

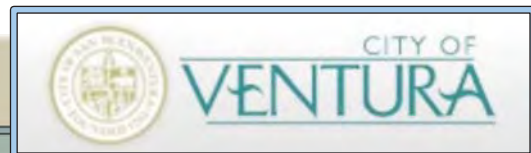
HOPKINS GROUNDWATER CONSULTANTS, INC.

PRELIMINARY HYDROGEOLOGICAL STUDY

PHASE 3 SANTA CLARA RIVER ESTUARY GROUNDWATER SPECIAL STUDY VENTURA, CALIFORNIA

Prepared for:
City of San Buenaventura

February 2018





February 19, 2018

Project No. 01-009-07B1

Ventura Water

Post Office Box 99

Ventura, California 93002

Attention: Gina Dorrington
Wastewater Utility Manager

Subject: City of Ventura, Phase 3 Santa Clara River Estuary Groundwater Special Study,
Ventura, California.

Dear Ms. Dorrington:

PURPOSE AND SUMMARY

The purpose of this letter-report is to comply with the requirements of the City of Ventura, Ventura Water Reclamation Facilities' NPDES permit which states in section VI.C.2.b.iii:

"Groundwater Special Study - The Discharger must perform a special study to document the interaction between the estuary, discharge, and groundwater and determine if the beneficial use of MUN applies to the water impacted by the discharge."

In the Fact Sheet of the NPDES permit, section III.C.1.b there is further explanation of this special study requirement summarized here as several major points:

- i) The wildlife ponds and estuary are known to be hydraulically connected to the underlying groundwater basin, the unconfined and perched Oxnard Plain Groundwater Basin. Effluent from the facility must not negatively impact beneficial uses of the groundwater basin.
- ii) The State's drinking Water Policy states that all groundwaters of the state are considered to be potentially suitable for domestic supply unless Total Dissolved Solids (TDS) is greater than 3,000 mg/l, there is contamination that cannot be treated, or the source does not provide sufficient yield (average yield of 200 gallons per day).
- iii) The special study required includes investigation of the groundwater basin and the interaction between the groundwater and the ponds and estuary. Results of the study should be sufficient to determine whether additional controls to protect the groundwater are necessary and if the groundwater is a potential source of drinking water.

The major findings of this study are as follows:

- The Santa Clara River Estuary (SCRE or Estuary) is located within the Mound Subbasin, Department of Water Resources (DWR) Bulletin 118 Subbasin number 4-004.03 (not the Oxnard Subbasin, Bulletin 118 Subbasin number 4-004.02) (DWR, 2003)0
- The Mound Basin has a semi-perched aquifer in the vicinity of the estuary that extends to a depth of approximately 40 to 50 feet below mean sea level (MSL) and is underlain by clay layers that extend to a depth of approximately 300 feet below MSL, which separate the semi-perched aquifer from the main groundwater production zones.
- There are no known wells producing from the semi-perched aquifer zone (based on Ventura County records) with the shallowest well found having a well screen section starting at a depth of 360 feet below ground surface, which is below the clay layer.
- The semi-perched or shallow groundwater is of poor quality with historical data showing TDS values up to 3,907 milligrams per liter (mg/l). These higher values likely reflect the influx of seawater into the Estuary.
- The shallow groundwater inland of the SCRE has high enough elevations to maintain a gradient toward the ocean preventing seawater that intrudes the semi-perched aquifer from traveling landward of the Estuary.

Based on these findings, it is concluded that a MUN designation is not appropriate for the semi-perched aquifer beneath the Estuary or for surface water within the Estuary.

INTRODUCTION

This letter-report was prepared at the request of the City of Ventura (City) to evaluate hydrogeologic conditions in the vicinity of the SCRE. Stillwater Sciences (Stillwater) is currently preparing the City of Ventura Special Studies – Phase 3: Assessment of the Physical and Biological Conditions of the Santa Clara River Estuary, Ventura County, California (Phase 3 report) (Stillwater, 2018, [public draft November 1, 2017, interim draft January 1, 2018]). The City has requested Hopkins Groundwater Consultants, Inc. to address several specific hydrogeologic conditions for the semi-perched aquifer beneath the SCRE, including characterization of the semi-perched aquifer soils and clay aquitard/cap, groundwater flow direction, water quality, and potential for seawater intrusion. This hydrogeologic study is intended to supplement the Phase 3 studies being performed by the City and complete the characterization of groundwater flow in the vicinity of the SCRE. The SCRE project area is shown on Plate 1 – Project Location Map. The area within which pertinent data were available and utilized for the study is shown on Plate 2 – Study Area Location Map.

Data Sources

The Phase 3 Report (Stillwater, 2018) is the third phase of comprehensive studies performed by Stillwater for the SCRE. The Phase 3 study includes physical monitoring of surface water and groundwater at numerous locations in the SCRE over a 22-month period (from about January 28, 2015 through December 6, 2016), evaluation of the monitoring data, and reporting to summarize the findings. Prior to the Phase 3 study, Stillwater performed Phase 1 and 2 studies for the SCRE that also included data collection and monitoring, evaluation, and reporting.

This groundwater study incorporates data from all 3 Phases of studies, as well as hydrogeological data available from nearby monitoring wells, water wells, and oil wells. Additional sources of data include hydrogeological and geotechnical studies conducted for the Ventura Water Reclamation Facility (VWRF), Ventura Harbor Keys Dredge Material Impoundment Basin, and the Harbor Boulevard Bridge over the Santa Clara River. These data are listed in the reference section of this letter-report, are used to describe the local hydrogeologic setting, and used to construct a shallow subsurface profile along the coastline through the SCRE.

FINDINGS

Local Hydrogeologic Setting

The SCRE is located in the southwestern portion of the Mound Basin, however, a portion of the study area at McGrath State Beach extends into the adjacent Oxnard Plain Basin. A review of available geological data from deep water wells and oil wells indicates that the basins are separated by the McGrath Fault zone (also known as the Montalvo Fault, [Yeats, 1988]) which has a vertical offset in the deeper freshwater aquifer zones of up to approximately 500 feet. Plate 3 – Hydrogeological Cross-Section Location Map indicates the approximate Mound Basin boundary (as delineated by Bulletin 118 [DWR, 2003]), the location of the McGrath Fault zone, the approximate location of wells with pertinent subsurface data, and the location of the hydrogeological cross-section lines prepared for this study. Plates 4 through 8 – Hydrogeological Cross-Section A-A', B-B', C-C', D-D', and E-E' respectively, show our interpretation of the regional subsurface hydrogeology within the vicinity of the study area.

As described by Staal, Gardner and Dunne, Inc. (SGD, 1991), the southwestern portion of the Mound Basin is underlain by undifferentiated recent and older alluvial sediments that extend to a depth of about 300 feet. The interpretation of data provided by this study indicates the undifferentiated recent and older alluvial sediments likely extend to a greater depth of approximately 500 feet in the vicinity of the SCRE. Aquifer zones in the Mound Basin that comprise the uppermost coarse-grained layers available for groundwater beneficial uses, including municipal, are located within the base of the older alluvial sediments and are separated from the semi-perched aquifer by approximately 300 feet of fine-grained sediments (aquiclude materials). These aquifer zones are believed to be equivalent to either the Oxnard Aquifer or Mugu Aquifer in the Oxnard Plain Basin.

Groundwater in the recent alluvium that comprises the semi-perched aquifer in the vicinity of the SCRE is unconfined and receives recharge as; a) direct precipitation, b) underflow from the Mound Basin to the north and the Oxnard Plain Basin to the south, c) surface water infiltration from the Santa Clara River (SCR), and d) infiltration of irrigation water (SGD, 1991).

Shallow Subsurface Materials

An interpreted shallow subsurface profile in the vicinity of the SCRE was constructed at the location presented on Plate 9 – Hydrogeological Cross-Section F-F’ Location Map. As shown, the north-south Cross-Section F-F’ extends from north of the Ventura Harbor southward through the SCRE and across the McGrath State Beach area. The subsurface profile shown in Plate 10 – Hydrogeological Cross-Section F-F’ was compiled from existing data obtained from water well and oil well descriptive logs and electrical resistivity surveys, hydrogeologic studies and geotechnical data from the VWRf (SGD, 1991, and Fugro, 1996), the Harbor Boulevard Bridge over the SCR (Ventura County, 1955), and Ventura Keys Dredge Material Impoundment Basin study (SGD, 1991).

A cross-section constructed as part of the City’s dredge project study (SGD, 1991) extends generally east-west from the VWRf eastward through the Olivas Links golf course. The location of the cross-section is shown on Plate 9, and a copy is included in Appendix A – Ventura Keys Dredge Material Impoundment Basin Data along with other pertinent hydrogeological data.

As depicted on Cross-Section F-F’, the subsurface conditions in the SCRE area consist of about 40 to 50 feet of primarily granular coarse-grained alluvial sediments (sand, silty sand with gravel lenses) to an elevation of -40 feet underlain by primarily fine-grained clay (aquiclude) deposits with interbedded coarse-grained sand and gravel lenses to elevation -300 feet. The upper coarse-grained unit is referred to as the “semi-perched aquifer” and the lower predominantly fine-grained unit is referred to as the “clay cap.” In the Oxnard Plain Basin south of the McGrath Fault zone, the coarse-grained permeable Oxnard Aquifer is located beneath the base of the fine-grained clayey aquiclude units at a depth of approximately 150 feet (see Cross-Section F-F’).

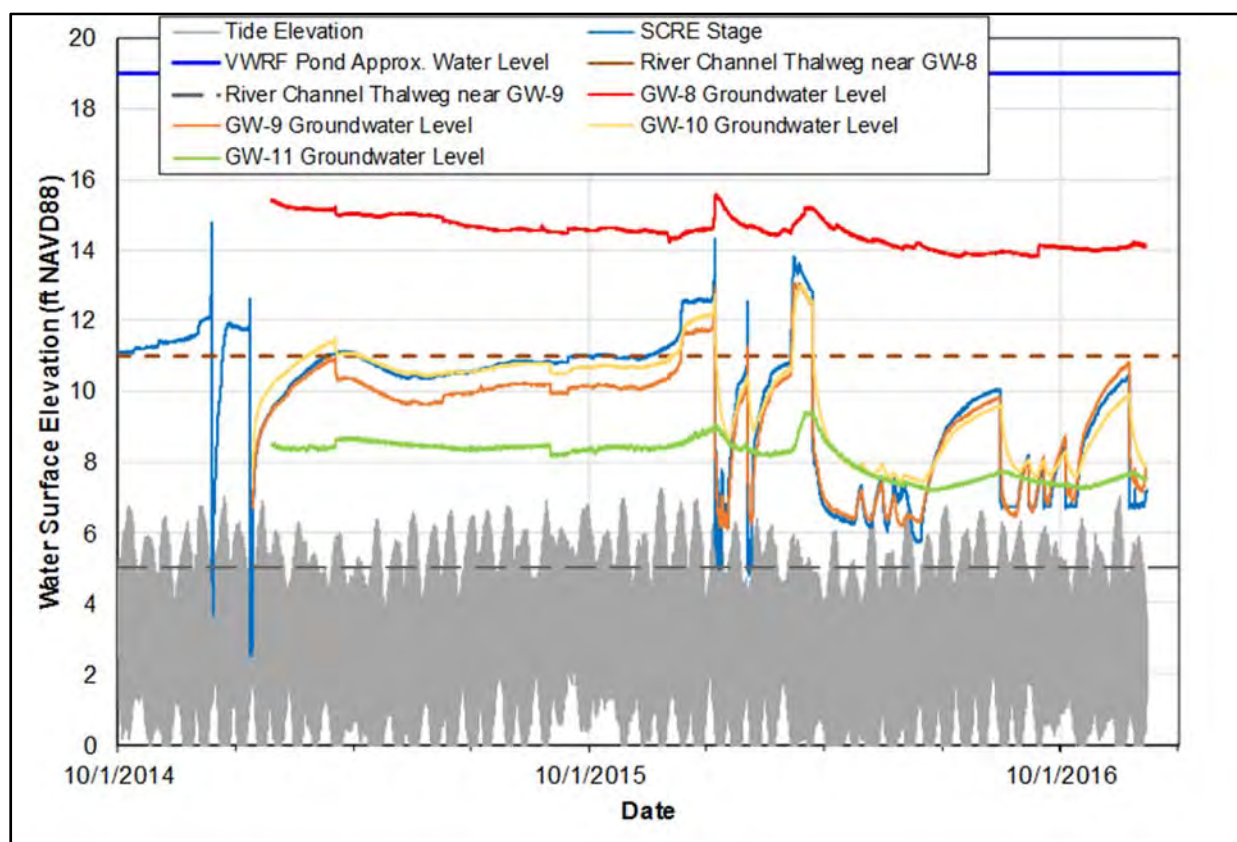
North of VWRf, the subsurface materials in the Ventura Harbor area consist of a thin layer of granular surficial soil underlain by nearly 300 feet of clay and sandy clay soil (see Cross-Section F-F’). Discussions with City of Ventura engineering staff (Mr. Brad Starr) indicate the Ventura Harbor has been dredged to elevation 18 feet below mean lower low water (MLLW) level. We note that an elevation of 18 feet below MLLW is equal to an elevation of approximately -20 to -21 feet MSL. Cross-Section F-F’ depicts the Ventura Harbor dredge elevation at about 20 feet below MSL.

Groundwater Evaluation by Stillwater

As described in the Phase 3 report (Stillwater, 2018), groundwater along the north bank of the SCR near the VWRf wildlife ponds and directly east of Harbor Boulevard, *“that portion of the north-bank floodplain situated closer to the SCRE, had groundwater levels responding to changes in SCRE stage in a similar fashion as that observed in the south bank wells along McGrath State Beach. In these four wells (GW-8 through GW-11), groundwater levels typically fluctuated*

with changes in SCRE stage, river flow, and direct precipitation (Figure 3-21a), with groundwater-levels in wells positioned closest to the SCRE (i.e., GW-9 and GW-10) coinciding the most with SCRE stage.” For reference, Figure 1 – Response of Groundwater Levels to Changes in SCRE Stage (Stillwater Figure 3-21a) is included below and the approximate location of monitoring facilities used in the Phase 3 Report (Stillwater, 2018) is indicated on Plate 11 – Designated Monitoring Station Location Map.

Figure 1 – Response of Groundwater Levels to Changes in SCRE Stage (Stillwater Figure 3-21a)



These data show that under high SCRE stage heights, MW-9 and MW-10 were consistently lower than the SCRE and indicate significant flow to the north toward MW-11. The reverse is true under low stage conditions where groundwater flow moves from MW-10 and MW-11 toward MW-9 and into the SCRE.

The Phase 3 Report (Stillwater, 2018) went on to observe that, “Groundwater levels were consistently higher than the nearby portion of the river bed elevation (or “thalweg”) by approximately 2 to 8 feet, and were consistently lower than the approximate water surface levels in the VWRP Wildlife/Polishing Ponds located to the west. The correlation between groundwater levels and SCRE stage did not appear to deviate during the presumed irrigation season in the drier

months, indicating that irrigation activities at Olivas Links golf course and the nearby agricultural fields either: (1) do not cause seasonal changes in the local water table, or (2) do not influence the water table to the same degree as does the SCRE water volume.”

The Olivas Links golf course uses recycled water from the VWRf for irrigation and does not utilize a water well. The adjacent farmland north of Olivas Park Drive in the Mound Basin and south of the Santa Clara River in the Oxnard Plain Basin have wells constructed in the deeper more productive aquifer zones and do not pump water from the semi-perched aquifer zone.

The Phase 3 Report (Stillwater, 2018) concludes that “groundwater flow was consistently directed toward the SCRE during open-mouth periods and away from the SCRE during closed-mouth periods (see Figure 3-20a). As such, the groundwater-flow gradient generally has an inverse relationship with SCRE stage (Figure 3-21b).”

