POSEIDON WATER

Appendix T
Drought Proofing Through Desalting
The SDG&E Approach

Renewal of NPDES CA0109223
Carlsbad Desalination Project

HYDROGEOLOGIC INVESTIGATION
SDG&E ENCINA POWER PLANT
CARLSBAD, CALIFORNIA

Prepared for
BOYLE ENGINEERING CORPORATION

Project No. 1555
March 23, 1994

APEX GEOTECHNOLOGY, INC., *in association with*
GROUP DELTA CONSULTANTS, INC., A Joint-Venture Partnership

Dr. Balakrishna Rao, Sc.D., RCE, RGE
Walter F. Crampton, RCE, RGE
Barry R. Bevier, RCE, RGE
Braven R. Smillie, RG, CEG
Phillip C. Birkhahn, RG, CEG
Welford E. Garner, RG, CEG
Matthew W. Eckert, Ph.D., RCE
Francis O. Moreland, RG

APEX GEOTECHNOLOGY, INC.
in association with
GROUP DELTA CONSULTANTS, INC.
A Joint-Venture Partnership

4455 Murphy Canyon Road, Suite 100
San Diego, California 92123
Fax: (619) 573-0069 Tele: (619) 573-1777

Project No. 1555
March 23, 1994

Mr. Don MacFarlane
BOYLE ENGINEERING CORPORATION
7807 Convoy Court, Suite 200
San Diego, California 92111

HYDROGEOLOGIC INVESTIGATION
SDG&E ENCINA POWER PLANT
CARLSBAD, CALIFORNIA

Dear Mr. MacFarlane:

We are pleased to submit the accompanying report for the existing SDG&E Encina Power Plant in Carlsbad, California. This report presents the results of our hydrogeologic investigation, which includes a summary of our review of available historical site information, a description of our geologic site reconnaissance, the results of our field investigative work, including production well siting and design and pumping test analyses, and our conclusions and recommendations pertaining to the proposed on-site groundwater pumping operation.

We appreciate the opportunity to work with you on this project and trust this information meets your needs. If you have any questions, please give us a call.

Very truly yours,
for APEX GEOTECHNOLOGY, INC., in association with
GROUP DELTA CONSULTANTS, INC.,

Barry R. Bevier
R.C.E. 31461, R.G.E. 143

David Huntley, Ph.D.
Professor of Geological Sciences

Jeffery M. Krusinga
R.C.E. 49295

BRB/DH/JMK/jc

(5) Addressee

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HYDROGEOLOGIC INVESTIGATION
SDG&E ENCINA POWER PLANT
CARLSBAD, CALIFORNIA

1 INTRODUCTION

The existing San Diego Gas and Electric (SDG&E) Encina Power Plant is located at 4600 Carlsbad Boulevard in the City of Carlsbad, California. The facility is generally bounded by Interstate 5 (I-5) on the east, Cannon Road on the south, Carlsbad Boulevard and the Pacific Ocean on the west, and Agua Hedionda Lagoon on the north. The layout of the northwesterly portion of the site, which contains the majority of the existing plant facilities is shown on the Site Plan, Figure 1.

The existing power generation plant currently relies entirely upon the City of Carlsbad municipal water supply to meet all on-site industrial and potable water needs. We understand that SDG&E is committed to the development of an independent water supply, for both potable and industrial uses, to eliminate the current dependance of the Encina Power Plant upon the City of Carlsbad. It is envisioned that this alternative water supply can be derived from on-site wells (or nearby off-site wells) that would extract brackish or seawater quality groundwater. This water would then be fed directly into a proposed on-site reverse osmosis (RO) facility to produce process and potable water for the plant. To meet all on-site needs we understand that SDG&E anticipates a peak demand of approximately 400 gallons per minute (gpm) of product from the RO facility.

The purpose of our study is to locate the most promising area(s) for a potential groundwater well field (with priority given to on-site locations), which would supply sufficient feed water to the RO system to meet the anticipated demands of the plant.

2 SCOPE OF WORK

Our scope of work included the following:

- Reviewing existing maps, reports, photographs, and other historical information pertinent to the subject site;
- Performing a geologic reconnaissance of the site, including the drilling of four exploratory borings, constructing monitoring wells in selected borings, and conducting a gravity survey;
- Performing laboratory testing on selected samples from our exploratory borings;
- Selecting a suitable site for locating a production well;
- Designing and constructing a production well;
- Performing a step-drawdown test on the production well to assess its long-term yield; and
- Preparing a written report documenting our investigation and testing, and presenting our results and conclusions.

3 DATA REVIEW

3.1 Initial Document Review/Well Site Alternatives

Our preliminary selection of potential production well sites was performed in late October 1993, and was based on our site reconnaissance and on a review of available in-house documents, including topographic maps and air photos. A list of the most useful documents reviewed is included in the reference section of this report. Based on our initial document review, three sites were identified as possible locations for a production well:

1. Plant Site. This was the most desirable location due to the proximity to existing power plant facilities. However, the anticipated underlying formational materials are known to be poor water producers.

Pertinent reports and plans provided by SDG&E included a geotechnical investigation report prepared by Dames and Moore (1951), performed for the initial plant construction. The site plan and boring logs included with the Dames and Moore report indicated the existence of a tributary "slough" (channel) containing upwards of 100 feet of potentially water-bearing alluvial sediments. This channel was located generally under the existing plant, administration offices and parking area adjacent the launch ramp, and was filled during grading operations associated with plant construction. Based on our interpretation of the Dames and Moore report, the depth of alluvium in the old (now filled) channel made it a likely prospect for a production well.

2. Easterly of Plant Site - in the alluvial sediments of Agua Hedionda Lagoon. A possible well location was identified within an existing SDG&E power-line easement. Well yields near this area are known to be high. However, environmental concerns may seriously hinder drilling activities and construction of a water distribution system within the limits of the Lagoon. Therefore, distance from the site and environmental concerns may limit the potential of this area.

3. Northerly of Plant Site - on the linear strip of beach deposits (sand spit) parallel to Carlsbad Boulevard at the mouth of the lagoon. This was felt to be the most likely location for potential significant water production due to the anticipated permeable nature of the sediments and the suspected relatively thick sedimentary deposits.

Based upon our initial literature and aerial photograph review, and our understanding of property boundaries, a field exploration program was initiated that focused on the plant site and the northerly sand spit due to their proximity to the anticipated location of the RO facility.

4 FIELD INVESTIGATION

Our field investigation consisted of advancing four exploratory borings, installing groundwater monitoring wells in three of these borings, and performing a geophysical survey.

4.1 Exploratory Drill Borings

The four exploratory borings were advanced in selected areas to assist in identifying a location for construction of a production well, and to monitor any groundwater level changes during future aquifer testing. The approximate locations of these exploratory borings are indicated on the Site Plan, Figure 1.

The exploratory borings were advanced between November 30, 1993, and December 7, 1993, using a Mobile B-61 truck-mounted drill rig. The borings were advanced to depths ranging from 50 to 135.5 feet. Disturbed soil samples were obtained from the test borings and transported to the testing laboratory. The drilling operation was supervised, and borings logged and classified, by a geologist from our firm. Field logs of the materials encountered in the test borings were prepared based on a visual examination of the materials observed in samples and cuttings.

A Key to Excavation Logs is presented in Appendix A as Figure A-1. Final logs of the test borings were prepared, and are presented as Figures A-2 through A-5 in Appendix A. The descriptions on the logs are based on the field log descriptions, and on subsequent laboratory testing.

4.2 Groundwater Monitoring Wells

Monitoring wells were installed in Borings B-2 through B-4 to allow measurement of water levels during aquifer testing. The monitoring wells consisted of 2-inch-diameter PVC pipe, joined with threaded connections. The pipe was slotted (0.02-inch slots) from slightly below the water table to the bottom of the pipe. The annular space surrounding the screened section of the PVC was backfilled with Lone Star #3 sand. A bentonite seal extending slightly below the water table was placed above the sand. Details of the construction of the individual monitoring wells are presented graphically on the boring logs, Figures A-2 through A-5.

4.3 Geophysical Survey

A geophysical gravity survey was performed on December 4, 1993, subsequent to drilling Boring B-1 on the sand spit northerly of the Encina Power Plant. The approximate alignment of the gravity survey is presented on Figure 1, Site Plan. The gravity survey was performed to aid in defining the location and extent of the deeper portions of permeable water-bearing sediments, such as a now-infilled paleo-stream channel.

The gravity readings were taken with a Lacoste-Romberg G type meter. The data was reduced using Lacoste-Romberg programs. The survey indicated a buried channel, centered approximately 500 feet south of Boring B-1, with a thickness of sediments in excess of 60 feet.

The results of the gravity survey are presented in Appendix B.

5 GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Geologic Setting

The present-day configuration of the southern California coastline can be said to have had its early beginnings during Cretaceous time (120 to 85 million years ago) when the southern California Batholiths intruded existing Triassic and Jurassic-age strata, causing uplift to the east, and subsidence to the west where the deposition of marine sediments has continued through the last 80 to 60 million years.

