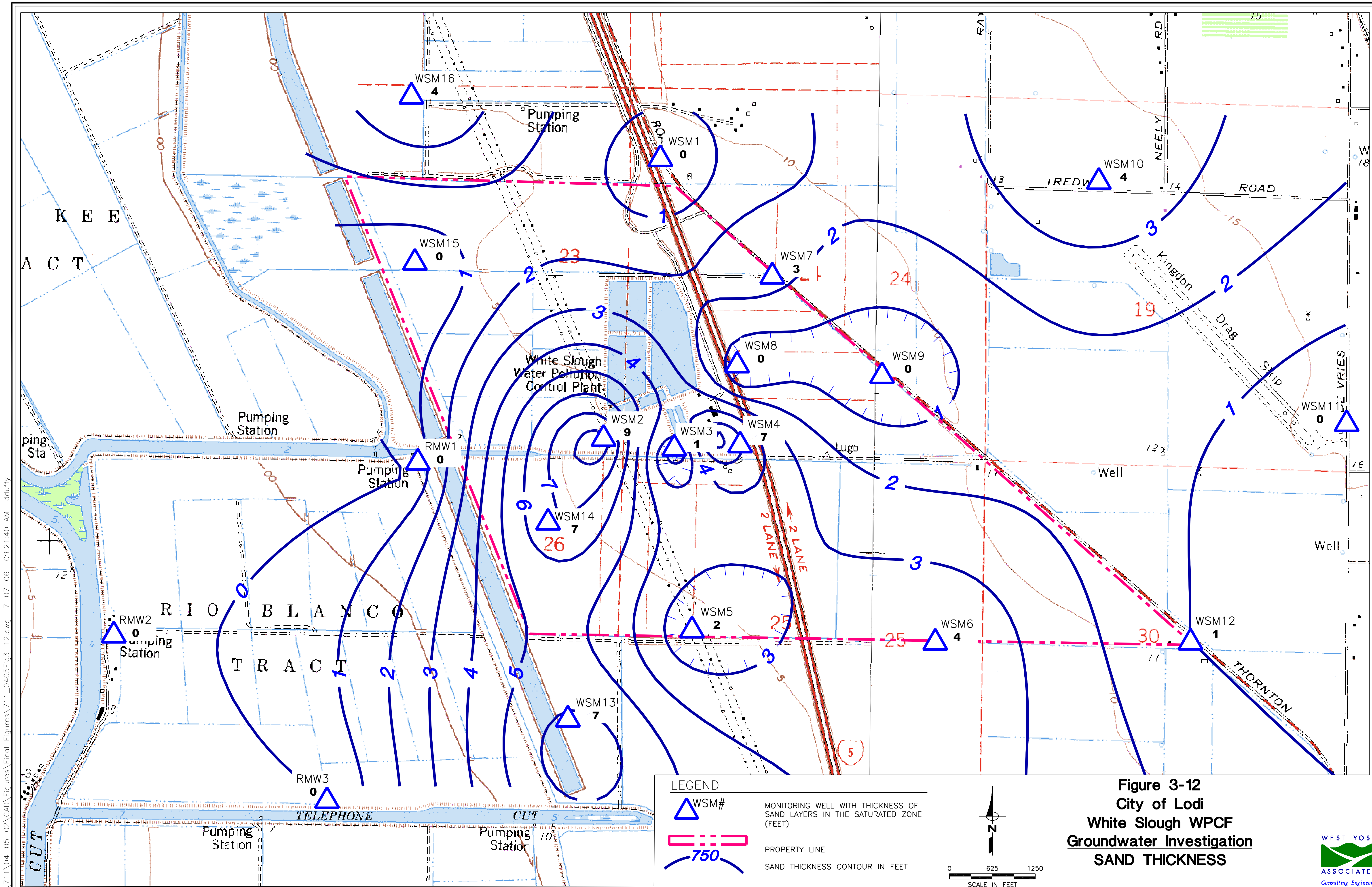


Figure 3-12
City of Lodi
White Slough WPCF
Groundwater Investigation
SAND THICKNESS

3.6 GROUNDWATER ELEVATIONS AND FLOW

This section provides an overview of regional groundwater flow followed by more detailed information on the site-specific groundwater conditions.