We concur with the Phase 3 Report (Stillwater, 2018) general assessments of groundwater flow proximate to the SCRE. In addition, available data indicate a prevailing west-southwest regional groundwater gradient exists in the semi-perched aquifer within the study area regardless of whether the SCR mouth is open or closed. As shown on Plate 12 – Groundwater Elevation Contour Map, October 1, 2015 (Berm in Place), we see the regional gradient in the semi-perched aquifer results in groundwater flow toward the coastline. In the vicinity of the SCRE, the groundwater gradient flattens out and flows into and around the estuary. Under these conditions, groundwater exits the coastal sediments as underflow; 1) through the SCRE berm along the beach, 2) into the Ventura Harbor to the north, 3) through the shoreline south of the river, and 4) into McGrath Lake to the south.

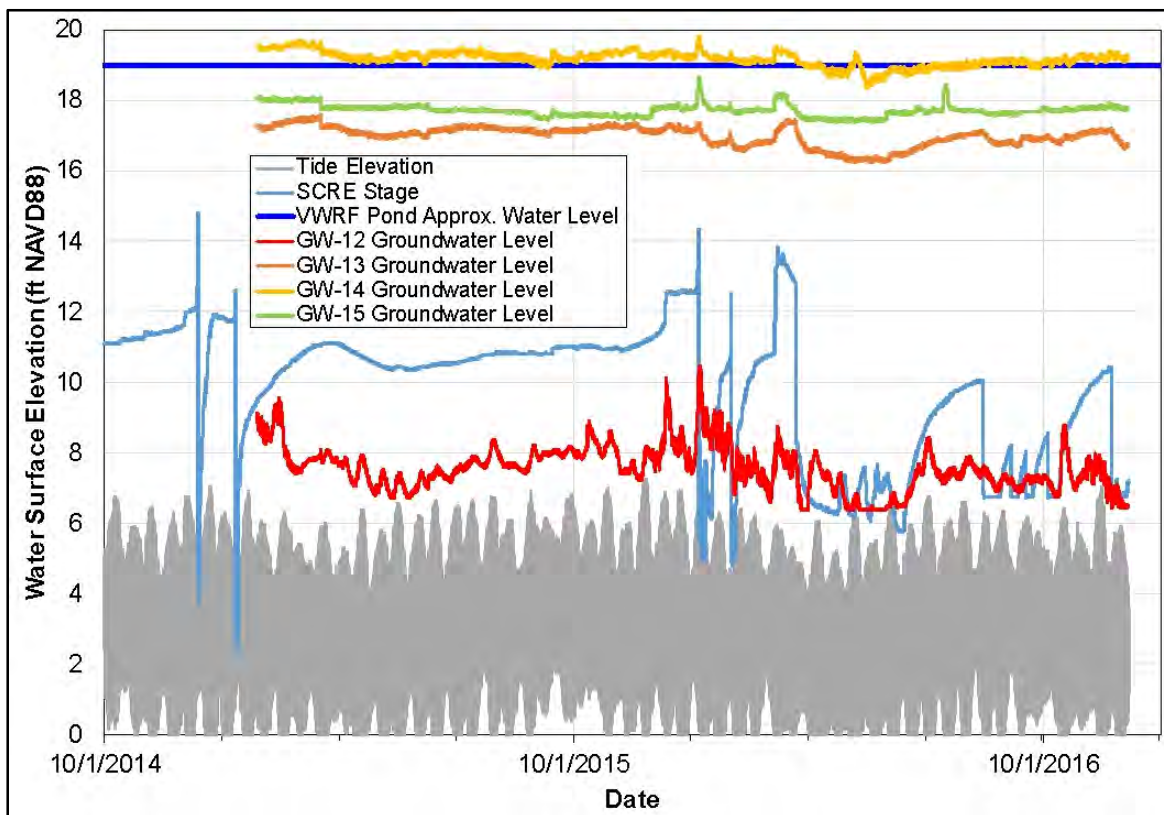
Plate 13 – Groundwater Elevation Contour Map, January 17, 2016 (Berm Breached) shows a similar prevailing regional gradient inland of the SCRE. The regional gradient under these conditions changes in the vicinity of the SCRE and forms a groundwater divide south of the SCRE where flow moves westward to the coastline, northward toward the estuary and the Ventura Harbor, and southward toward McGrath Lake. The available data indicate that changes in the SCR mouth conditions cause groundwater flow in the vicinity of the SCRE to range back and forth between these 2 extremes as the estuary drains and refills (see Plates 12 and 13).

Figure 2 – VWRf Wildlife Pond Monitoring Wells shows the approximate monitoring well locations. Data from the monitoring wells along the southern edge of the VWRf wildlife ponds (GW-13, GW-14, and GW-15) show only minor changes in water level due to the influence of changes in the SCRE stage. These data also show that the recharge mound in the immediate vicinity beneath the ponds remains above the SCRE stage. Figure 3 – Response of Groundwater Levels in Wildlife Pond Monitoring Wells (Stillwater Figure 3-20a) is included below for reference of these study data (Stillwater, 2018).

Figure 2 – VWRF Wildlife Pond Monitoring Wells



Figure 3 – Response of Groundwater Levels in Wildlife Pond Monitoring Wells (Stillwater Figure 3-20a)



The data from wildlife pond monitoring wells indicate that the fairly constant recharge from the VWRP ponds creates a groundwater mound and dominates the underlying groundwater elevations. The localized mound causes flow westward toward the coastline, southward toward the SCRE and northward toward Ventura Harbor. The westernmost monitoring well, GW-12, located on the west side (beach side) of the wildlife ponds, shows considerably lower groundwater elevations (10 to 15 feet) than the other 3 wells. This well shows very little mounding effect from the wildlife ponds, virtually no response to SCRE stage oscillations, and it fluctuates in a manner that shows tidal and perhaps storm surge influences. This may reflect the presence of highly permeable river bed deposits that are present in the vicinity of MW-12 and quickly transmit groundwater laterally toward the coastline.

Based on our interpretation and evaluation of these available data, we deduce that while the SCRE stage locally influences groundwater levels in monitoring wells GW-9 and GW-10, the groundwater conditions east of Harbor Boulevard are influenced primarily by SCR flows, regional precipitation, and irrigation return flows that recharge the semi-perched aquifer. This is shown by the groundwater levels in MW-8 which consistently remained at elevations between 14 and 15 feet above MSL throughout the observation period. The groundwater elevation in MW-8 was always above peak SCRE stage height (see Figure 1) and demonstrates that local groundwater conditions within the semi-perched aquifer, a short distance inland of the SCRE, provide protective heads and a constant offshore gradient.

McGrath Lake

Review of the monitoring well data for GW-1 located within about 800 feet of the SCRE, and GW-2 and GW-3, located about 2,000 and 3,500 feet south of the SCRE, shows an inverse groundwater flow relationship with the SCRE stages as described by the Phase 3 Report (Stillwater, 2018). We note the level of McGrath Lake is controlled by pumping water out of the lake and was typically maintained at an elevation of about 6 to 7 feet above MSL during the period from January 28, 2015 to December 6, 2016, except for a one-month-period in March 2016 when the lake level increased to approximately 9 feet above MSL. The higher level appears to be related to seasonal precipitation and runoff that resulted in corresponding increases in the SCRE stage and groundwater elevation in monitoring wells GW-1 through GW-3 for that period of time.

Because the three coastal monitoring wells are in a line along the shore, they show a linear gradient, not a plane surface. Groundwater contours shown on Plates 12 and 13 utilize the closest study wells perpendicular to the coastline and indicate groundwater flow is directed southward toward McGrath Lake when the SCR berm is in place and northwestward toward the SCRE when the berm breaches. Based on the available shallow groundwater monitoring well data south of the SCRE, it appears the groundwater inflow into McGrath Lake is likely dominated by native groundwater inflow from the shallow semi-perched aquifer east of McGrath Lake under most if not all SCRE conditions. The prevailing groundwater flow gradient east of Harbor Boulevard is established by the relatively constant elevated heads observed in the inland monitoring wells located just west of Victoria Avenue (see Plates 12 and 13).

Groundwater Quality/Seawater Intrusion

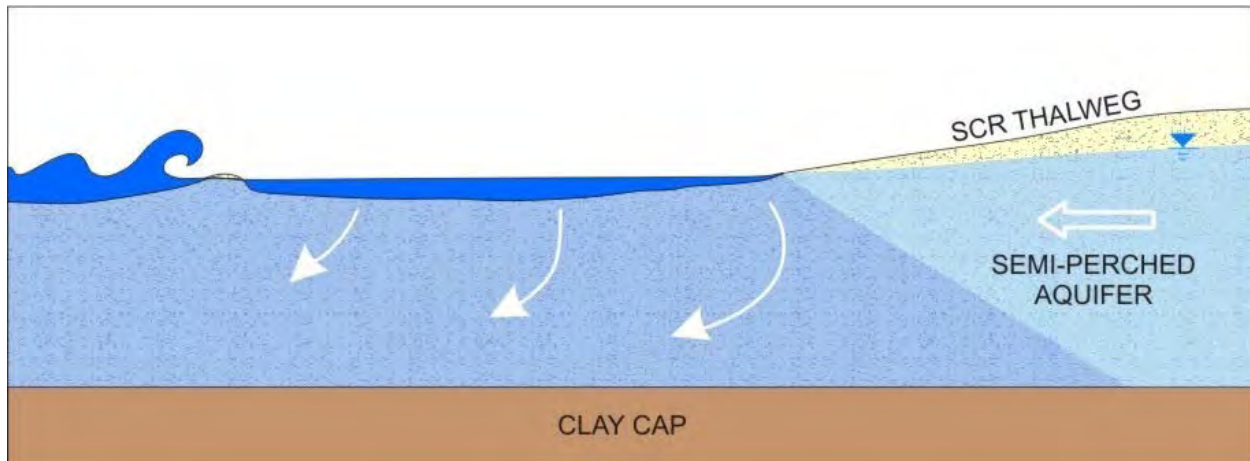
The SCRE studies present a large amount of data and analyses relative to surface water quality and interaction between surface water and groundwater flow into the SCRE from the adjacent VWRP wildlife ponds. This study focuses on the groundwater quality in the semi-perched aquifer in the immediate vicinity of the SCRE and the potential for seawater intrusion during times when wave run-up flows over the berm and contributes substantial seawater to the surface water impounded in the estuary. As depicted on the groundwater elevation contour maps shown on Plates 12 and 13, the overall groundwater flow direction for the semi-perched aquifer is westward, generally parallel to the SCR.

As indicated on Plate 9, the southern portion of Ventura Harbor is located about 500 to 1,200 feet north of the VWRP wildlife ponds and approximately 2,000 feet north of the SCRE. As depicted on Cross Section F-F' (see Plate 10), the Ventura Harbor dredged elevation of about 20 feet below MSL is well below the thalweg in the SCRE. Based on internet research, the Ventura Harbor commenced operations in 1963, and ocean water has been present in the Harbor for over 50 years. To date, none of the shallow monitoring wells constructed in the vicinity of the harbor indicate seawater intrusion into the semi-perched aquifer.

The City's report for the Ventura Keys dredge material impoundment basin (SGD, 1991) describes the hydrogeologic setting and groundwater quality in the semi-perched aquifer for the impoundment basin on the east side of Harbor Boulevard north of the SCR. The report describes the groundwater in the semi-perched aquifer at the dredge impoundment site as *"calcium-magnesium-sulfate in chemical character, with TDS (total dissolved solids) concentrations ranging from 1,268 to 3,596 parts per million (ppm)."* Based on their evaluation, the report concluded *"the semi-perched aquifer has been affected by water recharging the system from the Santa Clara River, irrigation water return flow (Olivas Park Golf Course and upgradient agriculture), and seepage from the VWRP clarification ponds. A comparison of semi-perched aquifer water quality to the effluent from the treatment plant was made using a trilinear analyses diagram. These data suggest the effluent to be of similar quality to the semi-perched aquifer water, with lower TDS on average."*

The study also reported that higher TDS and electrical conductivity (EC) concentrations were observed in the western portion of their study area (monitoring well MW-7 adjacent to the VWRP wildlife ponds). The study indicated *"monitoring well MW-7 has an EC of 5,880 μ mhos/cm and a TDS concentration of 3,907 ppm"* while the easternmost monitoring well near the Olivas Park Golf Course (MW-4) *"displayed the lowest EC and TDS values of 2,160 μ mhos/cm and 1,268 ppm, respectively."* They concluded *"these numbers suggest degradation in water quality to a more brackish nature to the west"* (SGD, 1991). We believe these data reflect the influx of seawater into the estuary, where mixing and above ground movement of the saltier water inland of the Harbor Boulevard Bridge contributes to the elevated salt levels in the underlying semi-perched groundwater. Figure 4 – SCRE Breached Berm and Refill Conditions conceptually shows the mixture of the various water sources that refill the estuary after the beach berm begins to re-establish and the furthest point inland where seawater can encroach.

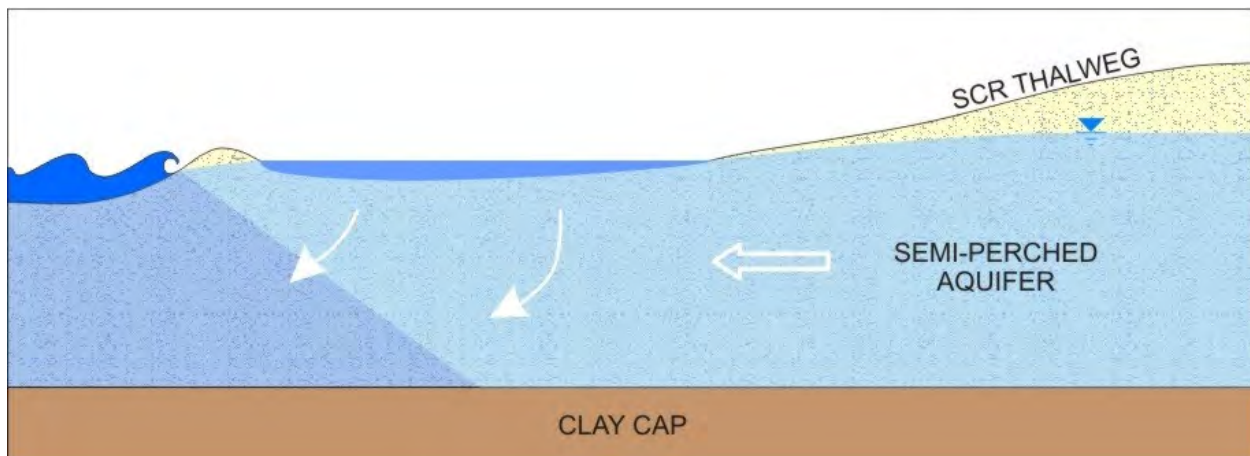
Figure 4 – SCRE Breached Berm and Refill Conditions



Under these conditions, there is likely moderate mixing of the denser brackish water in the estuary with the underlying groundwater as a result of the higher density of the saltwater mixture in the overlying body of water in the SCRE. After the beach berm is re-established and the estuary fills, the continued seaward movement of groundwater eventually pushes the shallow groundwater seaward and establishes a saltwater/freshwater interface nearer the shoreline. This condition is conceptually shown in Figure 5 – SCRE Full with Prevailing Shallow Groundwater Conditions.

This dynamic likely occurs on a cyclical basis and the extent to which brackish/saline water can be transported inland depends on the stage of the SCRE and the elevation of the SCR thalweg when ocean water is introduced into the SCRE. Because the VWRP wildlife ponds are located on the western portion of the SCRE, groundwater recharge from the ponds will continue to discharge along the shoreline westward of the natural groundwater recharge location that is provided by brackish/saline surface water within the SCRE.

Figure 5 – SCRE Full with Prevailing Shallow Groundwater Conditions



The semi-perched aquifer is relatively shallow and based on the Ghyben-Herzberg principle, only 2 feet of fresh groundwater above MSL in the semi-perched aquifer is required to provide sufficient freshwater head to retard seawater intrusion based on the density difference between ocean water and groundwater. Even during drought conditions, the groundwater elevations measured in MW-8, MW-9, MW-10, and MW-11 provide protective heads at all times around the estuary (see Figure 1). Available data from MW-1, MW-2, and MW-3 indicate that the coastal area between the SCRE and McGrath Lake also has sufficient head that prevents landward movement of seawater. These protective water level conditions are observed by the study to be present even during drought conditions.