The site lies predominantly on estuarine sediments deposited at the mouth of Agua Hedionda Lagoon. The lagoon includes an alluviated ancestral channel (paleo-channel), which had been incised approximately 180 feet into the 1/2-mile-wide coastal terrace approximately 18,000 years ago during a glacial episode when the sea stood approximately 300 feet below current sea level.

5.2 Subsurface Conditions

Borings B-1 through B-4 and the production well (see Figure 1) encountered artificial fill soils, estuarine deposits, and soils of the Santiago Formation. These soil units, depicted stratigraphically on the boring logs in Appendix A, are described below in the order of increasing age.

Artificial Fill - Soils encountered in the upper approximately 10 to 20 feet of Borings B-1 through B-4 consist generally of moist, light grayish-brown, silty to clayey fine sands, with sparse gravels. These man-placed fill soils, which appear to have been derived from late Pleistocene-age terrace deposits, were likely excavated on site during grading for the construction of the Encina Power Plant.

Estuarine Deposits - Loose to very dense (typically medium dense), saturated, pervious, light gray, silty fine sands, with interbeds of gravel, shells, and clay, characterize the estuarine deposits encountered in Borings B-1 through B-4 and the production well. These interbedded fluvial, lagoonal, and marine deposits, which are typical of the intertidal sediments that fill aggraded canyons throughout San Diego County, extend to a depth of approximately 180 feet at the production well location. These sediments may exist to somewhat greater depths elsewhere along the alignment of Carlsbad Boulevard within the limits of Agua Hedionda Lagoon.

Santiago Formation - Very dense, saturated, light olive-gray to grayish-brown, clayey fine to medium sands characteristic of the Santiago Formation, underlie the entire project area at depth. These relatively horizontally-stratified nearshore marine sediments, which were deposited during middle Eocene time (40 to 50 million years ago), appear to be of low permeability and do not exhibit abundant jointing.

6 PRODUCTION WELL SITING AND CONSTRUCTION

6.1 Production Well Siting Study

The production well, which was used for testing, was sited based upon our understanding of the SDG&E property boundaries, our review of the available soil and geologic literature, and the subsurface conditions encountered in our borings. Early in our study, we determined that the target aquifer would likely be alluvial soil in the vicinity of Agua Hedionda Lagoon or surrounding areas, as the underlying formational materials are typically quite impermeable. Three areas were identified as potential sites for wells: the north-central area of the plant site near the southern lagoon boundary, the sand spit that extends north of the plant site at the mouth of the lagoon, and the low-lying property at the south side of the lagoon, east of I-5. Of these three areas, the most desirable site was the sand spit, due to the likelihood of encountering the deepest section of permeable alluvium. The plant site was given a secondary priority due to the interbedded less-permeable clay layers and the potential for subsidence of the fill soil underlying the plant site. Due to logistical and potential environmental constraints, the area east of I-5 was given the lowest priority.

As discussed in Section 5.1, Geologic Setting, significant depths of permeable alluvium were anticipated as infilling paleo-channels where the Lagoon entered the ocean. As these paleo-channels are now filled with sediments to the surface, their location and extent are difficult to define from visual observation. A gravity survey was performed to define the location and extent of any paleo-channels. The gravity survey indicated a buried channel 500 feet south of Boring B-1, with a depth in excess of 60 feet. Following the evaluation of the results of the gravity survey, exploratory Boring B-4 was advanced near the channel centerline as indicated by the gravity survey. Boring B-4 disclosed in excess of 135 feet of alluvial sediments, and indicated highly favorable conditions for installation of a production well.

After evaluation of the exploratory data, the sand spit was determined to be a far superior site due to the depth and grain-size distribution of the sandy alluvial soil.

6.2 Production Well Design, Construction and Development

The preliminary production well design was based upon the stratigraphy identified in Boring B-4 and the results of grain-size distribution tests performed on soil samples obtained from Boring B-4. The final design was confirmed with the lithologic and geophysical logs of the production well. A detailed description of the well design procedure, which describes the design of the gravel pack and well screen, is provided in Appendix D, Production Well Design. The geologic and gamma logs of Production Well W-1, along with the as-built well configuration, are presented on Figure 2, Production Well Logging and Construction.

After the installation of casing, screen, and gravel pack, the well was developed by using a surge block. Suspended sediments in the well bore were brought to the surface by using compressed air. During well development operations, the bottom plug apparently became dislodged, causing sediment to fill the lower 5± feet of the well bore. The lower 10 feet of the well was subsequently filled with grout to plug the breach.

After initial development with a surge block, further development was performed by pumping the well at full capacity. Periodic pumping was conducted for several days prior to commencement of aquifer testing.

7 AQUIFER TESTING

A step-drawdown test was performed on Production Well W-1 to evaluate the yield of the well and the characteristics of the aquifer. The test was conducted between February 2 and 4, 1994. Pumping was conducted for a period of 25.3 hours, followed by monitoring recovery for an additional 24.0 hours.

Water levels in the production well and Monitoring Wells B-2 and B-4 were measured continuously using electronic pressure transducers and data loggers. Water levels were also monitored manually at random intervals with a well probe.

The pumping test at Production Well W-1 was conducted in four steps, as summarized below.

Pumping Test Design, Production Well W-1

Step	Pumping Rate (gpm)	Duration (min)	Maximum Corrected Drawdown (ft)
1	55	93	9
2	110	109	11.1
3	220	174	10.6
4	330	1144	13.9
Recovery	0	1443	NA

The results from the step-drawdown test were analyzed using the approach described by Birsoy and Summers (1980) after correction for ocean tidal effects. The procedure used to correct the data for tidal effects is described in Appendix E. The Birsoy and Summers' method is a modification of the standard Cooper-Jacob method of analyzing pump test and recovery data. It involves plotting the ratio of s/Q (drawdown divided by pumping rate) versus the log of a corrected time for each step. The corrected time for each of the four different pumping rates and the recovery is calculated by the five equations presented below.

<u>Step 1</u>

$$t_{corr} = t_1 \qquad (1)$$

<u>Step 2</u>

$$t_{corr} = \left(\frac{t_1}{t_1'}\right)^{\frac{Q_1}{Q_2}} t_2 \qquad (2)$$

Step 3

$$t_{corr} = \left(\frac{t_1}{t_1'}\right)^{\frac{Q_1}{Q_3}} \left(\frac{t_2}{t_2'}\right)^{\frac{Q_2}{Q_3}} t_3 \qquad (3)$$

Step 4

$$t_{corr} = \left(\frac{t_1}{t_1'}\right)^{\frac{Q_1}{Q_4}} \left(\frac{t_2}{t_2'}\right)^{\frac{Q_2}{Q_4}} \left(\frac{t_3}{t_3'}\right)^{\frac{Q_3}{Q_4}} t_4 \qquad (4)$$

Recovery

$$t_{corr} = \left(\frac{t_1}{t_1'}\right)^{\frac{Q_1}{Q_4}} \left(\frac{t_2}{t_2'}\right)^{\frac{Q_2}{Q_4}} \left(\frac{t_3}{t_3'}\right)^{\frac{Q_3}{Q_4}} \left(\frac{t_4}{t_4'}\right) \qquad (5)$$

where:

t_1 = time since the beginning of step 1.
t'_1 = time since the end of step 1.
Q_1 = well discharge during step 1.

The resulting plot of s/Q versus the log of corrected time for the production well is shown on Figure 3. The plot of s/Q versus the log of corrected time for the production well should result in parallel, straight-line plots for each of the steps, shifted upwards with increasing discharge due to turbulent well loss. The plot of s/Q versus log of corrected time for a monitoring well should result in parallel, straight-line plots that are not shifted upward because there is no turbulent well loss at the monitoring well. In both cases, the slope of the line can be used to calculate transmissivity using the equation;

$$T_e = \frac{2.3}{4\pi\Delta\left(\frac{s}{Q}\right)} \qquad (6)$$

where $\Delta(s/Q)$ = Change in s/Q per log cycle.

Aquifer storage coefficient, S, cannot be calculated using the production well data because of turbulent well loss. However, the storage coefficient can be calculated using the observation well response by extending the straight-line portion of the plot backwards to the time intercept (t_0) where drawdown (or s/Q) is equal to zero. The resulting intercept time is used to calculate storage coefficient by;

$$S = \frac{2.25\ T\ t_0}{r^2} \qquad (7)$$

With the exception of the first step, at 55 gpm, the data for Production Well W-1 (Figure 3) do plot as parallel lines, but they are shifted downward, to decreasing values of s/Q, contrary to theory. The data from the first step show much variation, likely due to fluctuation in discharge during the early parts of the step. This variation is common when a well is pumped significantly below its capacity. The downward, instead of upward, shift in the plots of steps three and four, at 220 and 330 gpm, suggests that there was minimal increase in turbulent well loss resulting from the increase in discharge. In contrast, the decrease in the values of s/Q from steps one to two to three suggest that turbulent well loss was decreasing, not increasing with increasing discharge. It is our opinion that the well was developing during steps one, two, and three, which caused this response.

The transmissivities calculated by equation (6) above and the slopes from steps two, three, four, and the recovery data are 5550, 7500, 7500, and 8800 ft^2/day, respectively. These values, together with the response of the well to increases in production suggest that the well is capable of yields in excess of 450 gpm.