3.6.1 Regional Conditions

This section presents a discussion of the following regional groundwater conditions near the WPCF:

- Gradient
- Elevations

The regional groundwater information used to develop this section was obtained from groundwater elevation contour maps prepared by San Joaquin County (2004), supply well hydrographs prepared using data obtained from the DWR Water Data Library, and San Joaquin County Flood Control and Water Conservation District semiannual groundwater monitoring reports. Documentation of regional groundwater conditions is provided in Appendix A.

3.6.1.1 Gradient

Regional groundwater flow is to the east-southeast towards a cone of depression that persists throughout the year (San Joaquin County, 2004). This cone of depression is the primary control on groundwater flow directions in the vicinity of the WPCF. As shown in Appendix A-1 and A-2, the cone of depression was located approximately five miles east-southeast of the WPCF in the spring of 1998, but had moved two miles closer by fall 1998 (San Joaquin County, 2004). This shift increased the magnitude of the groundwater flow gradient in the vicinity of the WPCF but had little effect on the horizontal direction of regional flow.

Review of regional groundwater elevation data from the DWR Water Data Library and from the San Joaquin County Flood Control and Water Conservation District semi-annual reports (shown in Appendix A-3 through A-13) indicates that regional flow directions in the vicinity of the WPCF have been east-southeasterly to southeasterly during both spring and fall measurement periods since at least 1971. These data span both wet and dry year conditions and include the multi-year droughts experienced in 1976-1977 and 1986-1992, and wet years experienced in 1993, 1995 and 1998.

3.6.1.2 Elevations

The closest wells for which hydrographs are available at the DWR Water Data Library indicate that groundwater levels in the vicinity of the WPCF fluctuate seasonally and in response to varying levels of precipitation from year to year (Appendix A-14 through A-23). Fluctuations in groundwater elevations were greatest to the east of the WPCF, probably because the Delta area is subject to less pumping and more uniform recharge throughout the year, regardless of climatic conditions.

Groundwater elevations measured in production wells in the vicinity of the WPCF typically fluctuate by up to about 10 feet annually in response to seasonal variations in groundwater production and precipitation. The lowest groundwater elevations typically occur near the end of the irrigation season

(September), and the highest elevations occur near the end of the non-irrigation season (March). Nearly all the precipitation occurs during the non-irrigation season.

Variations in groundwater elevations over multi-year periods have occurred in response to wet and dry years. For example, groundwater elevations in well 03N05E24L (located on the northeastern corner of the WPCF property) fluctuated by about 10 between the fall of 1983, a very wet year, and the fall of 1992 (Appendix A-17). Fall 1992 was the end of a multi-year statewide drought (DWR, 2000).

3.6.2 Site-Specific Groundwater Conditions

This section presents a discussion of the following site-specific groundwater conditions at the WPCF:

- Gradient
- Elevations
- Velocities

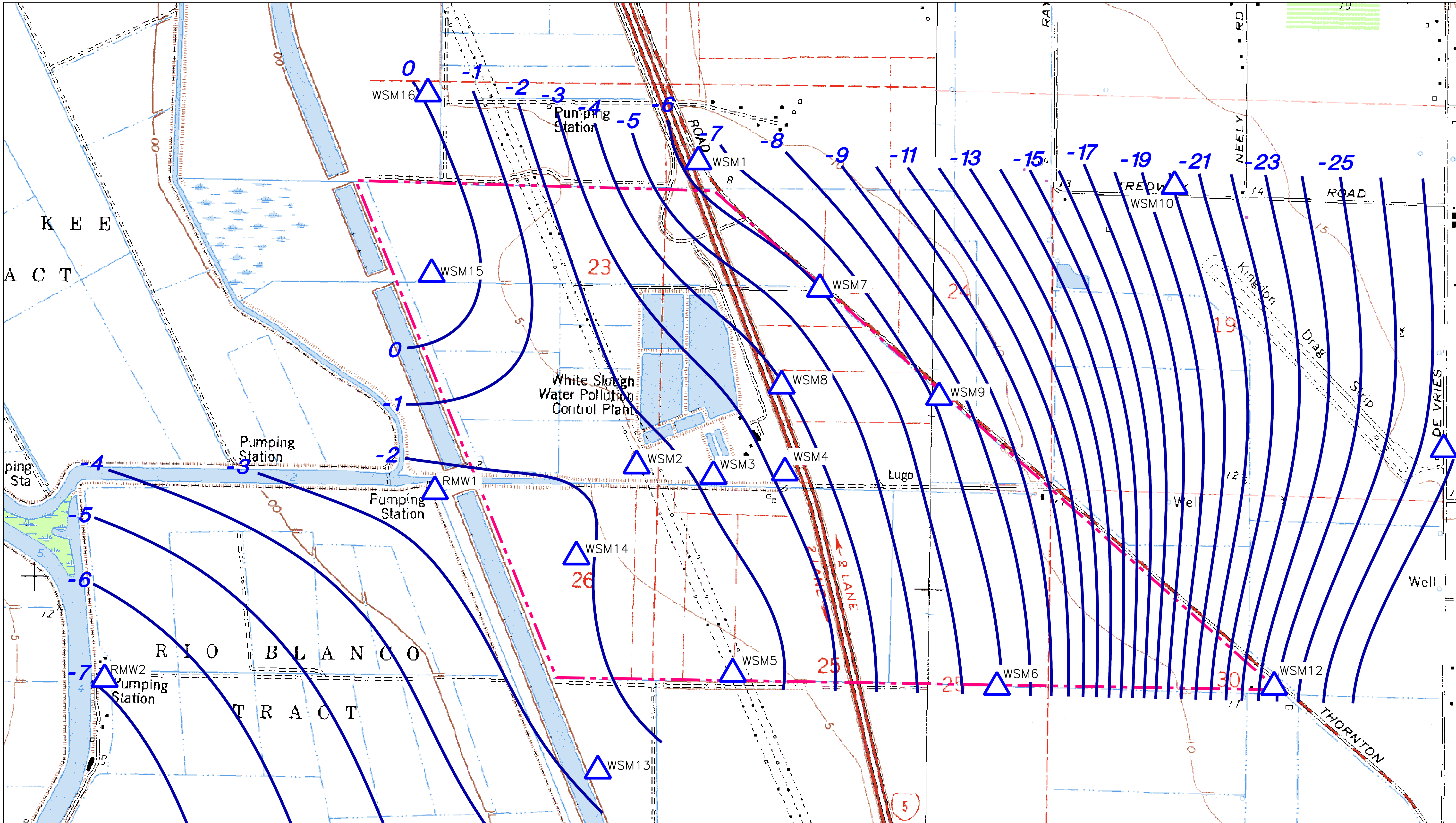
Much of the information presented in this section is based on the extensive site-specific groundwater elevation information and analyses available in previous reports produced on the City's behalf (Whitley, Burchett and Associates, 1989; Saracino Kirby Snow, 2000 and 2003).

3.6.2.1 Gradient

Review of the available groundwater level information indicates that the groundwater elevations and flow directions can be summarized by review of typical fall and spring groundwater elevation contour maps. The site-specific groundwater elevation contours for September 2003 and March 2004 are shown on Figures 3-13 and 3-14 respectively. As shown, most of the flow has an easterly component because of the large cone of depression located roughly three to five miles east-southeast of the WPCF (Section 3.6.1.1). However, there are also localized deflections in groundwater flow away from the regional drawdown cone. These localized groundwater gradients beneath the WPCF property are affected by the following:

- Local groundwater pumping
- Groundwater recharge

Additional discussion of these localized deflections is provided below. Note that these localized deflections are not apparent on the regional groundwater elevation contour maps because the regional maps are based on water levels in wells that are widely spaced in comparison to the WPCF monitoring wells. The closer spacing of the WPCF wells allows a more detailed analysis of site-specific groundwater elevations, which revealed evidence of the localized variation in groundwater gradients from regional trends.