Based on the available data (SGD, 1991), the water quality data indicate the groundwater in the semi-perched aquifer beneath and in the vicinity of the SCRE is generally not suitable for use as a potable water supply because of the natural comingling of ocean water recharge from within the estuary.

Active Wells in the Vicinity of the SCRE

The semi-perched aquifer in the Mound Basin and the northwest portion of the Oxnard Plain is not presently and has not historically been produced for beneficial uses. The absence of wells in this aquifer zone is largely a function of its poor quality water and low production potential. Historical well records indicate that wells have been constructed beneath the clay cap in deeper more productive aquifer zones with a better quality groundwater. Table 1 – Active Wells Proximate to the SCRE summarizes existing wells and the construction details of the well screen section.

Table 1 – Active Wells Proximate to the SCRE

MOUND BASIN WELLS			
WELL NO.	STATE WELL NUMBER	DEPTH OF PRODUCTION ZONE (FEET)	BENEFICIAL USE
1	02N23W14H01S	407 – 1,137	AGRICULTURE
2	02N23W13E01S	523 – 1,123	AGRICULTURE
3	02N23W13F02S	521 – 982	AGRICULTURE
4	02N23W13G01S	360 – 860	AGRICULTURE
5	02N23W13K03S	800 – 1,200	AGRICULTURE
6	02N23W13K04S	800 – 1,200	AGRICULTURE
7	02N22W18N01S	660 – 1,200	AGRICULTURE
8	02N23W24F01S	365 – 927	AGRICULTURE

Table 1 – Active Wells Proximate to the SCRE (continued)

OXNARD PLAIN BASIN WELLS			
WELL NO.	STATE WELL NUMBER	DEPTH OF PRODUCTION ZONE (FEET)	BENEFICIAL USE
9	02N22W19P01S	160 – 300	AGRICULTURE
10	02N23W25G02S	100 – 206	INDUSTRIAL
11	02N23W25H01S	130 – 238	AGRICULTURE
12	02N23W25M01S	150 – 223	AGRICULTURE
13	02N23W25R02S	162 – 182	AGRICULTURE
14	02N23W25Q01S	190 – 220	DOMESTIC
15	02N23W35B01S	140 – 196	INDUSTRIAL

The approximate location of these wells in relation to the SCRE is shown on Plate 14 – Active Water Well Location Map. As indicated by available data, all wells in the Mound Basin have perforated intervals (production zones) that begin at depths greater than 350 feet below ground surface. In the Oxnard Plain Basin, the production zones of active water wells are at depths greater than 100 feet below ground surface (see Table 1). In both basins, the well production zones are located below the shallow confining clay layers. The lower aquifer zones produced by historical wells are protected from degradation that could emanate from the SCRE in the semi-perched aquifer zone because of: 1) the clay aquitard layers, 2) the protective groundwater elevations, and 3) the offshore gradient that persists even during drought conditions.

CONCLUSIONS

The SCRE is located in the southwestern portion of the Mound Basin and is underlain by the semi-perched aquifer. The semi-perched aquifer consists of an unconfined layer of sand and gravel and extends to an elevation of approximately 40 to 50 feet below MSL. The semi-perched aquifer is underlain by an aquitard layer(s) (clay cap) consisting primarily of clay and sandy clay with lenses of sand and gravel to an elevation of approximately 300 feet below MSL which separates the semi-perched aquifer from the main groundwater production zones. There are no known wells producing from the semi-perched aquifer zone. Based on Ventura County records, all active wells produce from aquifer zones that are over 350 feet below ground surface.

Shallow groundwater in the semi-perched aquifer remains at elevations that are sufficiently high enough to prevent landward movement of saltwater that could result from a greater density

of the ocean water. Groundwater quality in the semi-perched aquifer beneath the SCRE is poor and non-potable as a result of natural ocean water influx into the estuary. The prevailing offshore groundwater gradient in the vicinity of and beneath the SCRE continues to control the brackish/saline water that mixes within the estuary and degrades the underlying semi-perched groundwater (see Figures 4 and 5). Available data indicate that the various inland sources of groundwater recharge to the semi-perched aquifer maintain the prevailing offshore flow conditions that prevent further onshore movement of the brackish groundwater, even during drought climatic cycles. Based on these conditions, we conclude that a MUN designation is not appropriate for the semi-perched aquifer beneath the Estuary or for the surface water in the Estuary.

CLOSURE

This report has been prepared for the exclusive use of City of Ventura and its agents for specific application to the VWRf Estuary Studies. The findings, conclusions, and recommendations presented herein were prepared in accordance with generally accepted hydrogeological engineering practices. No other warranty, express or implied is made.

□



Sincerely,

HOPKINS GROUNDWATER CONSULTANTS, INC.

Curtis J. Hopkins
Principal Hydrogeologist
Professional Geologist GEO 5695
Certified Engineering Geologist EG 1800
Certified Hydrogeologist HG 114

Attachments: Plate 1 – Project Location Map
Plate 2 – Study Area Location Map
Plate 3 – Hydrogeological Cross-Section Location Map
Plate 4 – Hydrogeological Cross-Section A-A'
Plate 5 – Hydrogeological Cross-Section B-B'
Plate 6 – Hydrogeological Cross-Section C-C'
Plate 7 – Hydrogeological Cross-Section D-D'
Plate 8 – Hydrogeological Cross-Section E-E'
Plate 9 – Hydrogeological Cross-Section F-F' Location Map
Plate 10 – Hydrogeological Cross-Section F-F'
Plate 11 – Designated Monitoring Station Location Map
Plate 12 – Groundwater Elevation Contour Map October 1, 2015 (Berm in Place)
Plate 13 – Groundwater Elevation Contour Map January 17, 2016 (Berm Breached)
Plate 14 – Active Water Well Location Map
Appendix A – Ventura Keys Dredge Material Impoundment Basin Data

REFERENCES

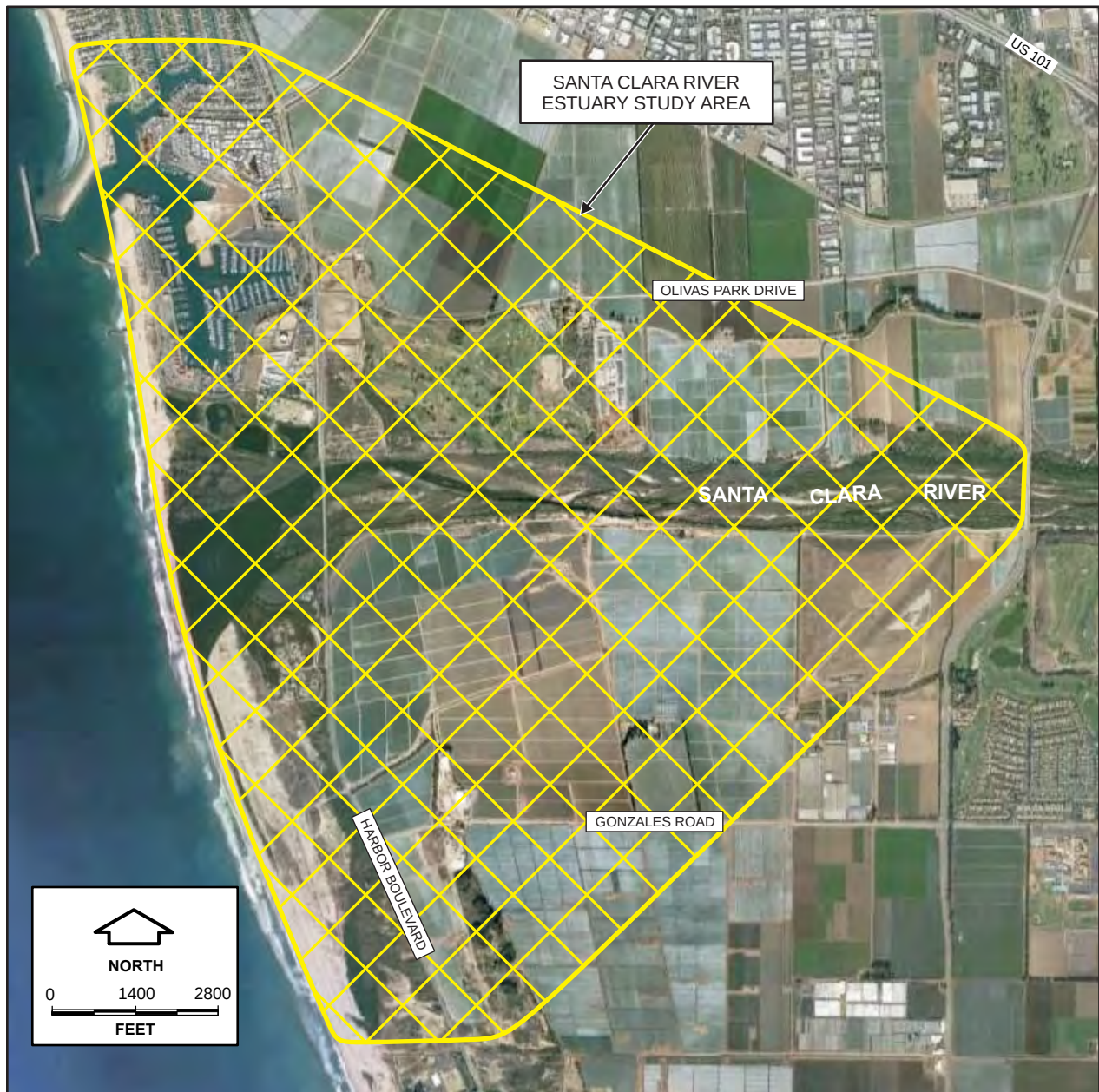
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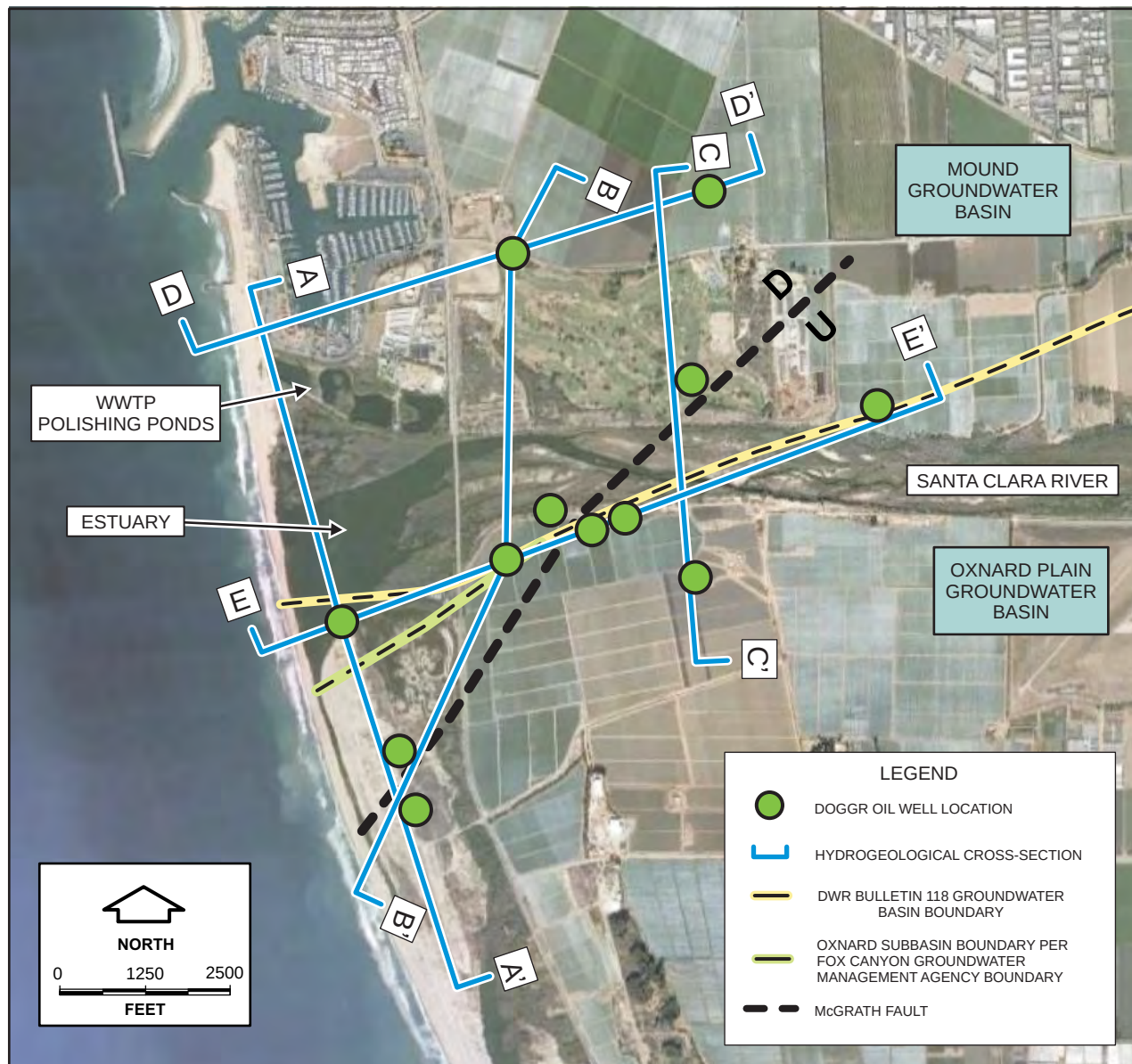
PLATES