The data from Monitoring Well B-4, located 42 feet north of Production Well W-1, were corrected for tidal fluctuations similar to Production Well W-1. Water levels in Monitoring Well B-4 were monitored for about two days prior to the pumping test at Production Well W-1. Correction of the data from Monitoring Well B-4 for tidal fluctuations is even more important than it was for

Production Well W-1. An uncorrected plot of water-level variations in Monitoring Well B-4 through the pumping test (Figure 4), shows that tidal effects produce a 2-foot variation in water level that is superimposed on a drawdown of about 2 feet from the pumping test. Correction of the data (Figure 5) for tidal influences removes most, but not all of the variations due to ocean tides. A residual tidal fluctuation of about 0.3 foot is still apparent in the data during the 330 gpm step.

As noted above, step-drawdown test data from an observation well can be analyzed in the same manner as the production well (Figure 6). Residual tidal fluctuations, even after correction, make it very difficult to evaluate step 4 (330 gpm). Water levels during step 2 were recovering (rising), rather than declining, due to ongoing development of the production well during the test. The best data come from step 1 (55 gpm), step 3 (220 gpm), and the recovery of the well (Figure 6). Each of these steps show some parallel response, with the line slopes indicating transmissivities of 5500 to 9400 ft^2/day. These values are very similar to those calculated from the production well. In addition, the observation well data can be used to calculated the storage coefficient of the aquifer. The late responses of step 1 and step 3 both suggest storage coefficients of 0.07, indicating that the aquifer is unconfined.

8 CONCLUSIONS AND RECOMMENDATIONS

1. The yield of Production Well W-1 is in excess of 450 gpm. The practical limitation of this well is the maximum capacity of a pump that can be placed in the eight-inch-diameter (nominal size) casing.

2. The yield of a well constructed with a larger-diameter casing, and larger slots and gravel-pack in the 145 to 180-foot interval, is likely to be in excess of 600 gpm.

3. The aquifer transmissivity is 5000 to 9000 ft^2/day. The storage coefficient measured during the aquifer test is 0.07. The long-term storage coefficient may be higher.

4. Production from the area of the well site at a rate of 600 gpm will produce about two to four feet of drawdown under the adjacent Carlsbad Boulevard and negligible drawdown under the SDG&E power plant.

5. Based on empirical correlations from SPT blow counts obtained in Boring B-4 and an assumed long-term drawdown of 4 to 6 feet, we estimate that ground settlement may affect up to 2,000 feet of Carlsbad Boulevard. Settlement of Carlsbad Boulevard near the well is estimated to be on the order of 2 inches. Settlement is anticipated to create a dish-shaped surface depression centered on the production well, where no improvements exist. Areal settlement under Carlsbad Boulevard is not anticipated to create sharp differential settlements. We do not anticipate this magnitude of settlement to cause objectionable distress to pavement or utilities.

6. Any future wells drilled and constructed near Production Well W-1 should be designed using information derived from the drilling and logging of Production Well W-1. Specifically:

   a. Samples collected from the 145-foot to 180-foot interval should be analyzed for grain-size distribution, and a larger gravel-pack and slot-size should be selected for that interval. The Lone Star #3 and 0.03-inch slots performed satisfactorily in the test well and should be used again above the medium-grained sand found at depth. To avoid silting of the well, the smaller slot size should extend down into the 145-foot to 180-foot interval by at least 10 feet, and the Lone Star #3 gravel pack should extend down into the 145-foot to 180-foot interval for at least 5 feet.

   b. The diameter of the casing should be at least 10 inches.

7. If the project is feasible by using additional wells, we recommend that:

   - Cone penetration testing (CPT) be utilized to confirm the area where the deepened channel exists along the spit;
   - Pumping tests be performed on any new wells; and
   - Potential ground settlement be reevaluated based on the final number and configuration of wells and proposed pumping rates.

9 LIMITATIONS

Geotechnical engineering and the earth sciences are characterized by uncertainty. We have investigated only a small portion of the pertinent soil, rock, and groundwater conditions at the project site. The opinions, conclusions, and recommendations expressed herein are based on the assumption that the soil and groundwater conditions do not deviate appreciably from those observed at the locations of our exploratory borings and test well.

Analyses of pumping test data and hydrogeologic conditions assume that the subsurface conditions consist of a homogenous medium, which rarely exists in nature. Therefore, there may be a considerable degree of error associated with the estimated aquifer parameters calculated from the pumping test results, and conclusions drawn from this data.

Professional judgements presented herein are based partly on our evaluation of the technical data gathered for this project, partly on our understanding of the proposed project, and partly on our experience in the field of geotechnical engineering and hydrogeology. We do not guarantee the performance of the project in any respect.

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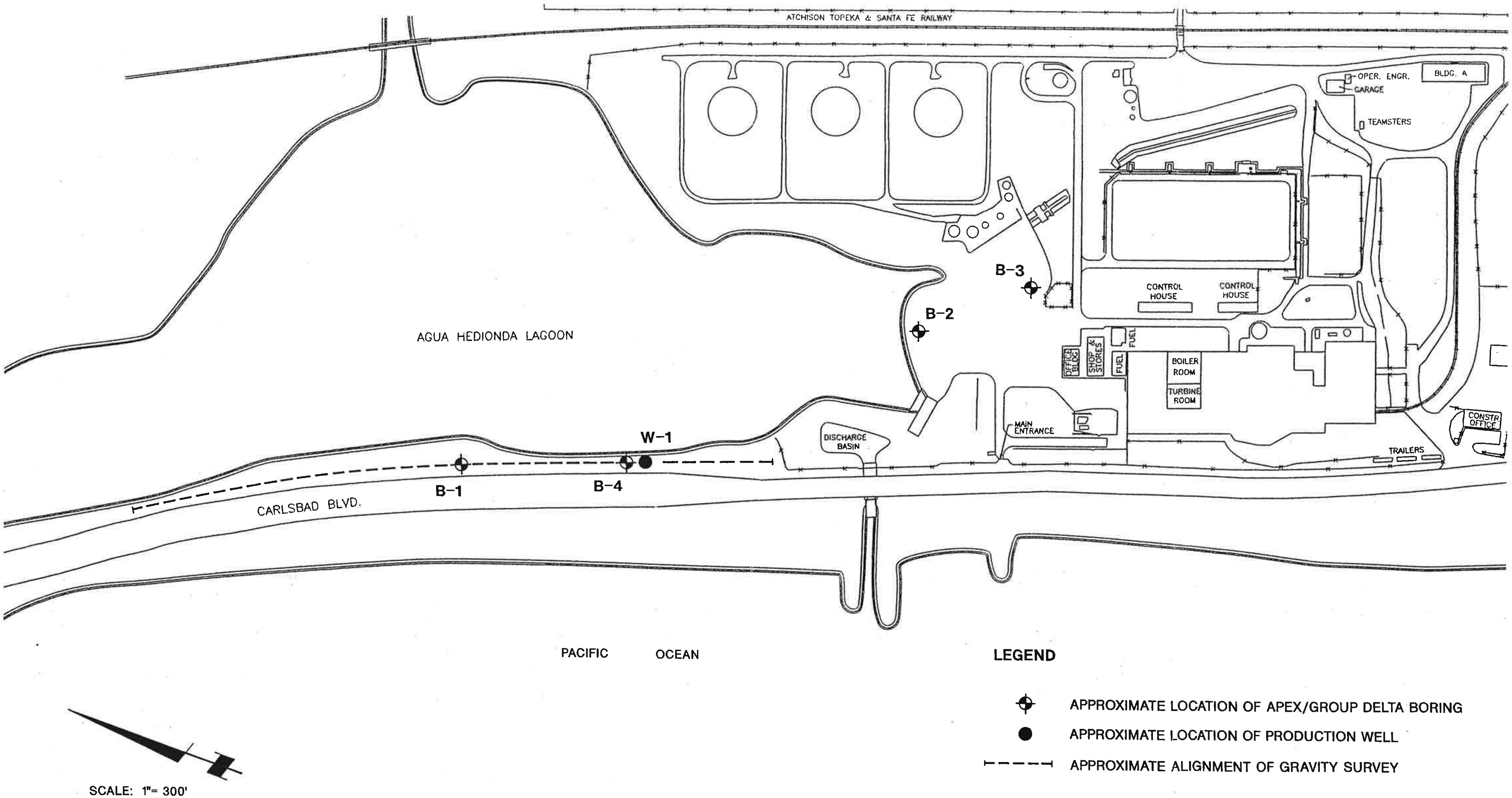
- Property Plot plan, 10/12/73, Pioneer Service & Engineering Company, scale 1":120'