LEGEND

WSM# MONITORING WELL

PROPERTY LINE

750 GROUND ELEVATION CONTOUR IN FEET

N

0 625 1250
SCALE IN FEET

Figure 3-13
City of Lodi
White Slough WPCF
Groundwater Investigation
GROUNDWATER CONTOURS
SEPTEMBER 2003

WEST YOST ASSOCIATES
Consulting Engineers

i:\711\04-05-02\CAD\Figures\Final Figures\711_0405Fig3-13.dwg 7-07-06 09:37:37 AM ddufty

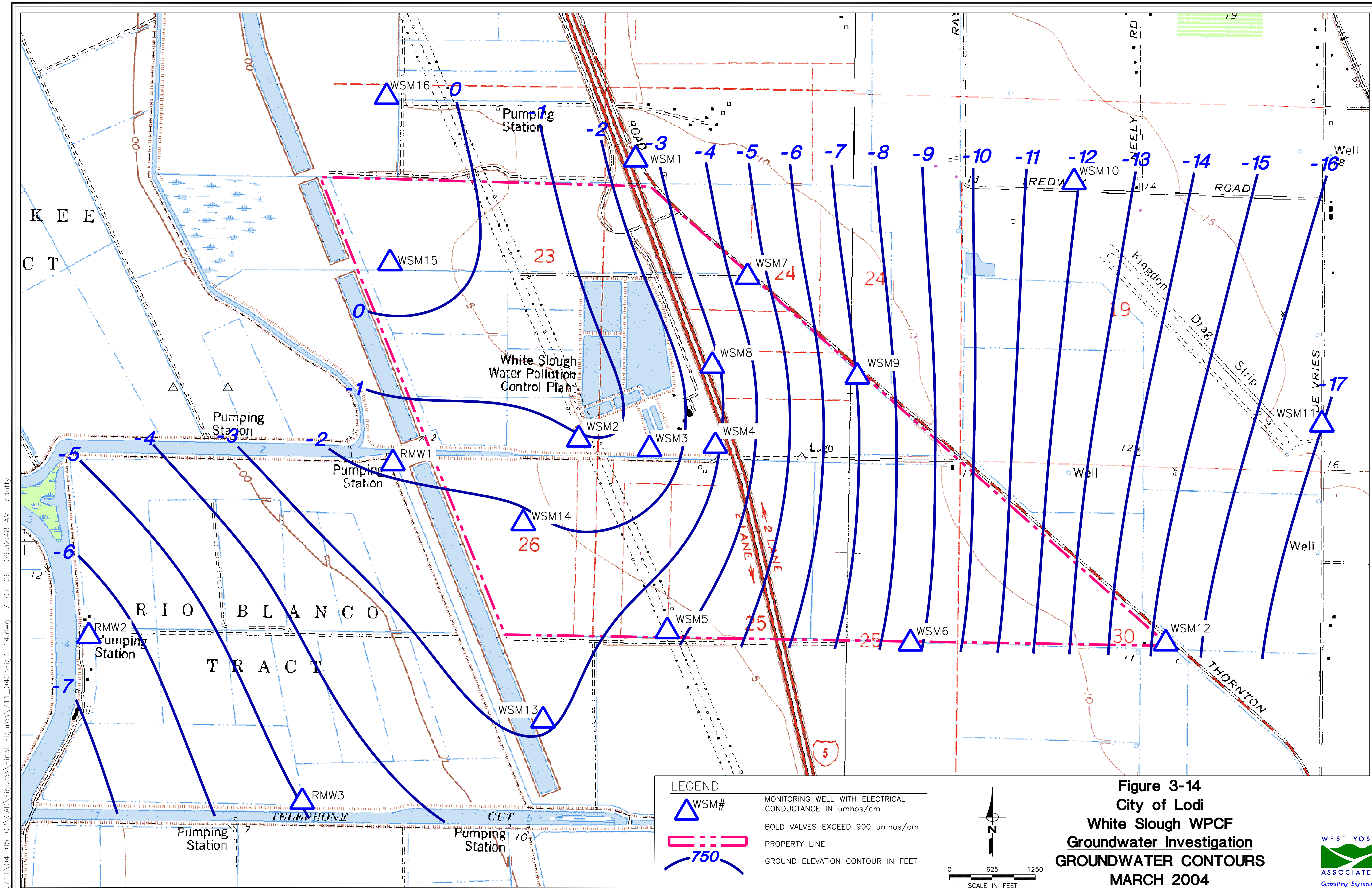


Figure 3-14
City of Lodi
White Slough WPCF
Groundwater Investigation
GROUNDWATER CONTOURS
MARCH 2004