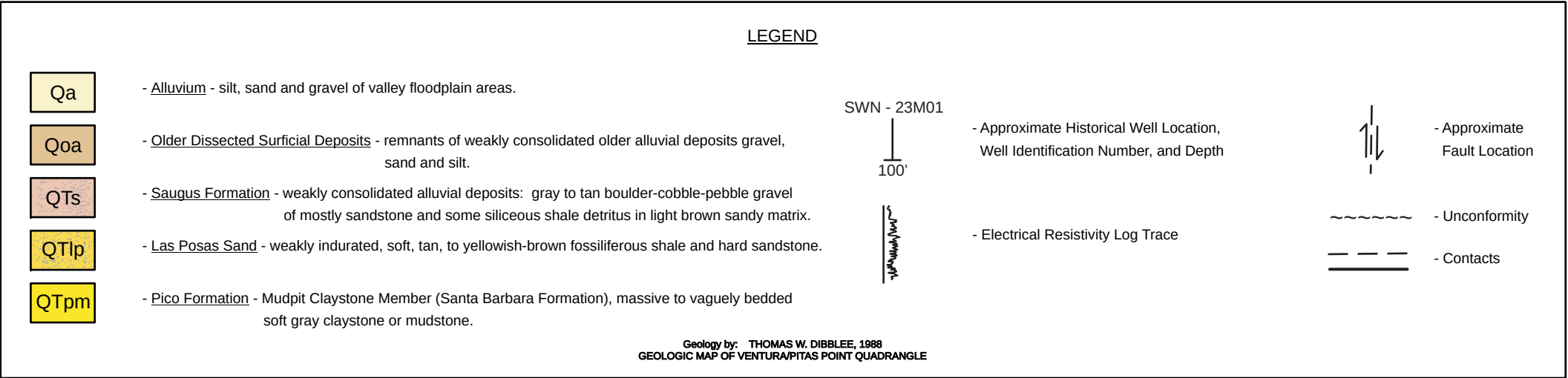
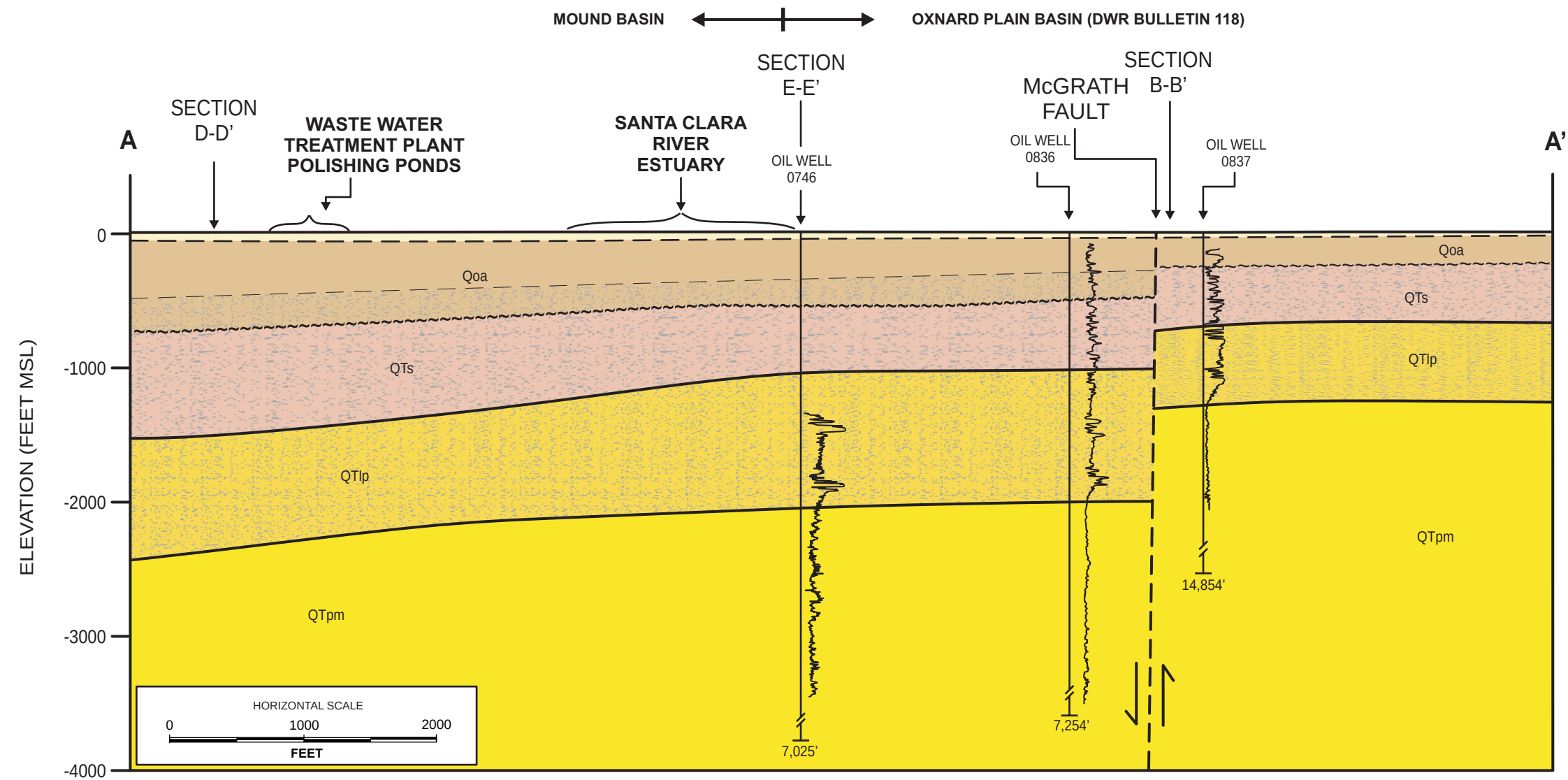
PROJECT LOCATION MAP
Phase 3 Santa Clara River Estuary Groundwater Special Study
City of San Buenaventura
Ventura, California



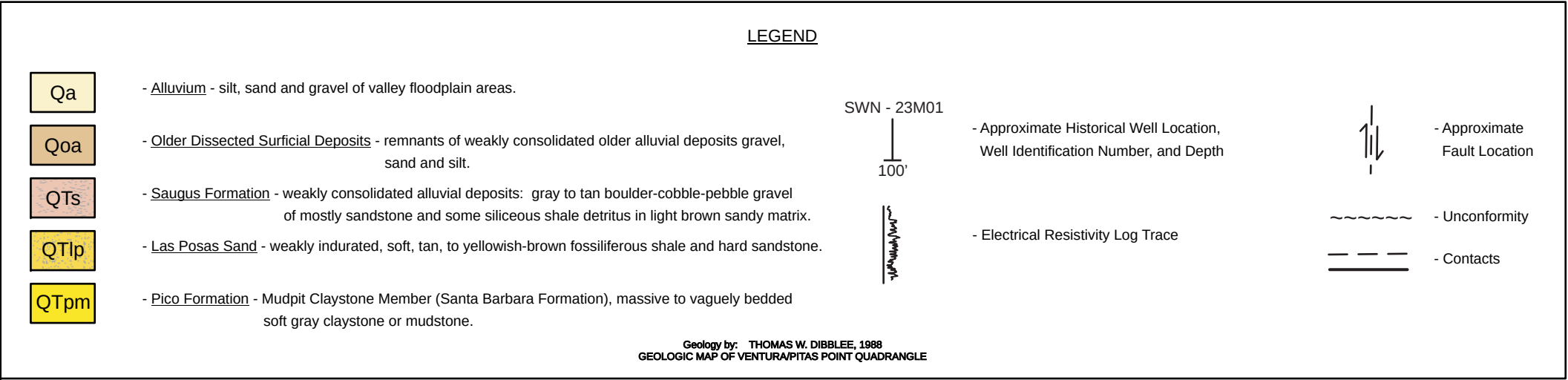
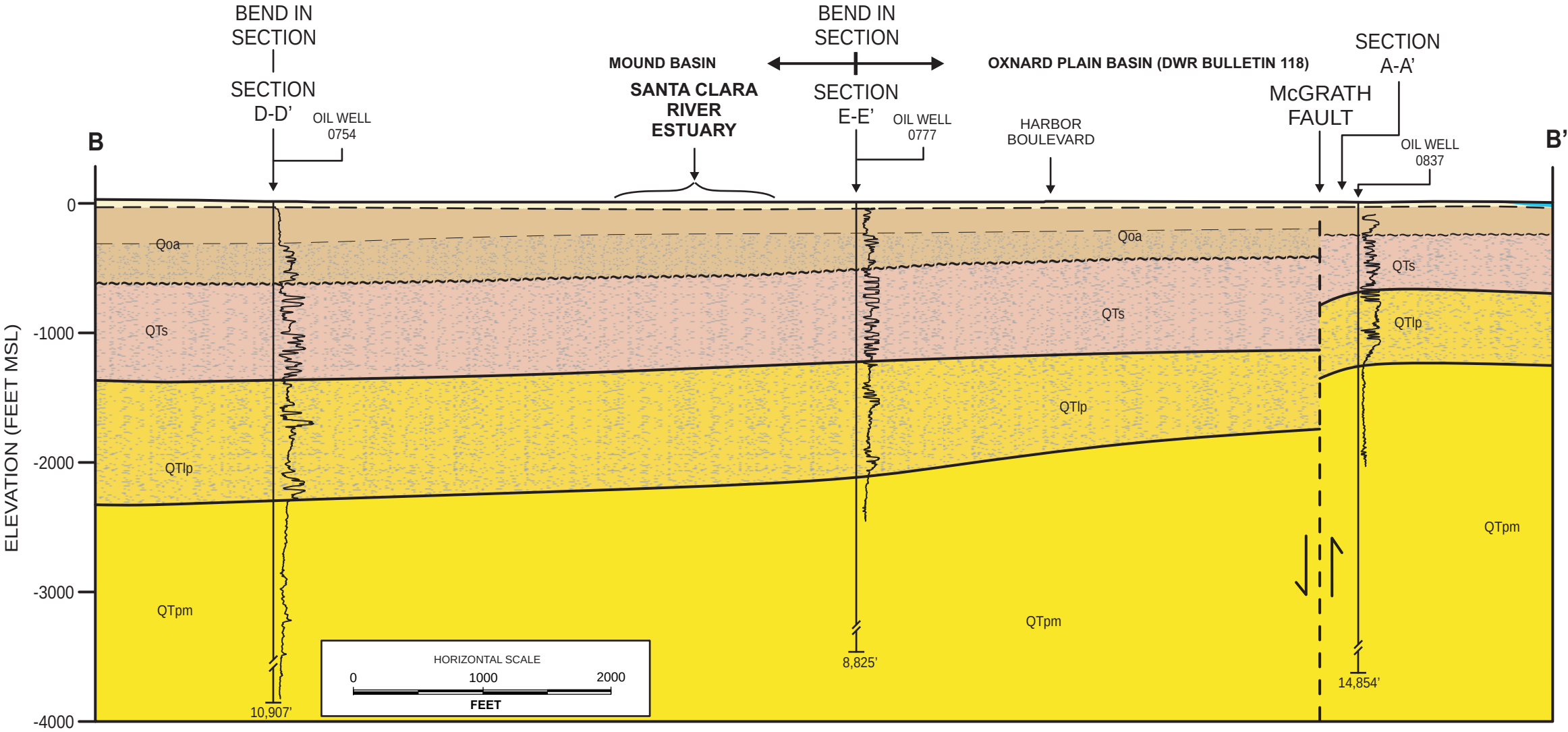
STUDY AREA LOCATION MAP
Phase 3 Santa Clara River Estuary Groundwater Special Study
City of San Buenaventura
Ventura, California



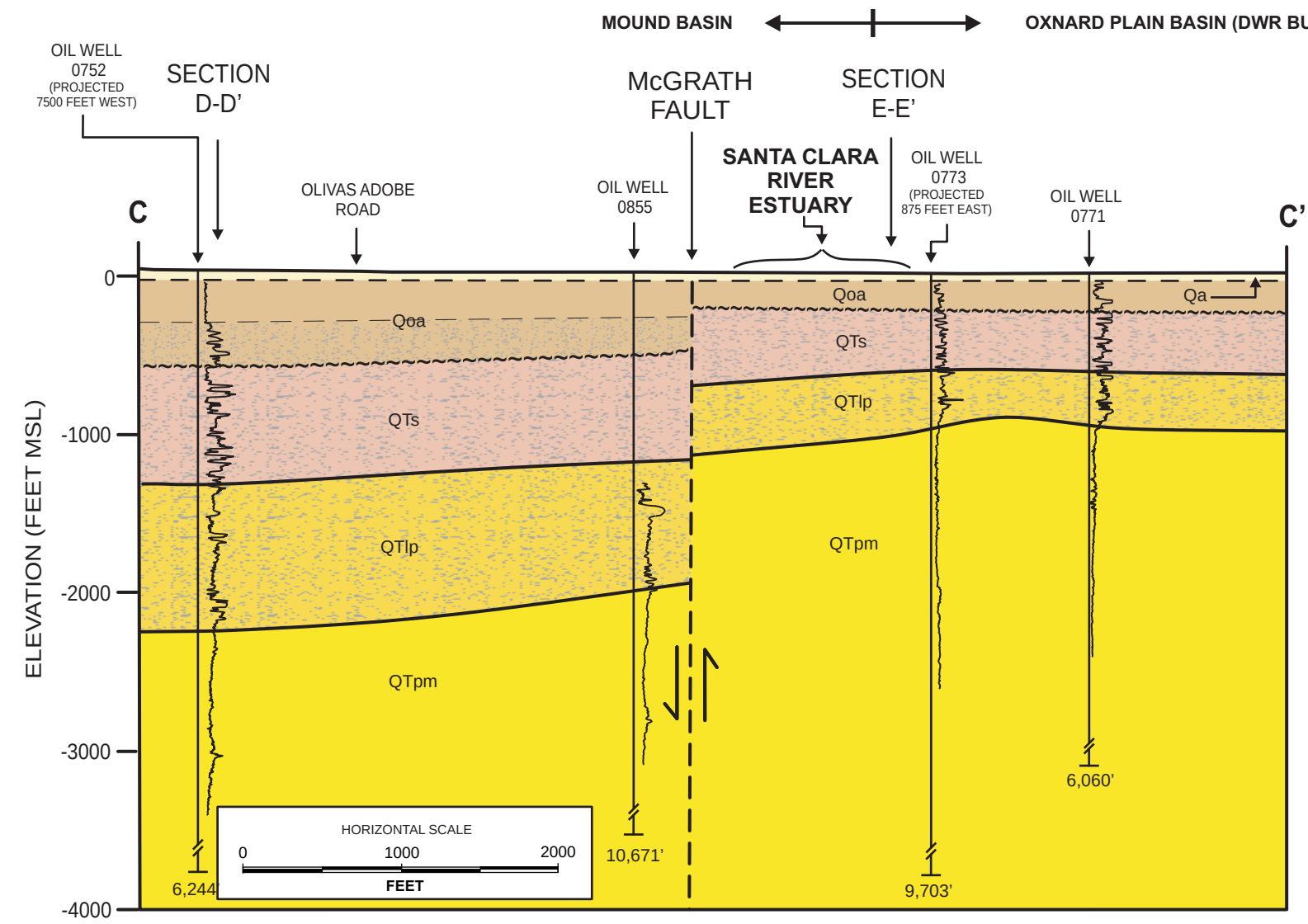
**HYDROGEOLOGICAL CROSS-SECTION
LOCATION MAP**
Phase 3 Santa Clara River Estuary Groundwater Special Study
City of San Buenaventura
Ventura, California



HYDROGEOLOGICAL CROSS-SECTION A-A'
Phase 3 Santa Clara River Estuary
Groundwater Special Study
City of San Buenaventura
Ventura, California



HYDROGEOLOGICAL CROSS-SECTION B-B'
Phase 3 Santa Clara River Estuary
Groundwater Special Study
City of San Buenaventura
Ventura, California



LEGEND

Qa	- <u>Alluvium</u> - silt, sand and gravel of valley floodplain areas.
Qoa	- <u>Older Dissected Surficial Deposits</u> - remnants of weakly consolidated older alluvial deposits gravel, sand and silt.
QTs	- <u>Saugus Formation</u> - weakly consolidated alluvial deposits: gray to tan boulder-cobble-pebble gravel of mostly sandstone and some siliceous shale detritus in light brown sandy matrix.
QTlp	- <u>Las Posas Sand</u> - weakly indurated, soft, tan, to yellowish-brown fossiliferous shale and hard sandstone.
QTpm	- <u>Pico Formation</u> - Mudpit Claystone Member (Santa Barbara Formation), massive to vaguely bedded soft gray claystone or mudstone.