BASE MAP FURNISHED BY BOYLE ENGINEERING CORPORATION

Project		Project No.	Figure
SDG&E ENCINA POWER PLANT	SITE PLAN	1555	1

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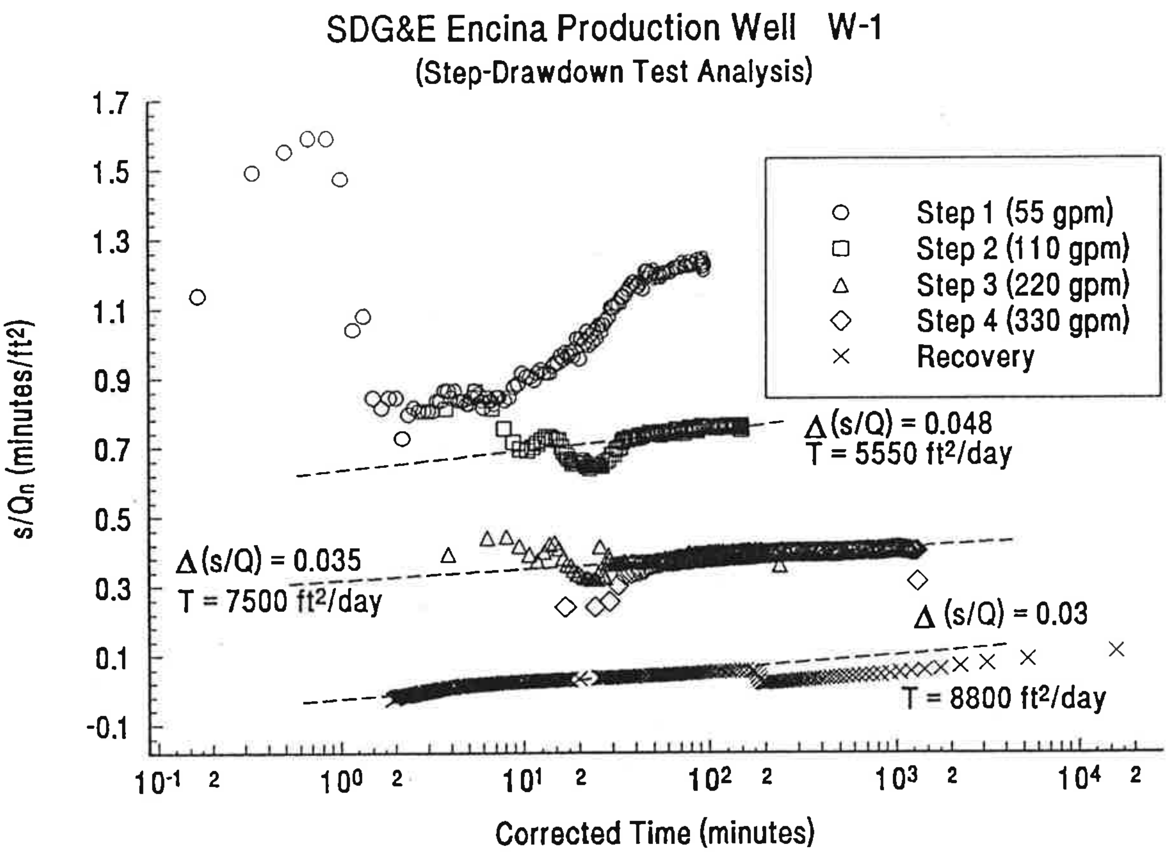
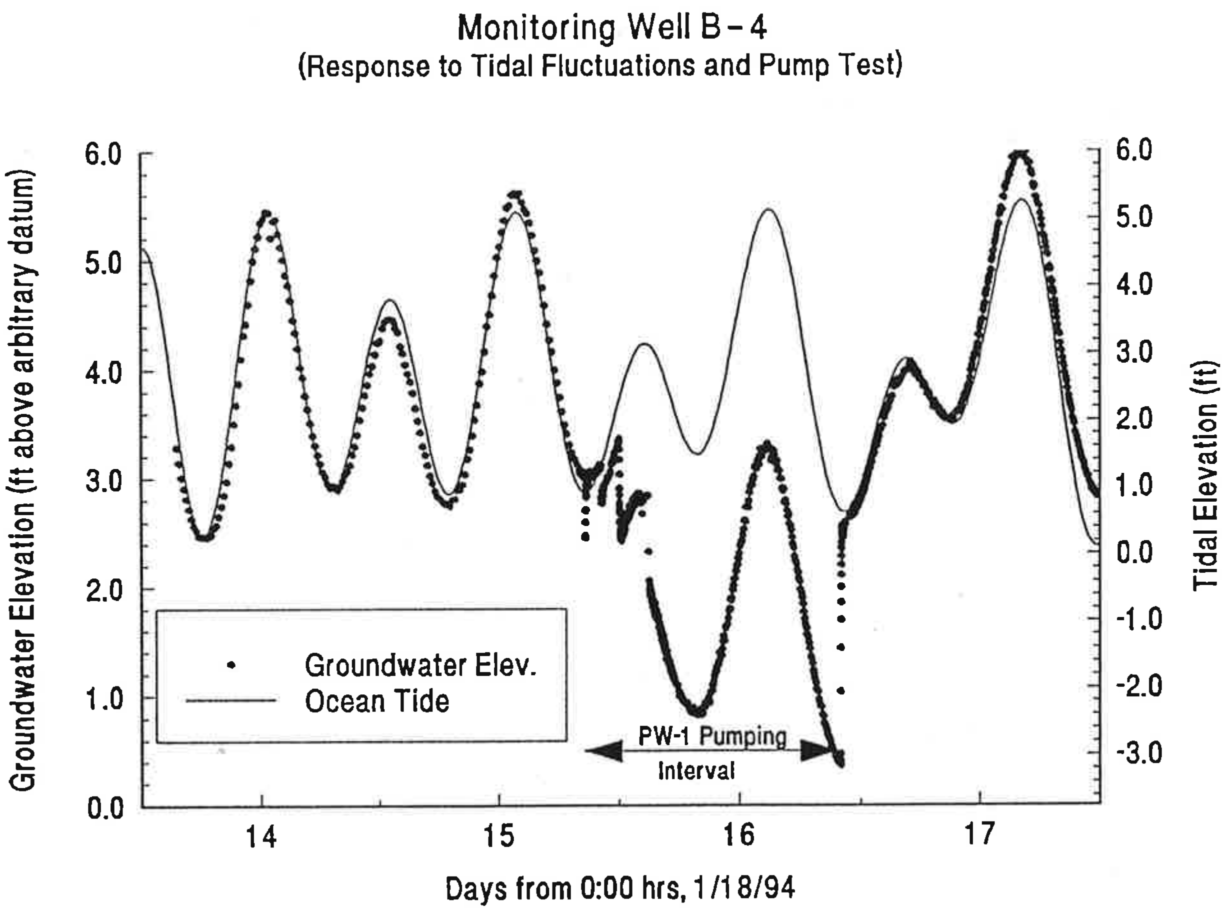


STEP–DRAWDOWN TEST ANALYSIS, PRODUCTION WELL W–1

Project No. 1555	SDG&E ENCINA POWER PLANT	Figure 3



WATER LEVEL MONITORING, MONITORING WELL B-4

Project No. 1555	SDG&E ENCINA POWER PLANT	Figure 4

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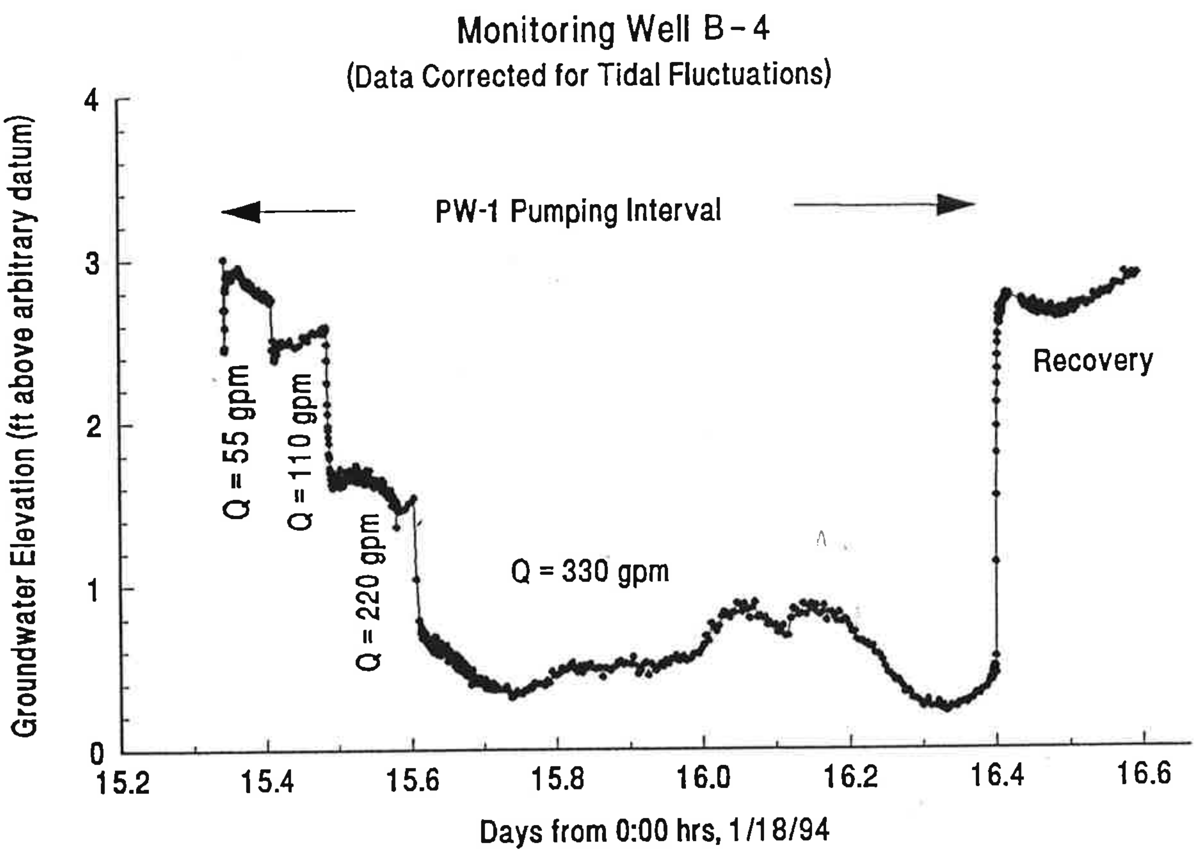