I:\711\04-05-02\CAD\Figures\Final Figures\711_0405Fig3-14.dwg 7-07-06 09:32:48 AM ddufty

3.6.2.1.1 Local Groundwater Pumping

Groundwater flow is deflected to the north by probable groundwater pumping that is especially apparent northeast of monitoring well WSM-1. The amount of northerly deflection is greatest in the fall, as is expected based on typical groundwater pumping patterns (Figure 3-13 and 3-14). Additional monitoring wells located to the northeast of the pumping area would help provide important information on the affects of groundwater pumping on the local gradients in this area.

Southwesterly flow also occurs from beneath the southwestern corner of the agricultural reuse area. Volumetrically and in terms of the potential for transport, this flow is probably minor. The overlying agricultural reuse area is small, the hydraulic gradient is relatively low (0.001), and the hydraulic conductivity of the aquifer is probably very low based on the soil classification and the sand thickness observed in this area (Section 3.5.2). Therefore, the existing monitoring network should be adequate to characterize the gradients in this area.

3.6.2.1.2 Groundwater Recharge

Significant groundwater recharge originates in vicinity of the WPCF. The potential sources of recharge include the following:

- Irrigated Delta lands and related waterways to the west of the WPCF
- Surface-water-irrigated lands to the north and east of the WPCF
- Potential recharge sources from the WPCF storage ponds
- Recharge from the WPCF land application areas

Throughout the year, the highest groundwater elevations occur along a northwesterly-southeasterly trending axis located slightly west of the primary WPCF treatment and storage facilities. The highest elevations along this trend fluctuate between wells WMS-15 and WSM-16. These wells are located in the northwestern portion of the City's monitoring well network (Figures 3-13 and 3-14), suggesting a very low gradient between the City's land application area and the irrigation area to the north. WSM-2 generally has the highest water elevations of the wells located closest to the WPCF (although there are times when the highest water elevations are in WSM-3 and/or WSM-4). Therefore, the axis of recharge is typically offset to the west and north of the WPCF land application facilities, and the WPCF and associated land application facility is probably not the only source of recharge.

Regardless of its origin, groundwater flows away from the WPCF along divergent flow paths. Because the groundwater gradients tend to be low along the axis of recharge, relatively small changes in groundwater elevation could have a significant influence on the flow directions. An additional well located north of WSM-16 will help resolve the groundwater flow directions to the north of the WPCF. Furthermore, a new well located at the southwest corner of the WPCF will help resolve groundwater gradients in the southwestern portion of the observed axis of recharge, near the WPCF.

3.6.2.2 Elevations

The depth to groundwater beneath the WPCF property is also affected both by local pumping and the recharge that occurs on the western side of the City's property. Groundwater elevations in the immediate vicinity of the WPCF treatment facilities change little throughout the year, ranging from about –1 to –2 feet mean sea level (msl) in spring to about –2 to –4 feet msl in fall. Fluctuations of similar magnitude also occur in most of the monitoring wells in the agricultural reuse area.

In contrast, groundwater elevations change by about 10 feet seasonally at the eastern edge of the monitoring well network (Well WSM-11 on Figures 3-12 and 3-13). This differential results in a decrease in the groundwater gradient from about 0.003 in fall to 0.002 in spring as measured between wells WSM-4 and WSM-11. Most of the change in groundwater gradient occurs east of Thornton Road (Figures 3-12 and 3-13). This is probably because the areas east of Thornton Road are at least partially irrigated with groundwater and the agricultural areas to the west are not.

The water levels in wells WSM-2, WSM-3 and WSM-4 provide information regarding the depth to groundwater beneath the WPCF treatment and storage facilities. A summary of the depth to groundwater in these three wells measured between September 2001 and November 2005 is shown in Table 3-5. An additional monitoring well at the southwest corner of the WPCF (mentioned in Section 3.6.2.1.2) will also help to better define the depth to groundwater beneath the treatment and storage facilities.