SWN - 23M01

100'

- Approximate Historical Well Location, Well Identification Number, and Depth

- Electrical Resistivity Log Trace

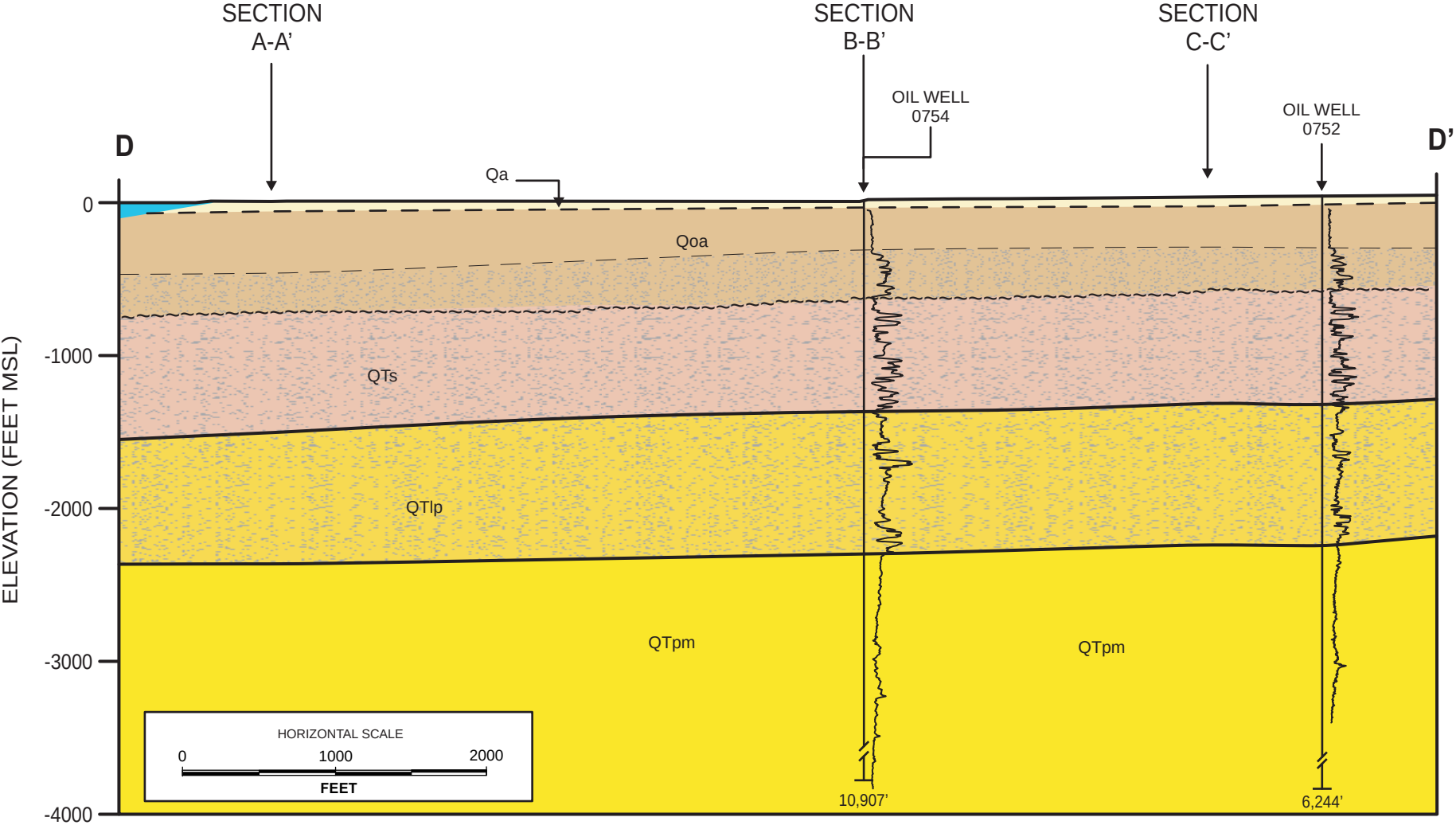
- Approximate Fault Location

- Unconformity

- Contacts

Geology by: THOMAS W. DIBBLEE, 1988
GEOLOGIC MAP OF VENTURA/PITAS POINT QUADRANGLE

HYDROGEOLOGICAL CROSS-SECTION C-C'
Phase 3 Santa Clara River Estuary
Groundwater Special Study
City of San Buenaventura
Ventura, California



Qa

Qoa

QTs

QTlp

QTpm

- Alluvium - silt, sand and gravel of valley floodplain areas.

- Older Dissected Surficial Deposits - remnants of weakly consolidated older alluvial deposits gravel, sand and silt.

- Saugus Formation - weakly consolidated alluvial deposits: gray to tan boulder-cobble-pebble gravel of mostly sandstone and some siliceous shale detritus in light brown sandy matrix.

- Las Posas Sand - weakly indurated, soft, tan, to yellowish-brown fossiliferous shale and hard sandstone.

- Pico Formation - Mudpit Claystone Member (Santa Barbara Formation), massive to vaguely bedded soft gray claystone or mudstone.

SWN - 23M01

100'

- Approximate Historical Well Location, Well Identification Number, and Depth

- Electrical Resistivity Log Trace

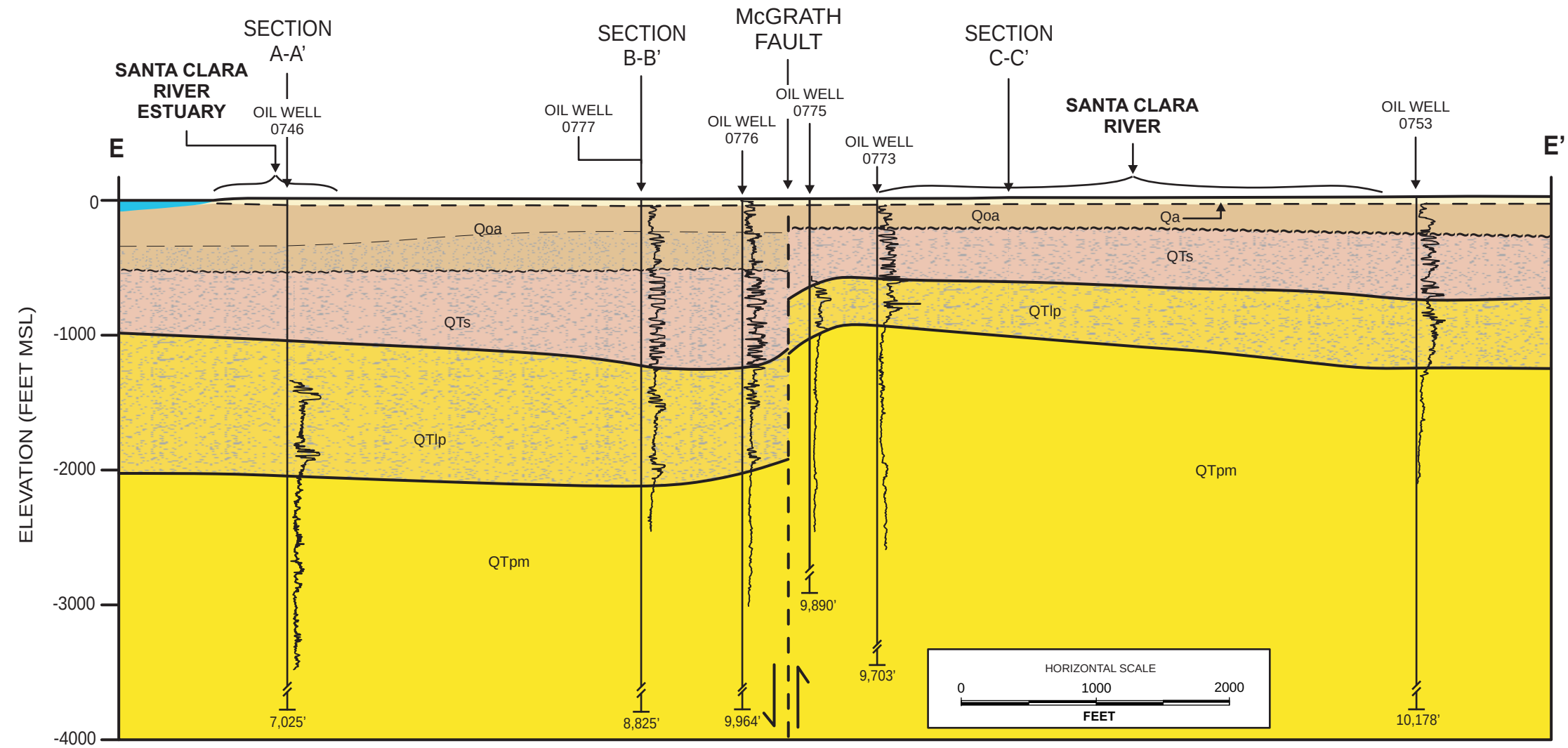
- Approximate Fault Location

- Unconformity

- Contacts

Geology by: THOMAS W. DIBBLEE, 1988
GEOLOGIC MAP OF VENTURA/PITAS POINT QUADRANGLE

HYDROGEOLOGICAL CROSS-SECTION D-D'
Phase 3 Santa Clara River Estuary
Groundwater Special Study
City of San Buenaventura
Ventura, California



Qa

Qoa

QTs

QTlp

QTpm

- Alluvium - silt, sand and gravel of valley floodplain areas.

- Older Dissected Surficial Deposits - remnants of weakly consolidated older alluvial deposits gravel, sand and silt.

- Saugus Formation - weakly consolidated alluvial deposits: gray to tan boulder-cobble-pebble gravel of mostly sandstone and some siliceous shale detritus in light brown sandy matrix.

- Las Posas Sand - weakly indurated, soft, tan, to yellowish-brown fossiliferous shale and hard sandstone.

- Pico Formation - Mudpit Claystone Member (Santa Barbara Formation), massive to vaguely bedded soft gray claystone or mudstone.

SWN - 23M01

100'

- Approximate Historical Well Location, Well Identification Number, and Depth

- Electrical Resistivity Log Trace

- Approximate Fault Location

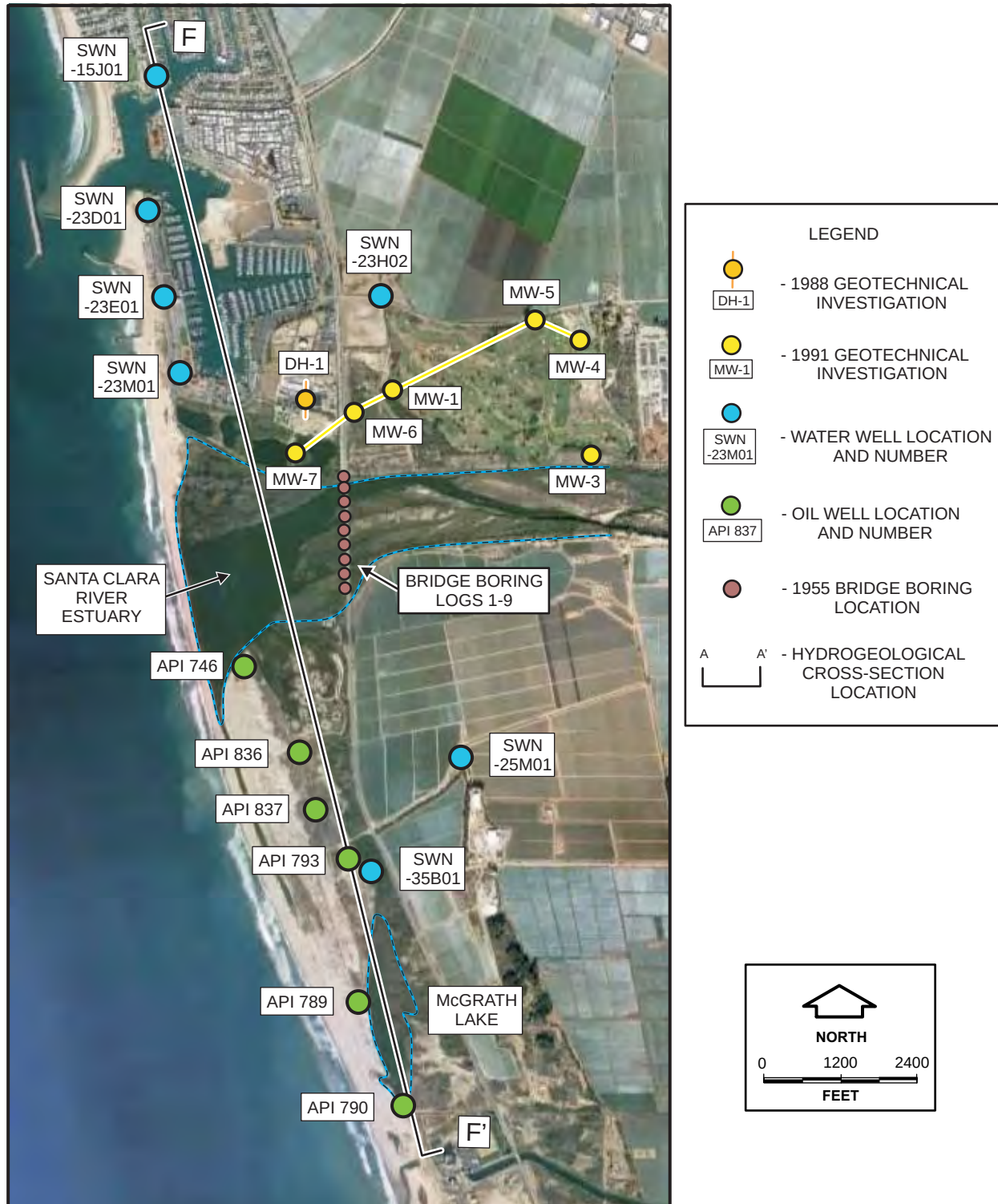
- Unconformity

- Contacts

Geology by: THOMAS W. DIBBLEE, 1988

GEOLOGIC MAP OF VENTURA/PITAS POINT QUADRANGLE

HYDROGEOLOGICAL CROSS-SECTION E-E'
Phase 3 Santa Clara River Estuary
Groundwater Special Study
City of San Buenaventura
Ventura, California



**HYDROGEOLOGICAL CROSS-SECTION F-F'
LOCATION MAP**
Phase 3 Santa Clara River Estuary Groundwater Special Study
City of San Buenaventura
Ventura, California

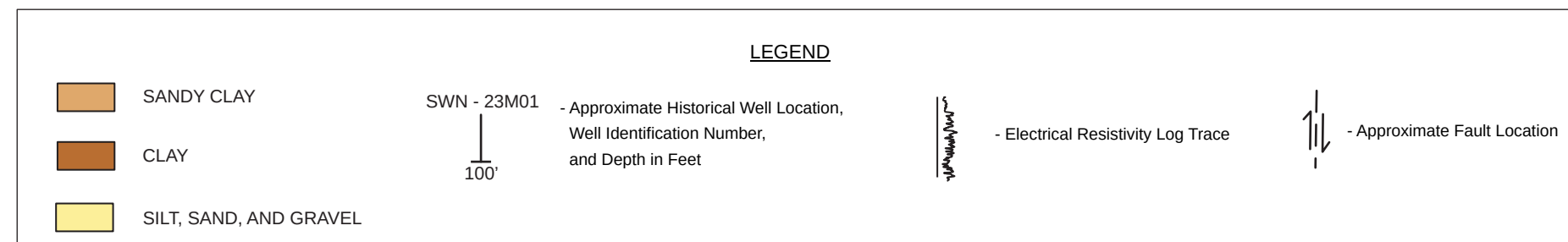
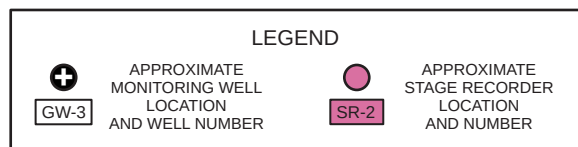
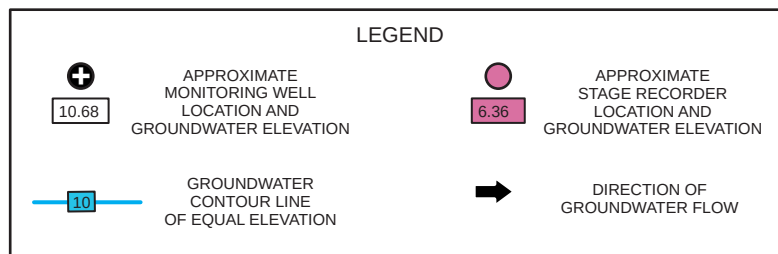
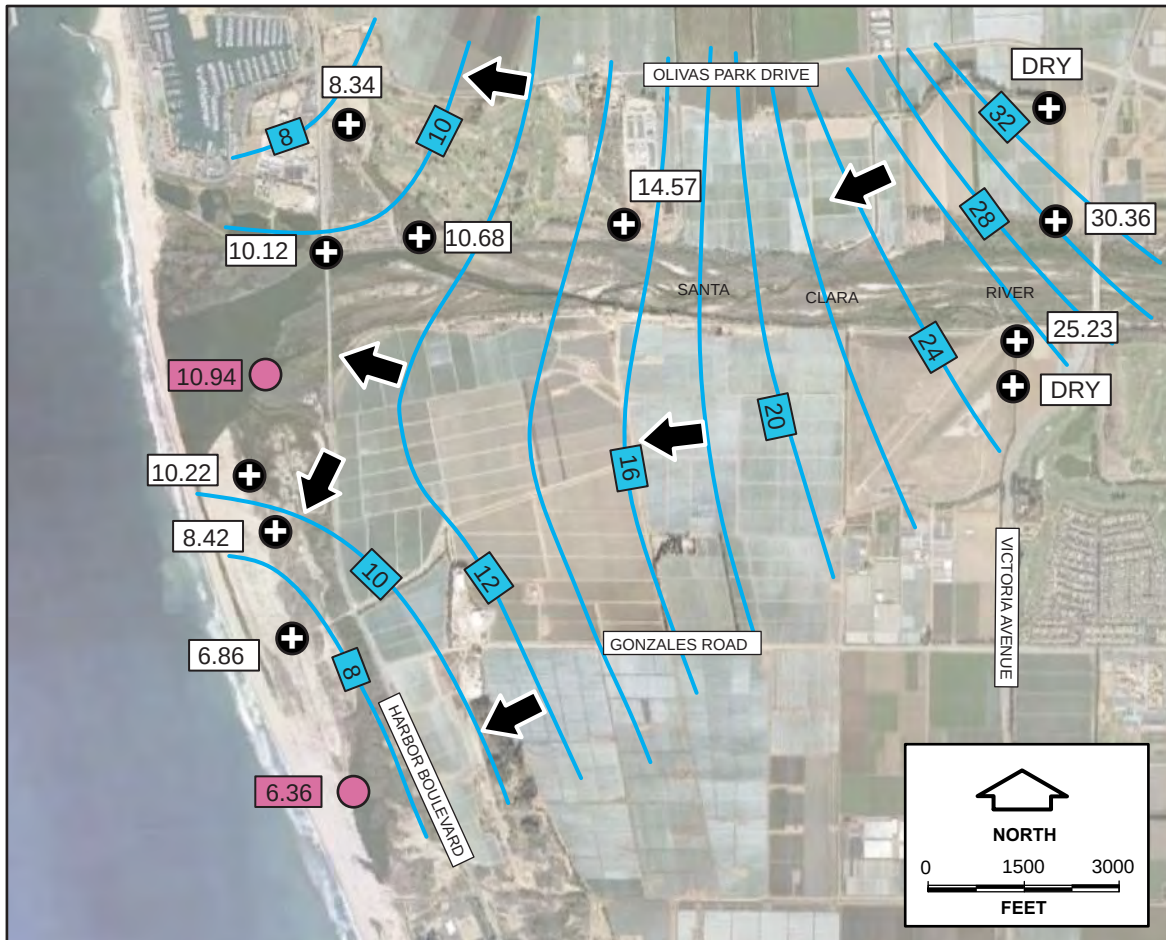