RESPONSE OF MONITORING WELL B-4 TO STEP-DRAWDOWN TEST AT PRODUCTION WELL W-1

Project No. 1555	SDG&E ENCINA POWER PLANT	Figure 5

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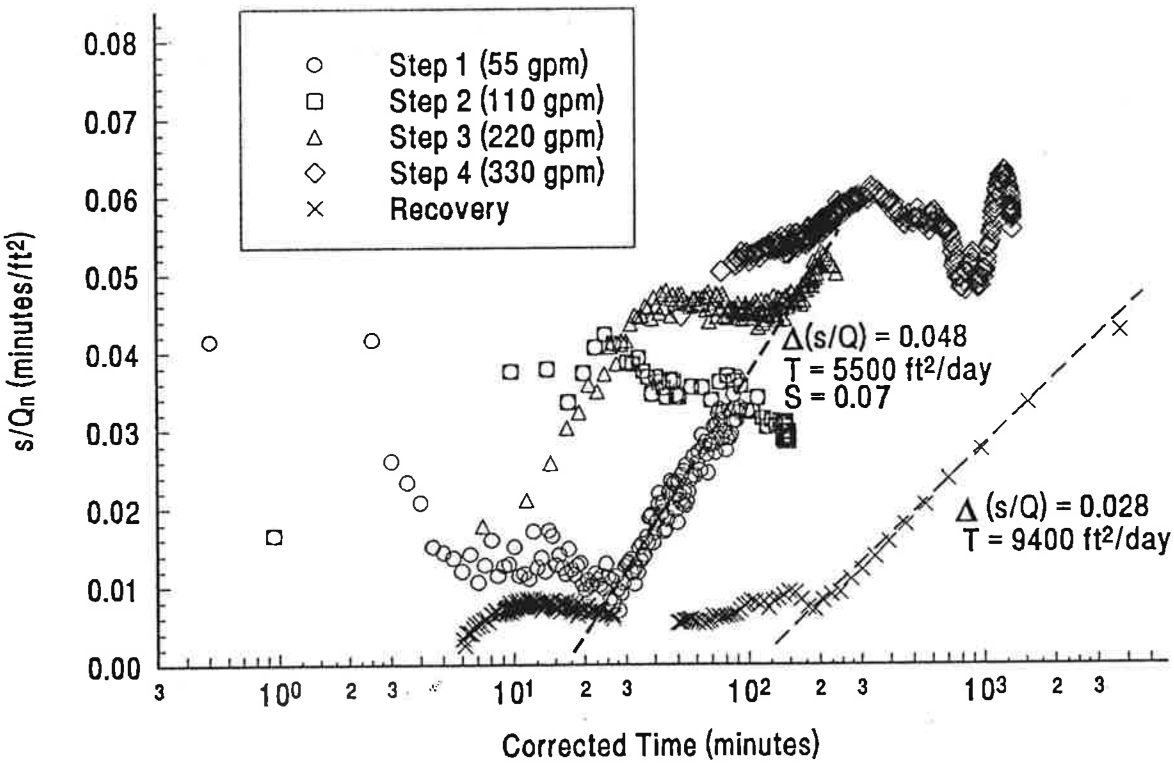
Monitoring Well B-4
(Step-Drawdown Test Analysis)



STEP-DRAWDOWN TEST ANALYSIS, MONITORING WELL B-4		
Project No. 1555	SDG&E ENCINA POWER PLANT	Figure 6

APPENDIX A
BORING LOGS AND
MONITORING WELL CONSTRUCTION

K E Y T O E X C A V A T I O N L O G S

LOGGED BY:	DATE DRILLED:	BORING ELEVATION:		BORING NO.:
DRILL RIG:	BORING DIAMETER:	HAMMER WT.:	DROP:	

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	D E S C R I P T I O N	WELL CONSTRUCTION DEAILS	OTHER TESTS
			14	▽	Medium dense, moist, brown SILTY FINE SAND (SM)		
5							

Unified Soil Classification

Water Table Measured At Time of Drilling

Number of Blows Required to Advance Sampler One Foot

Sample Type:
- C California Drive with Rings
- SP Standard Penetration Drive

Sample Location

Depth Below Surface Elevation

See Figure A-1b for key to Well Construction Details

Indicates Any Laboratory Tests Performed on Samples:
- GS Grain Size Analysis

N O T E S O N F I E L D I N V E S T I G A T I O N

1. Borings were advanced using a truck-mounted Mobile B-61 drill rig with an 8-inch hollow-stem auger.

2. Split-spoon samplers associated with either the Standard Penetration Test (SP) or California Drive (C) were driven into the soil with a 140-pound hammer falling 30 inches at selected depths as the boring was advanced. When the samplers were withdrawn from the boring, the samples were removed, visually classified, sealed in plastic containers, and taken to the laboratory for detailed inspection.

   The split-spoon sampler for the SP is an 18-inch-long, 2-inch O.D., 1-3/8-inch I.D. drive sampler.

   The California Sampler is an 18-inch-long, 2-1/2-inch I.D., 3-inch O.D., thick-walled sampler. The sampler is lined with eighteen 2-3/8-inch I.D. brass rings. Relatively undisturbed, intact soil samples are retained in the brass rings.

3. Free groundwater was encountered in the borings as shown on the logs.

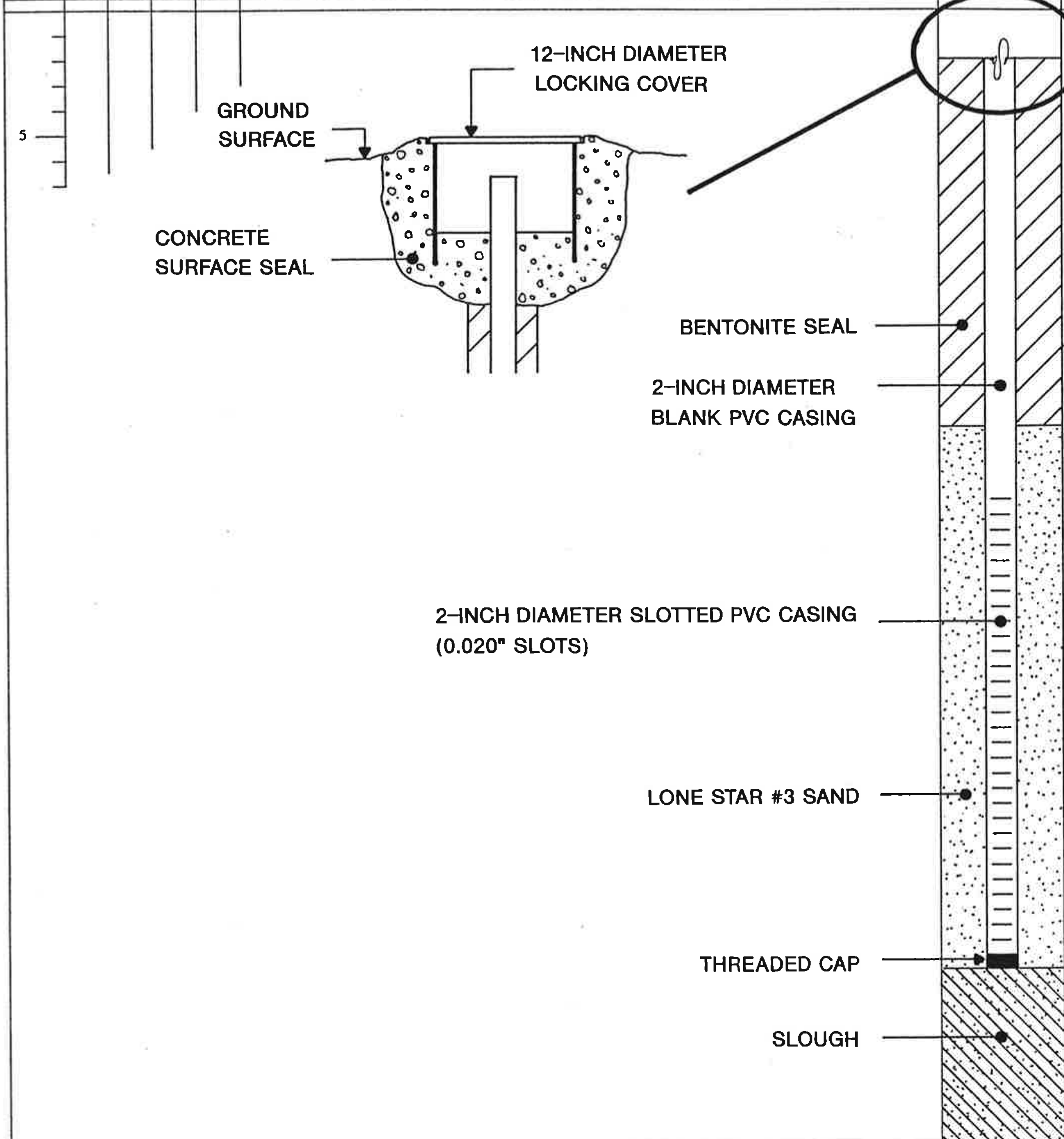
4. Classifications are based upon the Unified Soil Classification System and include color, moisture and consistency. Field descriptions have been modified to reflect results of laboratory inspection and testing where deemed appropriate.

Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

K E Y   T O   E X C A V A T I O N   L O G S

LOGGED BY:	DATE DRILLED:	BORING ELEVATION:		BORING NO.:
DRILL RIG:	BORING DIAMETER:	HAMMER WT.:	DROP:	

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	D E S C R I P T I O N	WELL CONSTRUC-TION DEAILS	OTHER TESTS



Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A-1b

B O R I N G   L O G

LOGGED BY: FOM	DATE DRILLED: 11-30-93	BORING ELEVATION: 9± feet	BORING NO.: B - 1
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	DESCRIPTION	WELL CONSTRUCTION DETAILS	LAB TESTS
0–10				▽ (approx. 7')	Moist to saturated, light grayish-brown, SILTY FINE SAND (SM) FILL; trace gravel; becomes saturated (approx. 7'); trace gravel (approx. 9')	WELL NOT CONSTRUCTED	
10	1	SP	33				
10–35					Medium dense, saturated, light gray, SILTY FINE SAND (SM) ESTUARINE DEPOSITS; sparse gravel and shells (13 to 13½'); moderate gravel and shells (13½ to 15')		
15	2	SP	14				
20	3	SP	21		approx. 3" layer of shells and gravel at 22'		
25	4	SP	36		becomes light gray		
30	5	SP	48		a few pieces of silty clay in cuttings (likely indicate thin clay interbeds)		
35	6	SP	52				
35–50					Very dense, saturated, light olive-brown, CLAYEY FINE TO MEDIUM SAND (SC) SANTIAGO FORMATION		
40	7	SP	50 / 4½"				
45	8	SP	54 / 6"				
50	9	SP	76 / 6"		BOTTOM OF BORING at 50 feet		

Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A - 2

APEX GEOTECHNOLOGY, INC., in association with GROUP DELTA CONSULTANTS, INC.
Engineers and Geologists

B O R I N G   L O G

LOGGED BY: FOM	DATE DRILLED: 12-1-93	BORING ELEVATION: 18± feet	BORING NO.:
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	B - 2

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	DESCRIPTION	WELL CONSTRUCTION DETAILS	LAB TESTS
0					5½" Asphalt Concrete Pavement / 6½" Class II Base		
					Moist to saturated, light brown, CLAYEY SAND (SC), with scattered gravel and cobbles — FILL		
9					— pieces of brown, sandy clay below 9'		
17				▽	becomes saturated		
19–20	1	SP	48		light gray silty sand at tip		
20					Medium dense, saturated, light gray, SILTY FINE SAND (SM), with shell fragments and sparse gravel (average 1/2") Gravel from 22½ to 23' and 23½ to 26½' — ESTUARINE DEPOSITS		
30					— abundant gravel		
35	2	SP	27		becomes very dense, saturated, SILTY FINE SAND (SM)		
40	3	SP	62				
45	4	SP	59				
50	5	SP	66				

Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

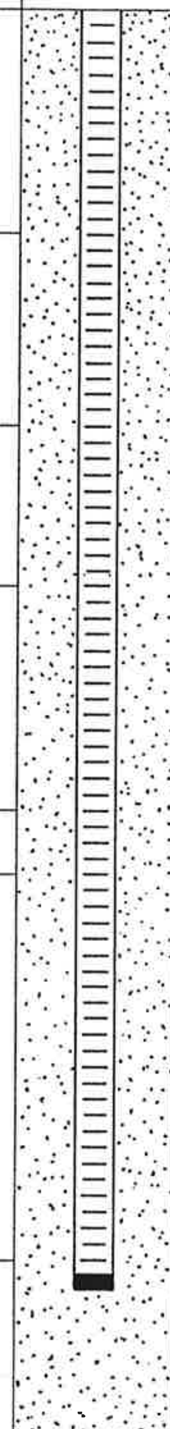
PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A - 3a

APEX GEOTECHNOLOGY, INC., in association with GROUP DELTA CONSULTANTS, INC.
Engineers and Geologists

B O R I N G   L O G

LOGGED BY: FOM	DATE DRILLED: 12-1-93	BORING ELEVATION: 18± feet	BORING NO.: B - 2
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	DESCRIPTION	WELL CONSTRUCTION DETAILS	LAB TESTS
					Very dense, saturated, light gray, SILTY FINE SAND (SM) — ESTUARINE DEPOSITS		
55	6	SP	38		becomes dense		
					Medium dense, saturated, gray, CLAYEY FINE SAND (SC), with sparse shell fragments		
60	7	SP	10				
					Medium dense, saturated, light gray, SILTY FINE SAND (SM)		
65	8	SP	22				
					Very stiff, saturated, gray, SANDY CLAY (CH)		
70	9	SP	20				
75	10	SP	19				
					Medium dense, saturated, light gray, SILTY FINE TO MEDIUM SAND (SM)		
					Stiff, saturated, gray, SANDY CLAY (CH)		
80	11	SP	11				
85	12	SP	14				
90	13	SP	50/3"		Very dense, saturated, light olive-gray, CLAYEY MEDIUM SAND (SC) — SANTIAGO FORMATION		
95	14	SP	100/5"		BOTTOM OF BORING at 94½ feet		
100							



Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

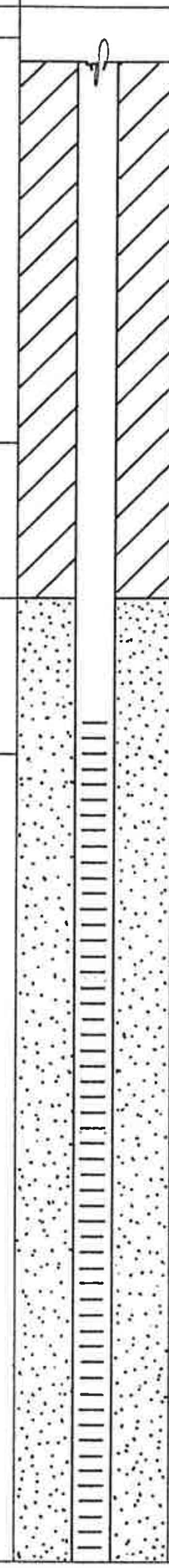
PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A - 3 b

B O R I N G   L O G

LOGGED BY: FOM	DATE DRILLED: 12-3-93	BORING ELEVATION: 17± feet	BORING NO.:
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	B - 3

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	DESCRIPTION
0					Asphalt Concrete Pavement
					Moist, light gray, CLAYEY FINE TO MEDIUM SAND (SC), with scattered gravel — FILL
5	1	C	26		
10	2	C	19		— becomes reddish brown
15	3	C	14	▽	Loose to medium dense, saturated, light gray, CLAYEY FINE SAND (SC) — ESTUARINE DEPOSITS
20	4	C	8		Soft, saturated, light gray, SANDY CLAY (CH) - organic odor
25	5	C	38		Medium dense, saturated, light gray, SILTY FINE SAND (SM), with sparse shell fragments
30	6	C	79		
35	7	C	79		
40	8	C	68		
45	9	C	35		
50	10	C	23		— no sample

WELL CONSTRUCTION DETAILS



LAB TESTS

Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A - 4 a

APEX GEOTECHNOLOGY, INC., in association with GROUP DELTA CONSULTANTS, INC.
Engineers and Geologists

BORING LOG

LOGGED BY: FOM	DATE DRILLED: 12-3-93	BORING ELEVATION: 17± feet	BORING NO.:
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	B - 3

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	DESCRIPTION	WELL CONSTRUCTION DETAILS	LAB TESTS
	10	C	55		Medium dense, saturated, light gray, SILTY FINE SAND (SM), with sparse gravel ESTUARINE DEPOSITS		
55	11	C	100/3½"		Very dense, saturated, light olive-gray, MEDIUM SAND (SW) SANTIAGO FORMATION (WEATHERED)		
	12	C	50/2"		Very dense, saturated, light olive-gray, CLAYEY MEDIUM SAND (SC) SANTIAGO FORMATION		
60	13	SP	100/3"				
65	14	SP	100/5"				
					BOTTOM OF BORING at 64½ feet		
70							
75							
80							
85							
90							
95							
100							

Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

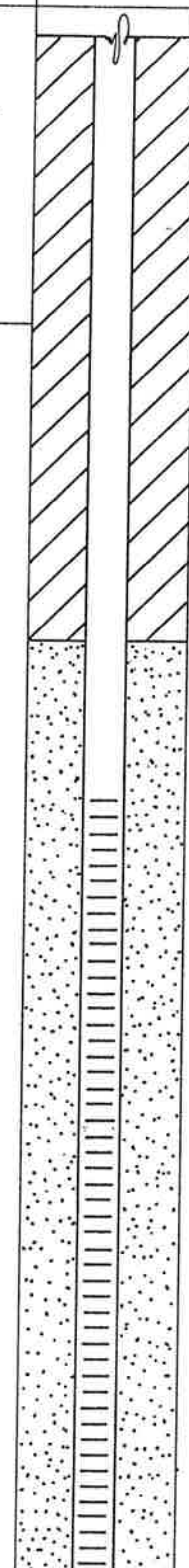
PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A - 4 b

BORING LOG

LOGGED BY: FOM	DATE DRILLED: 12-7-93	BORING ELEVATION: 9± feet	BORING NO.: B - 4
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	DESCRIPTION	LAB TESTS
0–10					Moist, light gray, FINE SILTY SAND (SM), with sparse gravel and cobbles — FILL	
10				▽	Medium dense, saturated, light yellowish-brown, SILTY FINE SAND (SM), gravel and cobbles to 12 feet — ESTUARINE DEPOSITS	
15	1	SP	25			
19					sparse gravel from 19 to 21½ feet	
25	2	SP	58		becomes very dense	
28					becomes light gray	
29					sparse gravel from 29 to 35 feet	
30	3	SP	50/5½"			GS
35	4	SP	58			GS
40	5	SP	73			
45	6	SP	51/6"			GS
50	7	SP	50/4½"			

WELL CONSTRUCTION DETAILS



Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A - 5a

APEX GEOTECHNOLOGY, INC., in association with GROUP DELTA CONSULTANTS, INC.
Engineers and Geologists

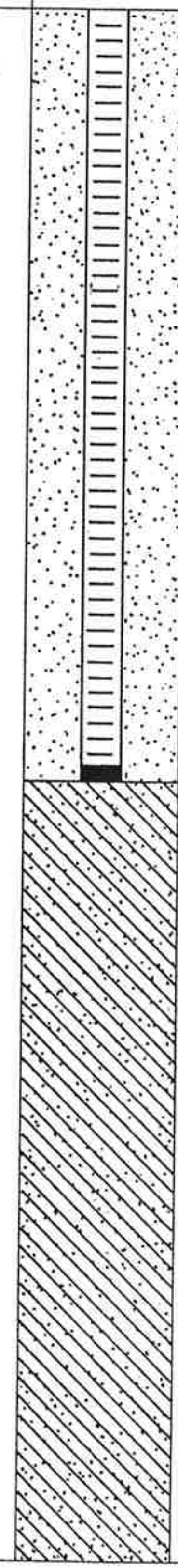
B O R I N G   L O G

LOGGED BY: FOM	DATE DRILLED: 12-7-93	BORING ELEVATION: 9± feet	BORING NO.: B - 4
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	

Description: Dense to very dense, saturated, light gray, SILTY FINE SAND (SM), with sparse gravel. ESTUARINE DEPOSITS

DEPTH (feet)	SAMPLE NO.	TYPE	BLOWS/FOOT	GROUND-WATER	LAB TESTS
55	8	SP	96		GS
60	9	SP	58		
65	10	SP	50/5½"		GS
70	11	SP	39		
75	12	SP	74		GS
80	13	SP	43		
85	14	SP	79		GS
90	15	SP	48		
95	16	SP	65		GS
100	17	SP	60		

WELL CONSTRUCTION DETAILS



Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

PROJECT NO.: 1555 | S D G & E ENCINA POWER PLANT | FIGURE NO.: A - 5 b

APEX GEOTECHNOLOGY, INC., in association with GROUP DELTA CONSULTANTS, INC.
Engineers and Geologists

BORING LOG

LOGGED BY: FOM	DATE DRILLED: 12-7-93	BORING ELEVATION: 9± feet	BORING NO.: B - 4
DRILL RIG: MOBILE B-61	BORING DIAMETER: 8"	HAMMER WT.: 140 LBS DROP: 30 IN	

DEPTH (feet)	SAMPLE NO	TYPE	BLOWS/FOOT	GROUND-WATER	DESCRIPTION	WELL CONSTRUCTION DETAILS	LAB TESTS
					Very dense, saturated, light gray, SILTY FINE SAND (SM)		
					ESTUARINE DEPOSITS		
105	18	SP	82				
					Stiff, wet, gray CLAY (CH)		
110	19	SP	12				
115	20	SP	12				
					(gradational contact)		
120	21	SP	32		Dense, saturated, light gray, SILTY SAND (SM)		
125	22	SP	18				
					Very stiff, saturated, gray CLAY (CH)		
					Dense, saturated, light gray, SILTY FINE SAND (SM)		
130	23	SP	41				
					— approximately 6" sandy clay at 134'		
135	24	SP	51				
					BOTTOM OF BORING at 135½ feet		
140							
145							
150							

Descriptions on this boring log apply only at the specific boring location and at the time the boring was made. The descriptions on this log are not warranted to be representative of subsurface conditions at other locations or times.

PROJECT NO.: 1555	SDG&E ENCINA POWER PLANT	FIGURE NO.: A - 5c

APPENDIX B
GRAVITY SURVEY

Gravity Profile of S.D.G.E. Property, Carlsbad, CA.

Essentials

This is a report of the gravity profile completed on December 4, 1993, by Clark Scott and Jeff Lewis. The profile extended along a line N40W and S40E feet from the existing boring and parallel to sub-parallel to the Pacific Coast Highway. Figure #1 shows a gravity low, - 0.3 mGals, 500 feet south of the existing boring and a gentle down gradient extending to the north under the public parking area.

A depth estimate can be made if certain assumptions are made. These assumptions include, but are not restricted to, a range of density contrast between the overburden and formation of 0.8 to 1.0 g/cc and the curve only reflects the overburden formation contact. Given these assumptions the minimum depth of the southern low can be calculated to be 20 to 30 feet below the contact in the existing boring, or 50 to 60 feet in depth.

The downward gradient to the north never quite reaches the same low as the area to the south, only 0.2 mGals at the end, and appears to continue to the north off the profile.

Methods

The stations were measured from the existing boring with a cloth tape and marked with orange paint. The existing boring was considered to be the hole under the orange cone approximately 30 feet south of the S.D.G.E. property gate/fence line. The stations are numbered sequentially from the well in both directions with 30 foot numbering intervals. The North line has 17 stations and is 1,020 feet long. These stations are spaced 60 feet apart and end approximately 500 feet short of the present channel. The South line has 31 stations spaced at 30 foot intervals to get better resolution on the S.D.G.E. property. The line is 930 feet long and ends 30 feet short of the fish hatchery fence line.

The gravity readings were taken with a Lacoste-Romberg G type meter. The meter has a reported absolute accuracy of .004 mGals and a relative standard deviation of 0.01 mGals (Scott, unpublished).

The surveying was done with a level and telescoping rod supplied by Group Delta and the northern and southern loops had closures of 0.02 and 0.1 feet respectively. Elevation differences for Terrain corrections were estimated out to 175 feet while more distant terrain were considered to impart a DC shift to the profile.

Reduction

The Data was reduced using Lacoste-Romberg programs. Terrain corrections were computed on 'GTerrain' using the Hammer zone method. The gravity readings were reduced on 'Gravpac' using overburden densities of 1.6 - 2.2 g/cc. The output was imported and plotted on Quattro-Pro (Figure #1).

Overburden Equation

The depth estimate made in this report is based on an overburden equation:

$$\Delta g = 0.0128\ \Delta\rho\ \Delta h \qquad (1)$$

Where $\Delta\rho$ is in g/cc and Δh is in feet

This equation is based on the Bouguer correction, the effect of a semi-infinite horizontal slab, and is best applied to shallow (low gradient) gravity anomalies. If the anomaly is steep, such as with the low to the south of the well, this equation can only supply a *minimum* depth.

Assumptions

There are several assumptions made when calculating depth to formation in a case such as this. First a density contrast has to assumed. In this report average values for the sediments were assumed to range from 1.4 to 2.5 g/cc and from 2 to 3 g/cc for the formation. For conservative reasons a density contrast of 0.8 to 1.0 g/cc was assumed and used to calculate the depth estimates. A lesser density contrast would increase the calculated depth while a greater contrast would decrease the depth. If the actual real density contrast can be found from boring samples, these contrasts can be used in Equation (1) to better define the minimum depth estimate.

A second and more critical assumption is the gravity reflects the overburden formation contact and not inhomogeneities in the overburden, structure in the formation, Nearby lagoon bottom variations, or cultural influences such as buried storm drains or flow channels perpendicular to the bar. I'm not familiar with this area nor the historical work done on this bar so it would be a good idea for the consulting firm to address and resolve these concerns.