Table 3-5. Depth to Groundwater in Wells Located Near the WPCF Treatment and Storage Facilities

Well	Median Feet Below Ground Surface	Maximum Feet Below Ground Surface	Minimum Feet Below Ground Surface
WSM-2	6.7	8.4	4.2
WSM-3	8.5	10.5	5.3
WSM-4	8.4	13.2	4.4

3.6.2.3 Velocities

Average groundwater flow velocities were calculated for several areas in the vicinity of the WPCF using Darcy's Law, the typical ranges of hydraulic conductivity for various soil types discussed in Section 3.5.2, and the hydraulic gradients presented in the preceding section. The calculated ranges are listed in Table 3-5.

As shown in Table 3-5, the groundwater transport velocities are very low, except within the sand bodies discussed previously in Section 3.5.2. These sands make up a small percentage of the aquifer materials encountered during drilling at the site. The sands probably comprise discontinuous lenses enclosed in the finer grained bulk of the aquifer. Minimal transport of site related constituents are anticipated to occur, except when source areas are underlain by sands.

Transport from these areas would be strongly influenced by the groundwater gradient and the geometry of the sand body.

Table 3-5. Calculated Average Groundwater Flow Velocities

Area[(a)]	Minimum K, ft/day	Maximum K, ft/day	Minimum Gradient	Maximum Gradient	Minimum Velocity, ft/day	Maximum Velocity, ft/day
Fine-gained sediments east of the WPCF	0.001	10	0.002	0.003	10^{-5}	0.1
Coarse-gained sediments east of the WPCF[(b)]	10	1,000	0.002	0.003	0.1	10
Fine-gained sediments southwest of the WPCF	0.001	10	0.001	0.001	10^{-6}	0.01

(a) All velocities were calculated assuming an effective porosity of 0.25. Velocities were rounded to the nearest order of magnitude.
(b) Sand bodies were assumed to be continuous and oriented parallel to the groundwater flow direction.

3.7 SUMMARY AND RECOMMENDATIONS

A significant amount of information is available to characterize the environmental setting in the vicinity of the City's property. This information provides the foundation for assessing the groundwater conditions surrounding these properties. The environmental conditions discussed in this section that are likely to have the greatest effect the groundwater conditions near the site are as follows:

- Surface Water Resources
- Soils
- Geology
- Groundwater Elevations and Flow

3.7.1 Surface Water Resources

The western portion of the City's property falls within the Delta, midway between the Mokelumne and Calaveras Rivers. Sections of the never-completed peripheral canal of the U.S. Bureau of Reclamation Central Valley Project are also located near the western edge of the agricultural reuse areas. Note that the peripheral canal is not connected to regional surface water bodies and any water contained in the canal sections is attributable to precipitation and interaction with shallow groundwater. There are no major surface water features located to the east of the City's property. The presence or absence of surface water resources in these two regions strongly affects the amount groundwater recharge and pumping that occurs in the respective regions. Both of these factors, in turn, affect the groundwater elevations (or depth to groundwater) and the overall groundwater gradient.

3.7.2 Soils

Soil conditions also vary across the site, which can have an affect on the potential for irrigation water to move past the root zone and impact underlying groundwater. The mapped soil types are the Guard and Devries soil series.

The Devries soil is located predominantly on the eastern half of the City's property. The water permeability class for this soil series is moderately rapid and the rooting depth is limited to 20 to 40 inches because of a shallow hardpan.

The Guard soil is located predominantly on the western half of the City's property. The water permeability for Guard soil series is slow. There are two soil phases of the Guard series in the WPCF vicinity, where the major distinction between these phases is the presence or absence of a perched water table (which affects rooting depth). Where the perched water tables are present, the effective rooting depths are limited to about 20 to 40 inches. Where perched water tables are not present, the effective rooting depth is generally greater than 60 inches. The Guard phase with a perched water table is mapped in the northwestern portion of the City's property, near the peripheral canal; and the areas where the perched water table are not present include the more south-easterly portions of the City's property.

3.7.3 Geology

The geologic conditions do not vary significantly across the site; however, these conditions should also be considered when assessing the potential for the City's practices to affect underlying groundwater conditions. The WPCF lies on a westward thickening and dipping sequence of sedimentary rock and unconsolidated sediment that underlies the eastern flank of the Central Valley. This sediment sequence consists of sedimentary rock overlain by unconsolidated alluvial and fluvial sediments.