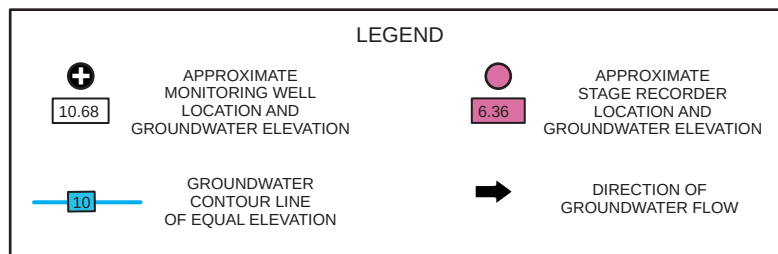
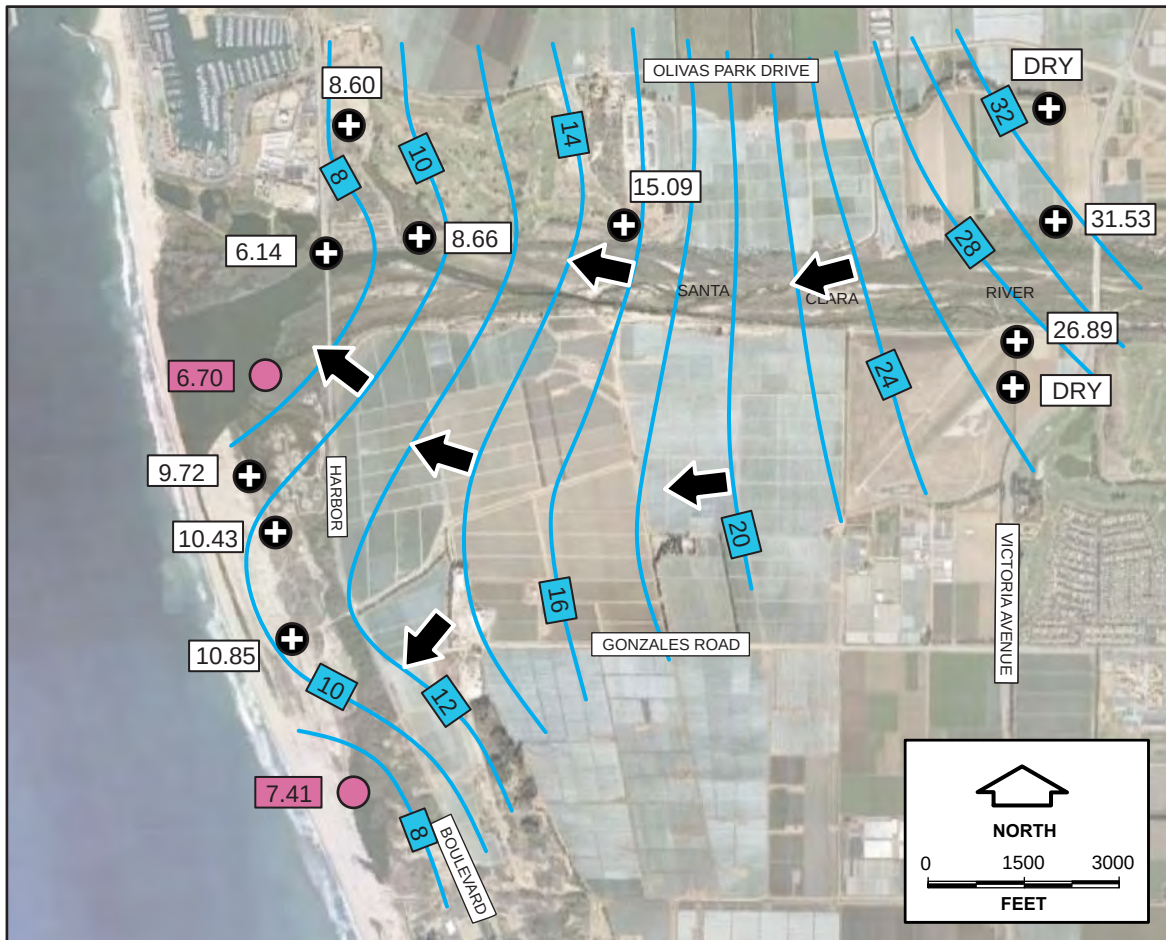
PLATE 10



DESIGNATED MONITORING STATION LOCATION MAP
Phase 3 Santa Clara River Estuary Groundwater Special Study
 City of San Buenaventura
 Ventura, California



GROUNDWATER ELEVATION CONTOUR MAP
OCTOBER 1, 2015 (BERM IN PLACE)
Phase 3 Santa Clara River Estuary Groundwater Special Study
 City of San Buenaventura
 Ventura, California



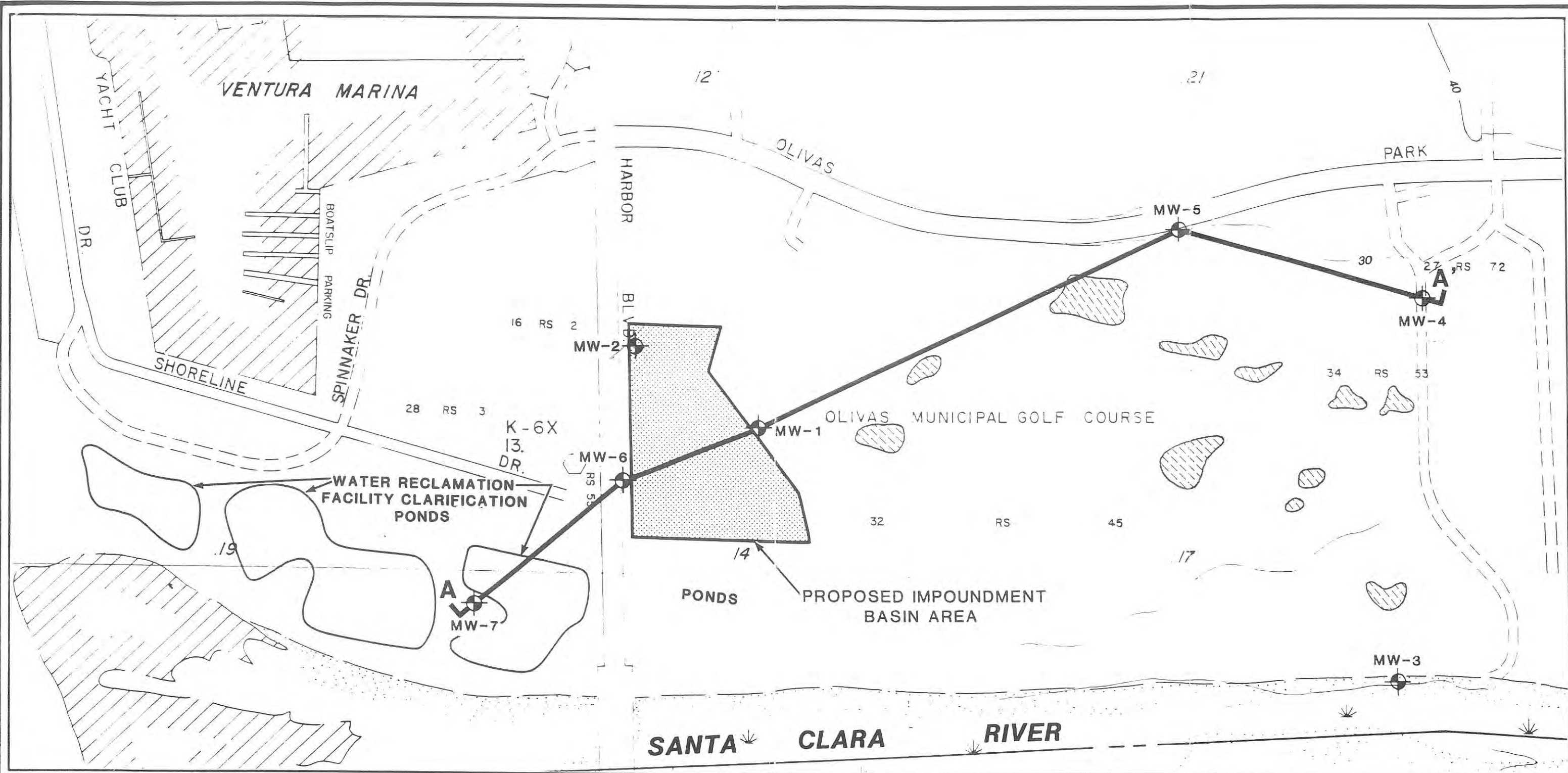
GROUNDWATER ELEVATION CONTOUR MAP
JANUARY 17, 2016 (BERM BREACHED)
 Phase 3 Santa Clara River Estuary Groundwater Special Study
 City of San Buenaventura
 Ventura, California



LEGEND		
	APPROXIMATE WATER WELL LOCATION AND WELL NUMBER SHOWN ON TABLE NO.1	
		DWR BULLETIN 118 GROUNDWATER BASIN BOUNDARY
		
		OXNARD SUBBASIN BOUNDARY PER FOX CANYON GROUNDWATER MANAGEMENT AGENCY BOUNDARY

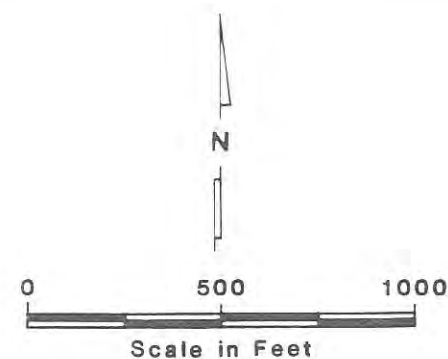
ACTIVE WATER WELL LOCATION MAP
Phase 3 Santa Clara River Estuary Groundwater Special Study
City of San Buenaventura
Ventura, California

APPENDIX A
VENTURA KEYS DREDGE MATERIAL
IMPOUNDMENT BASIN DATA



LEGEND

-  MW-1 MONITORING WELL LOCATION
-  A A' HYDROGEOLOGIC CROSS-SECTION LOCATION
-  GOLF COURSE POND



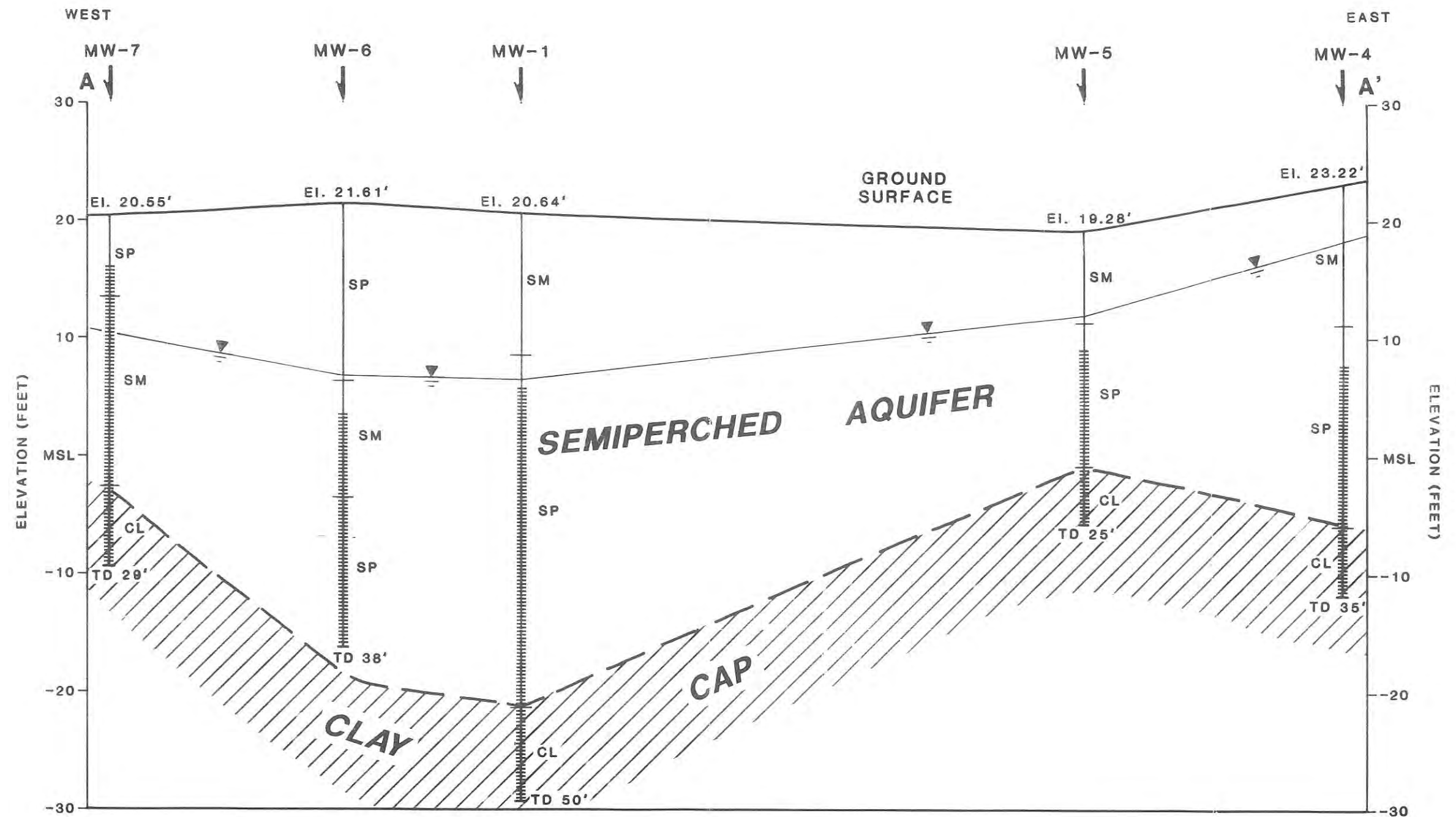
WELL LOCATION MAP

Ventura Keys Dredge Material
Impoundment Basin

For: CITY OF SAN BUENAVENTURA

V91061A December 1991 Plate 2

Staal, Gardner & Dunne, Inc.
Consulting Engineers and Geologists



LEGEND

SP - POORLY GRADED SAND

SM - SILTY SAND

CL - SILTY CLAY



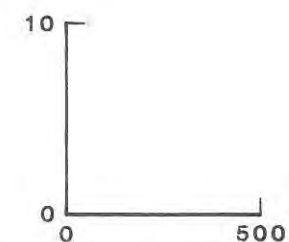
WATER LEVEL (5/24/91 DATA)



APPROXIMATE BOUNDARY BETWEEN
SAND/SILTY SAND AND CLAY



CLAY ZONE



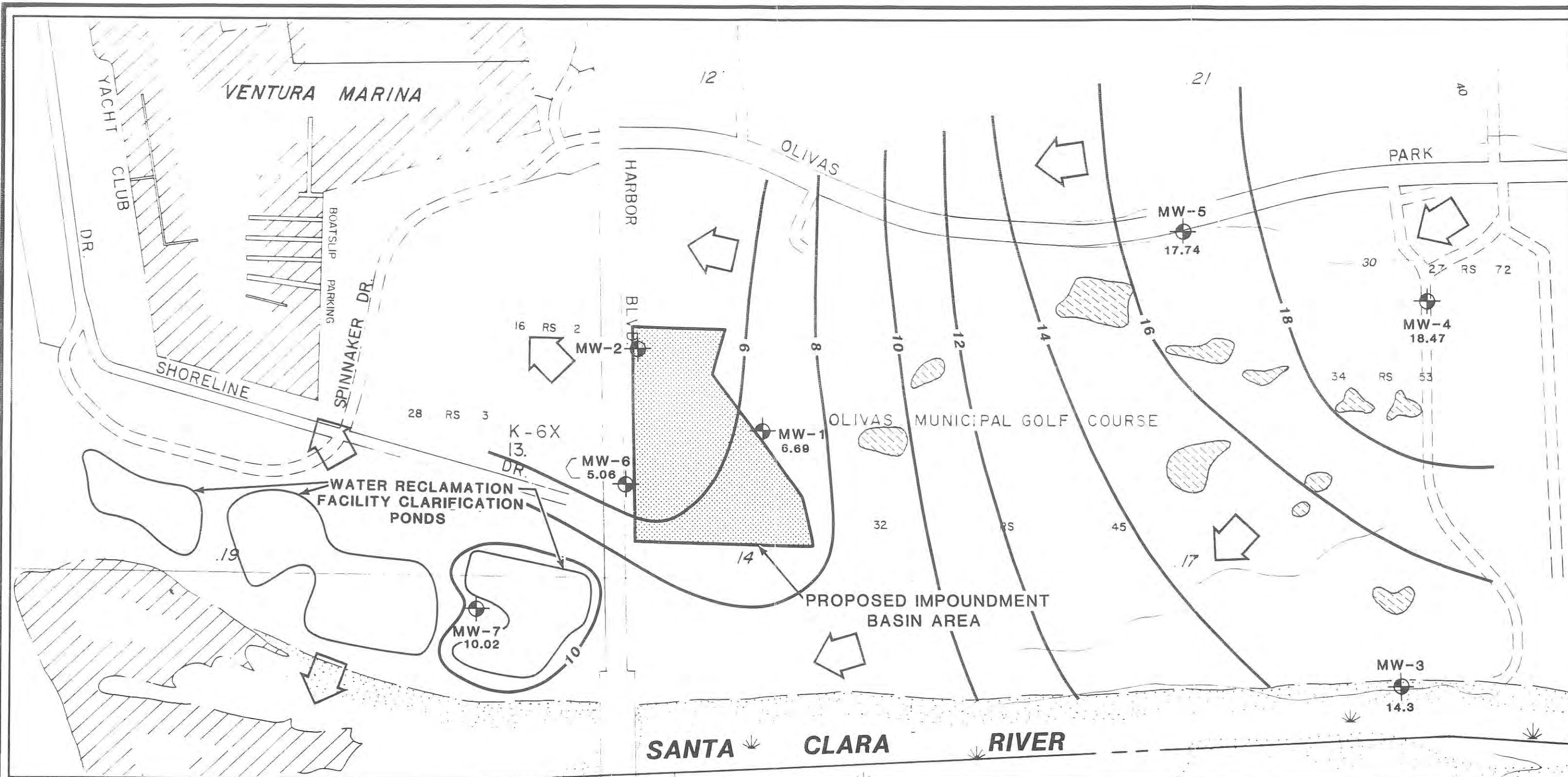
Horizontal and Vertical
Scales in Feet
Vertical Exaggeration 50:1

HYDROGEOLOGIC CROSS-SECTION A-A' Ventura Keys Dredge Material Impoundment Basin

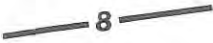
For: CITY OF SAN BUENAVENTURA

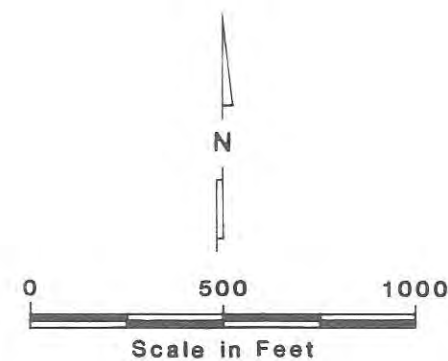
V91061A December 1991 Plate 3

Staal, Gardner & Dunne, Inc.
Consulting Engineers and Geologists



LEGEND

-  MW-1 MONITORING WELL LOCATION WITH WATER LEVEL ELEVATION AS MEASURED ON 5/24/91
-  GOLF COURSE POND
-  8 CONTOUR OF EQUAL ELEVATION OF GROUND WATER (SEMI-PERCHED AQUIFER)
-  INFERRED DIRECTION OF GROUND WATER MOVEMENT (SEMI-PERCHED AQUIFER)



WATER LEVEL CONTOUR MAP

Ventura Keys Dredge Material
Impoundment Basin

For: CITY OF SAN BUENAVENTURA

V91061A

December 1991

Plate 4

Staal, Gardner & Dunne, Inc.
Consulting Engineers and Geologists

December 1991

-A1-

V91061A

APPENDIX A

WELL LOGS

LOG OF MONITORING WELL

JOB NO. : V91061A

PROJECT : Ventura Keys Impoundment

LOCATION: 1500'S/750'E-Harbor/Olivas Park

DRILLING METHOD: Hollow Stem Auger 8"

LOGGED BY : J.K. Summerlin

DRILLED BY: Valley Well Drilling

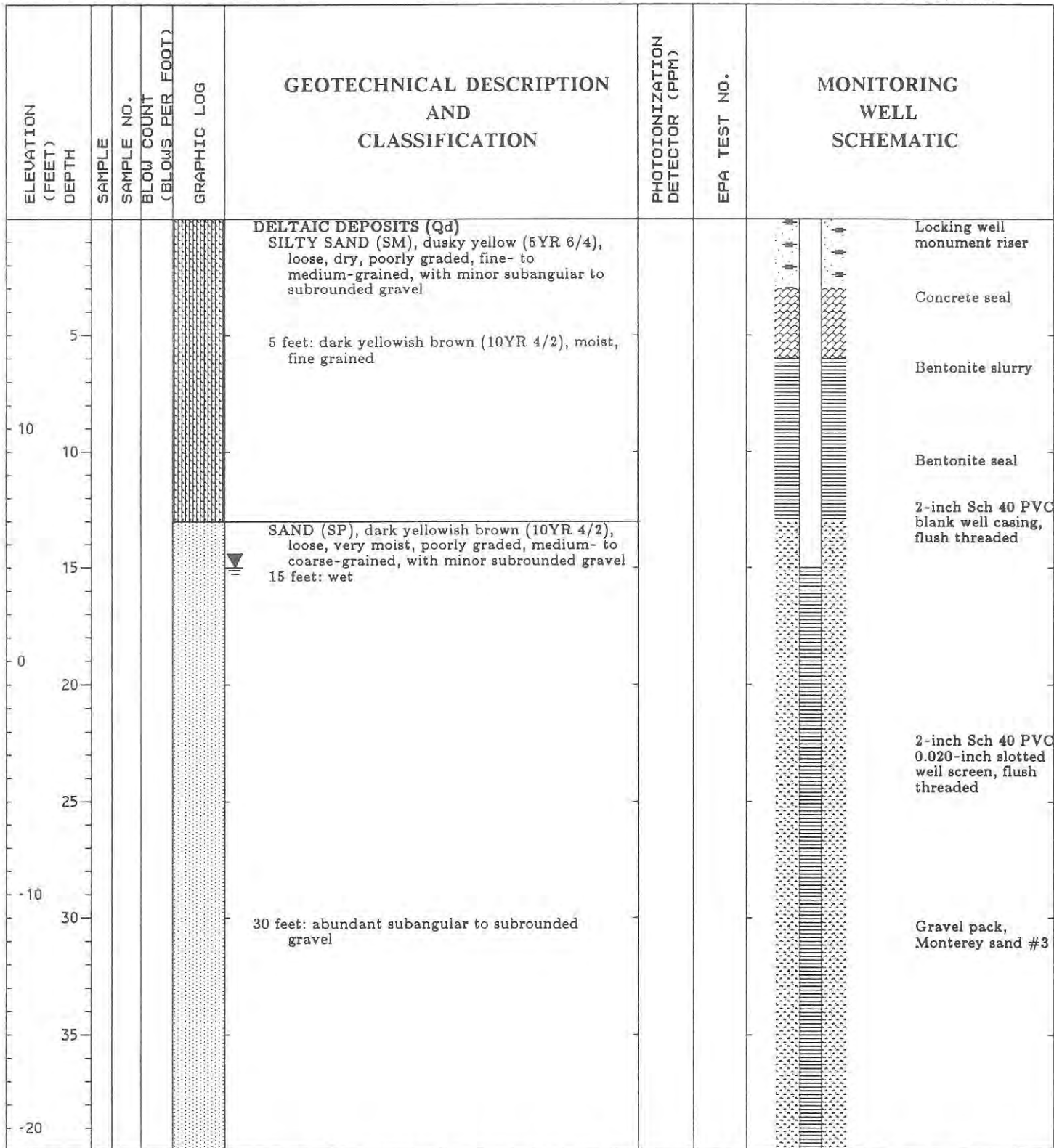
TIME START: 0920 5/20/91

TIME STOP : 1115 5/20/91

MONITORING WELL NO.: MW-1

DATUM : MSL

REFERENCE EL. : 19 feet (approx.)



This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered.

E-5

LOG OF MONITORING WELL

JOB NO. : V91061A

PROJECT : Ventura Keys Impoundment

LOCATION: 1500'S/750'E-Harbor/Olivas Park

DRILLING METHOD: Hollow Stem Auger 8"

LOGGED BY : J.K. Summerlin

DRILLED BY: Valley Well Drilling

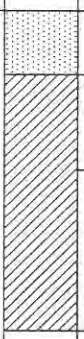
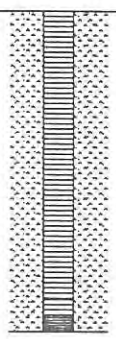
TIME START: 0920 5/20/91

TIME STOP : 1115 5/20/91

MONITORING WELL NO.: MW-1

DATUM : MSL

REFERENCE EL. : 19 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE SAMPLE NO. BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	PHOTOIONIZATION DETECTOR (PPM)	EPA TEST NO.	MONITORING WELL SCHEMATIC
45 -30 50			DELTAIC DEPOSITS (Qd) SAND (SP), dark yellowish brown (10YR 4/2), loose, wet, poorly graded, medium- to coarse-grained, with abundant subangular to subrounded gravel SILTY CLAY (CL), dusky yellowish brown (10YR 2/2), stiff, wet, plastic, with minor organic veining Bottom of drill hole at a depth of 50 feet. Ground water encountered at a depth of 15 feet. Drill hole completed as a 2-inch PVC ground water monitoring well, permit exempt.			 2-inch Sch 40 PVC 0.020-inch slotted well screen, flush threaded Gravel pack, Monterey sand #3 PVC end cap, flush threaded

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. E-5

LOG OF MONITORING WELL

JOB NO. : V91061A LOGGED BY : J.K. Summerlin MONITORING WELL NO.: MW-2
 PROJECT : Ventura Keys Impoundment DRILLED BY: Valley Well Drilling
 LOCATION: 1300'S along Harbor/W Olivas Pk TIME START: 1145 5/20/91 DATUM : MSL
 DRILLING METHOD: Hollow Stem Auger 8" TIME STOP : 1400 5/20/91 REFERENCE EL. : 21 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE NO.	BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	PHOTOIONIZATION DETECTOR (PPM)	EPA TEST NO.	MONITORING WELL SCHEMATIC
20				ARTIFICIAL FILL (af) SILTY SAND (SM), dusky yellow (5Y 6/4), loose, dry, poorly graded, fine- to medium-grained, minor rounded gravel			
5				SAND (SP), moderate yellowish brown (10YR 5/4), loose, moist, poorly graded, medium- to coarse-grained, with minor subangular to subrounded gravel 7 feet: sandstone boulders			
10				DELTAIC DEPOSITS (Qd) SAND (SP), moderate yellowish brown (10YR 5/4), loose, moist, poorly graded, medium- to coarse-grained, with abundant rounded to subrounded gravel and cobbles			
15				15 feet: very moist 16 feet: refusal Bottom of drill hole at a depth of 16 feet. No ground water encountered. Drill hole backfilled with native material.			

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. E-5

LOG OF MONITORING WELL

JOB NO. : V91061A

PROJECT : Ventura Keys Impoundment

LOCATION: 2600'S of Olivas Adobe

DRILLING METHOD: Hollow Stem Auger 8"

LOGGED BY : J.K. Summerlin

DRILLED BY: Valley Well Drilling

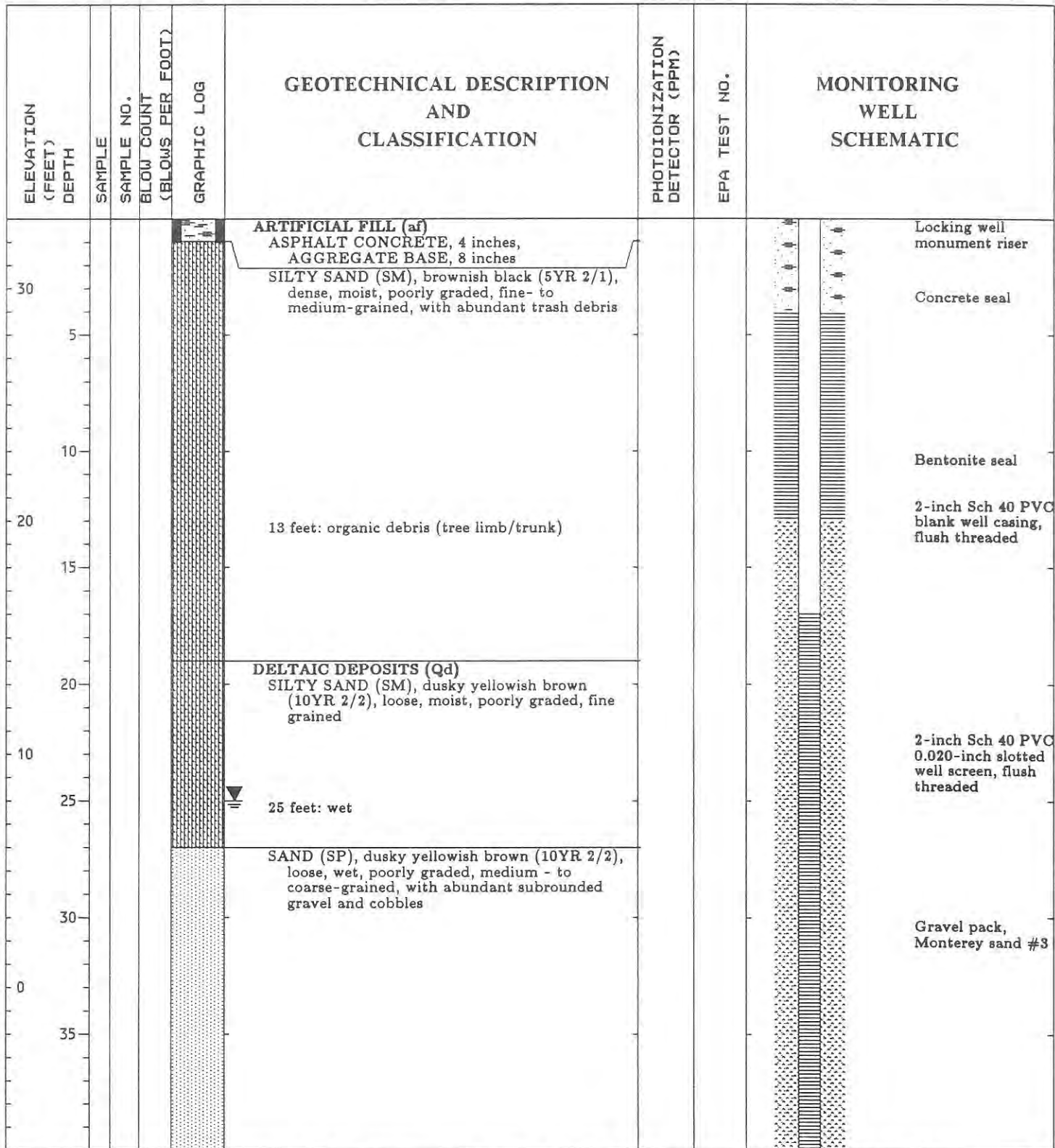
TIME START: 1435 5/20/91

TIME STOP : 1715 5/20/91

MONITORING WELL NO.: MW-3

DATUM : MSL

REFERENCE EL. : 33 feet (approx.)