Site-specific geologic conditions were assessed using the logs of test borings and 19 monitoring wells (these wells were installed by the City to monitor groundwater levels and quality near the WPCF). The sediments encountered during drilling are predominately fine-grained, ranging from silts and clays to silty fine sands. Typical hydraulic conductivity values for these materials range from roughly 0.001 to 10 feet per day (Freeze and Cherry, 1976). Several of the wells penetrate coarser grained layers without appreciable fine grained material intermixed. Typical hydraulic conductivity values for these materials range from roughly 10 to 1,000 feet per day (Freeze and Cherry, 1976).

In general, the average groundwater velocities are very low at the WPCF and vicinity, except within the coarser grained layers. However, these sands make up a small percentage of the aquifer materials encountered during drilling at the site, and probably comprise discontinuous lenses enclosed in the finer grained bulk of the aquifer. Therefore, minimal transport of site related sources is anticipated to occur, except when source areas are underlain by sands. Transport from these areas would be strongly influenced by the groundwater gradient and the geometry of the sand body.

Although not recorded in the drilling logs, observations made by WYA and facilities staff indicate that cemented and hard pan zones are present within the sediments at a depth of six to ten feet. These zones would tend to lower the vertical hydraulic conductivity of the sediments and impede the vertical flow of groundwater.

3.7.4 Groundwater Elevations and Flow

Regional groundwater flow is to the east and east-southeast towards a cone of depression that persists throughout the year (San Joaquin County, 2004). This cone of depression is a result of significant groundwater pumping that occurs to the east of the WPCF property and is the primary control on groundwater flow directions in the vicinity of the WPCF. However, there are localized deflections in groundwater flow away from the regional drawdown cone.

The land surface elevations on the City's property range from approximately 0 to 5 feet mean sea level (msl) near the western edge of the City's property to approximately 10 feet above msl near the eastern edge of the property and approximately 15 feet above msl near the eastern edge of the City's groundwater monitoring well network. Median groundwater elevations range from just below msl near the western edge of the City's property to greater than 20 feet below msl near the eastern edge of the City's monitoring well network. Therefore, depth to groundwater spans from a few feet below the surface in the City's western-most monitoring wells to more than 30 feet below the surface in the eastern-most groundwater monitoring wells.

Nearly all the precipitation occurs during the non-irrigation season. Therefore, the groundwater levels in the vicinity of the WPCF fluctuate seasonally due to pumping during the irrigation season and in response to varying levels of precipitation that occur from year to year during the non-irrigation season (the lowest groundwater elevations typically occur near the end of the irrigation season and the highest elevations occur near the end of the non-irrigation season).

Fluctuations in groundwater elevations are greatest to the east of the WPCF, and typically fluctuate by up to about 10 feet annually in both the production wells and in the City's shallow monitoring wells in this vicinity. Data collected from the City's monitoring wells indicate that groundwater flow northeast of the WPCF is deflected to the north-northeast by probable localized groundwater pumping. Additional monitoring wells are needed to better evaluate groundwater gradients in this area.

Groundwater flows from the southwestern portion of the WPCF property to the south-southwest. However flow velocities are very low based on the aquifer permeability and groundwater gradients. Therefore, volumetrically and in terms of the potential for transport, this south-southwesterly flow is probably minor and no additional monitoring wells are needed to evaluate it.

Groundwater elevations in the western portion of the City's property only fluctuate a few feet seasonally, indicating that this is an area of significant groundwater recharge. The highest groundwater elevations occur in the northwest portion of the City's monitoring well network, slightly west of the primary WPCF treatment and storage facilities. This indicates that the City's facilities are probably not the only source of recharge. The Delta and surface-water-irrigated lands north and east of the WPCF are other potential sources of recharge west and north of the City's property.

A new well located to the north of the WPCF property (north of WSM-16) will help resolve groundwater gradients and flow directions along this zone of recharge. A new well located near the southwest corner of the WPCF treatment facilities will help resolve the depth to groundwater and groundwater flow directions in the immediate vicinity of the WPCF.