This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered.

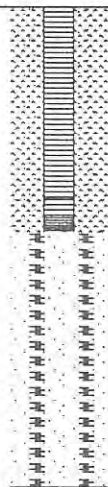
E-5

LOG OF MONITORING WELL

JOB NO. : V91061A
 PROJECT : Ventura Keys Impoundment
 LOCATION: 2600'S of Olivas Adobe
 DRILLING METHOD: Hollow Stem Auger 8"

LOGGED BY : J.K. Summerlin
 DRILLED BY: Valley Well Drilling
 TIME START: 1435 5/20/91
 TIME STOP : 1715 5/20/91

MONITORING WELL NO.: MW-3
 DATUM : MSL
 REFERENCE EL. : 33 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE SAMPLE NO. BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	PHOTOIONIZATION DETECTOR (PPM)	EPA TEST NO.	MONITORING WELL SCHEMATIC
-10 45 50 -20 55			DELTAIC DEPOSITS (Qd) SAND (SP), dusky yellowish brown (10YR 2/2), loose, wet, poorly graded, medium- to coarse-grained, with abundant subrounded gravel and cobbles SILTY CLAY (CL), dusky yellowish brown (10YR 2/2), stiff, wet, plastic			 2-inch Sch 40 PVC 0.020-inch slotted well screen, flush threaded Gravel pack, Monterey sand #3 PVC end cap, flush threaded Caved material
			Bottom of drill hole at a depth of 55 feet. Ground water encountered at a depth of 25 feet. Drill hole completed as a 2-inch PVC ground water monitoring well, permit exempt.			

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. E-5

LOG OF MONITORING WELL

JOB NO. : V91061A
 PROJECT : Ventura Keys Impoundment
 LOCATION: 600'S of Olivas Adobe
 DRILLING METHOD: Hollow Stem Auger 8"

LOGGED BY : J.K. Summerlin
 DRILLED BY: Valley Well Drilling
 TIME START: 0800 5/21/91
 TIME STOP : 0930 5/21/91

MONITORING WELL NO.: MW-4
 DATUM : MSL
 REFERENCE EL. : 24 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE NO.	BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	PHOTOIONIZATION DETECTOR (PPM)	EPA TEST NO.	MONITORING WELL SCHEMATIC
20				DELTAIC DEPOSITS (Qd) SILTY SAND (SM), pale yellowish brown (10YR 6/2), loose, dry, poorly graded, fine- to medium-grained			Traffic rated vault, waterproof, locking harness, flush mounted, with PVC slip cap
5				5 feet: moist			Concrete seal
10				7 feet: grayish brown (5YR 3/2), very moist			Bentonite seal
10				SAND (SP), dark yellowish brown (10YR 4/2), loose, wet, poorly graded, fine- to coarse-grained, with minor subrounded gravel and cobbles			2-inch Sch 40 PVC blank well casing, flush threaded
15							
20				22 feet: coarse- to medium-grained, with abundant subrounded gravel and cobbles			2-inch Sch 40 PVC 0.020-inch slotted well screen, flush threaded
0							
25							
30				CLAY (CL), olive gray (5Y 3/2), stiff, moist, plastic, with organic veining			Gravel pack, Monterey sand #3
-10							PVC end cap, flush threaded
35				Bottom of drill hole at a depth of 35 feet. Ground water encountered at a depth of 12 feet. Drill hole completed as a 2-inch PVC ground water monitoring well, permit exempt.			

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. E-5

LOG OF MONITORING WELL

JOB NO. : V91061A LOGGED BY : J.K. Summerlin MONITORING WELL NO.: MW-5
 PROJECT : Ventura Keys Impoundment DRILLED BY: Valley Well Drilling
 LOCATION: 1200'W Olivas Adobe/Olivas Pk TIME START: 1010 5/21/91 DATUM : MSL
 DRILLING METHOD: Hollow Stem Auger 8" TIME STOP : 1100 5/21/91 REFERENCE EL. : 20 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE SAMPLE NO. BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	PHOTOIONIZATION DETECTOR (PPM)	EPA TEST NO.	MONITORING WELL SCHEMATIC
20			DELTAIC DEPOSITS (Qd) SILTY SAND (SM), dark yellowish brown (10YR 4/2), loose, moist, poorly graded, fine grained, with abundant subrounded gravel and cobbles			Traffic rated vault, waterproof, locking harness, flush mounted, with PVC slip cap
5						Concrete seal
10			SAND (SP), dark yellowish brown (10YR 4/2), loose, wet, well graded, fine- to coarse-grained, with abundant subrounded gravel and cobbles			Bentonite seal
15			16 feet: poorly graded, medium- to coarse-grained			2-inch Sch 40 PVC blank well casing, flush threaded
20			CLAY (CL), dusky yellowish brown (10YR 2/2), stiff, moist, plastic, with organic veining			2-inch Sch 40 PVC 0.020-inch slotted well screen, flush threaded
25			Bottom of drill hole at a depth of 25 feet. Ground water encountered at a depth of 8 feet. Drill hole completed as a 2-inch PVC ground water monitoring well, permit exempt.			Gravel pack, native material
						PVC end cap, flush threaded

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. E-5

LOG OF MONITORING WELL

JOB NO. : V91061A

PROJECT : Ventura Keys Impoundment

LOCATION: 1800'S Harbor from W Olivas Park

DRILLING METHOD: Hollow Stem Auger 8"

LOGGED BY : J.K. Summerlin

DRILLED BY: Valley Well Drilling

TIME START: 1145 5/21/91

TIME STOP : 1330 5/21/91

MONITORING WELL NO.: MW-6

DATUM : MSL

REFERENCE EL. : 20 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE SAMPLE NO. BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	PHOTOIONIZATION DETECTOR (PPM)	EPA TEST NO.	MONITORING WELL SCHEMATIC
20			ARTIFICIAL FILL (af) SAND (SP), dusky yellow (5Y 6/4), loose, dry, poorly graded, fine- to medium-grained, with minor subrounded gravel			Locking well monument riser
5			4 feet: moist			Concrete seal
10			8 feet: sandstone boulders			Bentonite seal
15			12 feet: moist			2-inch Sch 40 PVC blank well casing, flush threaded
20			DELTAIC DEPOSITS (Qd) SILTY SAND (SM), grayish black (N2), loose, moist, poorly graded, fine- to medium-grained, with minor subrounded gravel			
25			19 feet: very moist, well graded, fine- to coarse-grained, with minor subrounded gravel and cobbles up to 1-inch diameter			2-inch Sch 40 PVC 0.020-inch slotted well screen, flush threaded
30			SAND (SP), grayish black (N2), loose, wet, poorly graded, medium- to coarse-grained, with abundant subrounded gravel and cobbles up to 1-inch diameter			Gravel pack, Monterey sand #3
35			35 feet: very coarse grained			PVC end cap, flush threaded
37			37 feet: minor shell fragments			Caved material

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered.

E-5

LOG OF MONITORING WELL

JOB NO. : V91061A LOGGED BY : J.K. Summerlin MONITORING WELL NO.: MW-6
 PROJECT : Ventura Keys Impoundment DRILLED BY: Valley Well Drilling
 LOCATION: 1800'S Harbor from W Olivas Park TIME START: 1145 5/21/91 DATUM : MSL
 DRILLING METHOD: Hollow Stem Auger 8" TIME STOP : 1330 5/21/91 REFERENCE EL. : 20 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE SAMPLE NO. BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	PHOTOIONIZATION DETECTOR (PPM)	EPA TEST NO.	MONITORING WELL SCHEMATIC
20			DELTAIC DEPOSITS (Qd) SAND (SP), grayish black (N2), loose, wet, poorly graded, medium- to coarse-grained, with abundant subrounded gravel and cobbles up to 1-inch diameter 42 feet: sandstone boulders, refusal Bottom of drill hole at a depth of 42 feet. Ground water encountered at a depth of 25 feet. Drill hole completed as a 2-inch PVC ground water monitoring well, permit exempt.			 Caved material

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. E-5

LOG OF WATER WELL

JOB NO. : V91061A LOGGED BY : J.P. Schaaf WELL NO.: MW-7
 PROJECT : Ventura Keys Impoundment DRILLED BY: Valley Well Drilling
 LOCATION: W side most E pond of Lake Lucy TIME START: 1420 5/21/91 DATUM : MSL
 DRILLING METHOD: Hollow Stem Auger 6" TIME STOP : 1535 5/21/91 REFERENCE EL. : 19 feet (approx.)

ELEVATION (FEET) DEPTH	SAMPLE SAMPLE NO. BLOW COUNT (BLOWS PER FOOT)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	WELL SCHEMATIC
5			DELTAIC DEPOSITS (Qd) SAND (SP), dark yellowish brown (10YR 4/2), loose, dry, poorly graded, fine- to medium-grained 4 feet: moist	Locking well monument riser Concrete seal
10			SILTY SAND (SM) , dusky yellowish brown (10YR 2/2), loose, very moist, poorly graded, fine grained 9 feet: wet	Bentonite seal 2-inch Sch 40 PVC blank well casing, flush threaded
25			CLAY (CL) , dark greenish gray (5GY 4/1), stiff, wet, plastic, minor organic material (small roots)	2-inch Sch 40 PVC 0.020-inch slotted well screen, flush threaded Gravel pack, Monterey sand #3
30			Bottom of drill hole at a depth of 30 feet. Ground water encountered at a depth of 9 feet. Drill hole was completed as a 2-inch diameter PVC ground water monitoring well permit exempt.	PVC end cap, flush threaded

This log applies only at the location of this drill hole and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. GW-1

LEGEND TO LOGS

SGD

SAMPLER TYPES:



Thin-walled Tube or Ring



Standard Penetration



Shelby Tube



Unsuccessful Attempt



Disturbed Bulk



BLOW COUNT: The number of hammer blows required to drive the sampler the last 12 inches, unless otherwise noted. To avoid damage to sampling tools, driving is limited to 50 blows during or after initial seating of sampler.

Symbol	Hammer Weight (pounds)	Drop Height (inches)	Hammer Type	Notes
7	140	30	Safety	
(3)				
[9]				
<4>				

RELATIVE DENSITY FOR SOILS:

Sands, Gravels, and Non-Plastic Silts	SPT Blow Count* (Blow/Foot)
VERY LOOSE	UNDER 4
LOOSE	5 - 10
MEDIUM DENSE	11 - 30
DENSE	31 - 50
VERY DENSE	OVER 50

CONSISTENCY FOR SOILS:

Clays and Plastic Silts	Unconfined Compressive Strength** (TSF)	SPT Blow Count* (Blows/Foot)
VERY SOFT	UNDER 0.25	UNDER 2
SOFT	0.25 - 0.50	2 - 4
MEDIUM STIFF	0.50 - 1.00	5 - 8
STIFF	1.00 - 2.00	9 - 15
VERY STIFF	2.00 - 4.00	16 - 30
HARD	OVER 4.00	OVER 30

* Number of blows of 140 pound hammer falling 30 inches to drive a 2-inch O.D. (1-3/8 inch I.D.) split spoon sampler (ASTM D1586).

** Unconfined compressive strength, in tons per square foot, as determined by laboratory testing or approximated by the standard penetration test (ASTM D1586), pocket penetrometer, torvane, or visual observation.

GROUND WATER LEVEL:



GROUND WATER SEEPAGE:



ADDITIONAL TESTS: All tests performed are summarized in Table B-1, Appendix B.

AC	Asphalt Core	GS	Grain-size Distribution	SE	Sand Equivalent
AL	Atterberg Limits	NG	Nuclear Gauge	SG	Specific Gravity
AS	Agricultural Suitability	PA	Paleontologic Analysis	TD	Triaxial Compression, drained
CONS	Consolidation	pH	Hydrogen Ion Concentration	TDy	Triaxial Compression, dynamic
CBR	California Bearing Ratio	PID	Photoionization Detector	TU	Triaxial Compression, undrained
COMP	Compaction	PERM	Permeability	UC	Unconfined Compression
CHEM	Chemical Analysis	PM	Pressuremeter	WP	Water Pressure
DS	Direct Shear	R	R-value	524.2	BTEX, EDC, EDB, TPH (water)
EI	Expansion Index	(RC)	Relative Compaction	7421	Total Lead
FID	Flame Ionization Detector	SC	Sand Cone	8260m	BTEX, EDC, EDB, TPH (soil)

UNIFIED SOIL CLASSIFICATION SYSTEM: Selection of soil classification based on ASTM D2487, Standard Test Method of Classification of Soils for Engineering Purposes.

MAJOR DIVISION			GROUP SYMBOL	DESCRIPTION	GRAPHIC LOG
COARSE GRAINED SOILS Over 50 percent by weight coarser than No. 200 sieve size	CLEAN GRAVEL Over 50 percent of coarse fraction larger than No. 4 sieve size	CLEAN GRAVEL Little or No Fines	GW	Well graded gravel and well graded gravel with sand	
			GP	Poorly graded gravel and poorly graded gravel with sand	
		GRAVELS WITH FINES Over 12 percent	GM	Silty gravel and silty gravel with sand	
			GC	Clayey gravel and clayey gravel with sand	
	SANDS Over 50 percent of coarse fraction smaller than No. 4 sieve size	CLEAN SANDS Little or No Fines	SW	Well graded sand and well graded sand with gravel	
			SP	Poorly graded sand and poorly graded sand with gravel	
		SANDS WITH FINES Over 12 percent	SM	Silty sand and silty sand with gravel	
			SC	Clayey sand and clayey sand with gravel	
FINE GRAINED SOILS Over 50 percent by weight finer than No. 200 sieve size	SILTS AND CLAYS Liquid limit less than 50 percent		ML	Inorganic silt, sandy silt, clayey silt, or gravelly silt	
			CL	Inorganic lean clay, sandy clay, silty clay, or gravelly clay	
			OL	Organic silt, clay, sandy silt, sandy clay, gravelly clay, or gravelly silt	
	SILTS AND CLAYS Liquid limit 50 percent or more		MH	Inorganic, elastic silt, sandy silt, clayey silt, or gravelly silt	
			CH	Inorganic fat clay, sandy clay, silty clay, or gravelly clay	
			OH	Organic clay, silt, sandy- or silty-clay, clayey- or sandy-silt, gravelly silts or clays	
	HIGHLY ORGANIC SOILS		PT	Peat or other highly organic soil	

COARSE PARTICLE SIZE:

SAND	FINE	0.0029 inch	to	0.017 inch
	MEDIUM	0.017 inch	to	0.079 inch
	COARSE	0.079 inch	to	0.19 inch
GRAVEL	FINE	0.19 inch	to	0.75 inch
	COARSE	0.75 inch	to	3.00 inches
COBBLE		3.00 inches	to	12.00 inches
BOULDER		Greater than 12 inches		

DATUM:

ABM	Assumed Bench Mark
MLLW	Mean Lower Low Water
MSL	Mean Sea Level
Other	

COLOR DESCRIPTION GUIDE: Based on Munsell Color System