Conclusions

Given the acceptance of the assumptions made above, the gravity profile could indicate a buried channel 500 feet south of the present boring and a overburden - formation contact deepening to the north. Given a reasonable range of density contrast, the southern channel could have a minimum depth of 50 to 60 feet while the depth of the northern channel, if one exists, is off the end of the profile and can not be determined. This depth estimate could be better constrained by using the actual density contrast and I suggest that this be done if possible.

Clark Scott, December 4, 1993

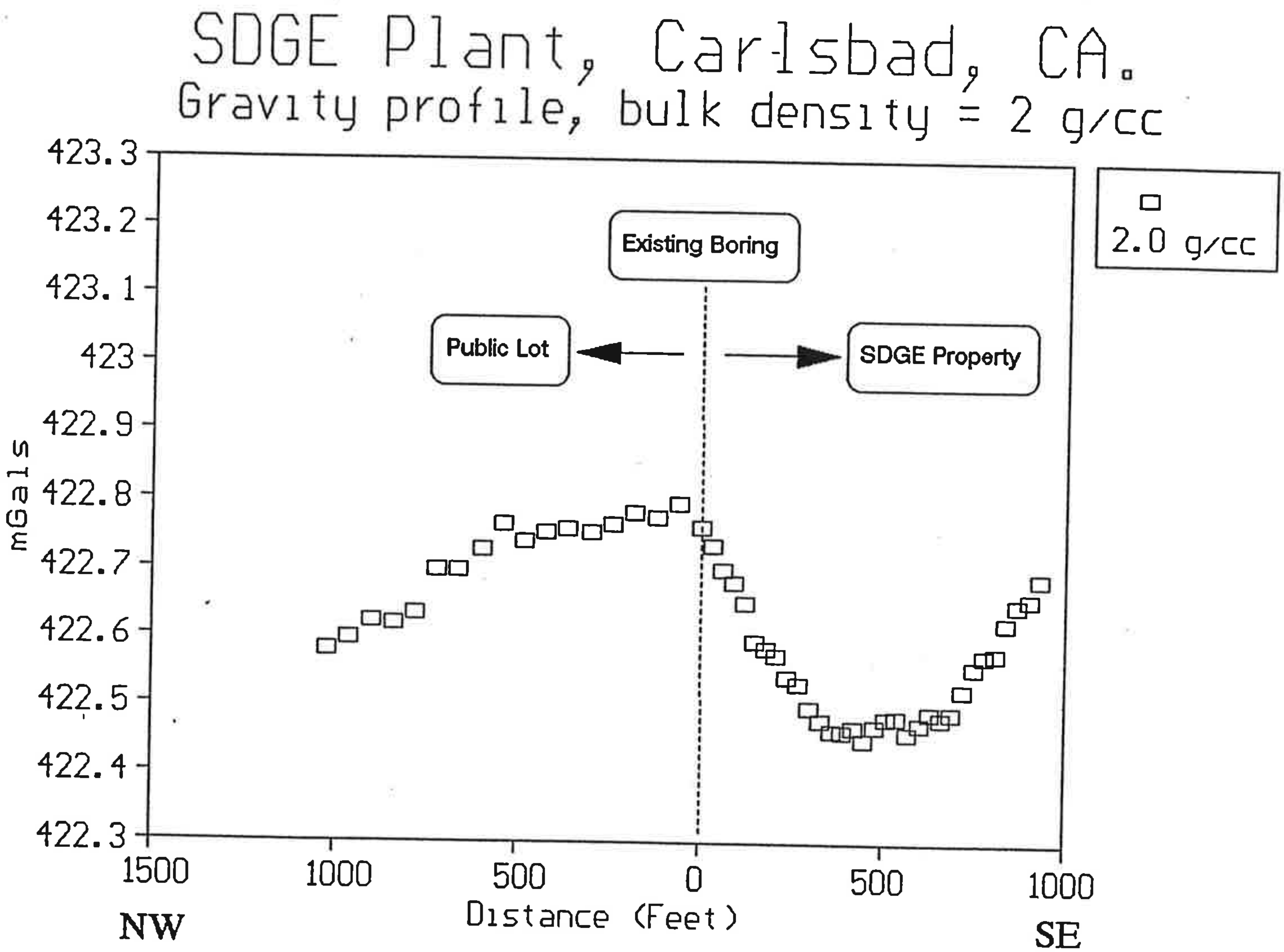


Figure #1 - Relative gravity profile calculated for a bulk density of 2.0 g/cc. Data has been corrected for elevation, drift, and nearby terrain.

Appendix

A1) Sample Depth Calculation

A2 - A7) Raw Data output from Gravpac

A8 - A10) Computed metered output from Gravpac

A11 - A13) Computed Bouguer output from Gravpac

A14) Figure #1

A15 - A16) Figure #2

Sample Depth Calculation:
$\Delta\rho = 0.8$ g/cc
$\Delta g = 0.3$ mGals

$$\Delta g = 0.0128\ \Delta\rho\ \Delta h$$

$$\Delta h = \frac{\Delta g}{0.0128\ \Delta\rho}$$

$$\Delta h = \frac{0.3}{0.0128\ (0.8)} = 29.3\ ft$$

$$Total\ depth = known\ depth + \Delta h$$

$$Total\ depth = 35\ ft + 29\ ft = \underline{\mathbf{64\ feet}}$$

```
GRAVPAC, Version 1.4, Serial Number 28
Property of Cal State Univ. - San Diego

Survey:   Carlsbad SDGE Gravity Line

Comments: This is a gravity profile down the length of the
          bay mouth bar near the SDGE Carlsbad plant

Time-keeping:     Local Standard Time, Zone: 8  West

Coordinates:      Feet N-S  &  E-W of: North 33.15 degrees
                                       West 117.28 degrees
                  Elevation in feet.

Gravity Meter:    LaCoste & Romberg meter G962
                  Meter Factor File: G962.FAC

Base Stations:    Station    Absolute Gravity (mGal)
                    WELL          980000
```

Obs. no.	Station i.d.	Date month/day/year	Time hour/minute	Dial Reading
1	WELL	12/ 4/93	6/53	3023.2700
2	N2	12/ 4/93	7/ 2	3023.2400
3	N4	12/ 4/93	7/ 7	3023.1799
4	N6	12/ 4/93	7/11	3023.2400
5	N8	12/ 4/93	7/16	3023.2200
6	N10	12/ 4/93	7/20	3023.2300
7	N12	12/ 4/93	7/23	3023.2600
8	N14	12/ 4/93	7/27	3023.2700
9	N16	12/ 4/93	7/30	3023.2600
10	N18	12/ 4/93	7/34	3023.3101
11	N20	12/ 4/93	7/39	3023.2100
12	WELL	12/ 4/93	7/44	3023.2900
13	WELL	12/ 4/93	9/ 9	3023.3301
14	N22	12/ 4/93	9/18	3023.2500
15	N24	12/ 4/93	9/22	3023.3501
16	N26	12/ 4/93	9/26	3023.2700
17	N28	12/ 4/93	9/30	3023.1799
18	N30	12/ 4/93	9/34	3023.2500
19	N32	12/ 4/93	9/37	3023.2600
20	N34	12/ 4/93	9/41	3023.2500
21	WELL	12/ 4/93	9/48	3023.3401
22	WELL	12/ 4/93	10/11	3023.3401
23	S1	12/ 4/93	10/15	3023.2700
24	S2	12/ 4/93	10/19	3023.2300
25	S3	12/ 4/93	10/23	3023.1799

Obs. no.	Station i.d.	Date month/day/year	Time hour/minute	Dial Reading
26	S4	12/ 4/93	10/30	3023.1101
27	S5	12/ 4/93	10/33	3023.0601
28	S6	12/ 4/93	10/36	3023.0500
29	S7	12/ 4/93	10/38	3023.0400
30	S8	12/ 4/93	10/42	3023.0000
31	S9	12/ 4/93	10/46	3022.9800
32	S10	12/ 4/93	10/49	3022.9399
33	S11	12/ 4/93	10/52	3022.9199
34	S12	12/ 4/93	10/54	3022.9299
35	S13	12/ 4/93	10/57	3022.9299
36	S14	12/ 4/93	11/ 1	3022.9299
37	S15	12/ 4/93	11/ 4	3022.9199
38	WELL	12/ 4/93	11/ 8	3023.3601
39	WELL	12/ 4/93	11/ 9	3023.3000
40	S16	12/ 4/93	11/17	3022.8701
41	S17	12/ 4/93	11/27	3022.8799
42	S18	12/ 4/93	11/30	3022.8701
43	S19	12/ 4/93	11/33	3022.8501
44	S20	12/ 4/93	11/36	3022.8701
45	S21	12/ 4/93	11/38	3022.8899
46	S22	12/ 4/93	11/41	3022.8799
47	S23	12/ 4/93	11/46	3022.8701
48	S24	12/ 4/93	11/50	3022.8999
49	S25	12/ 4/93	11/53	3022.9399
50	S26	12/ 4/93	11/56	3022.9399

Obs. no.	Station i.d.	Date month/day/year	Time hour/minute	Dial Reading
51	S27	12/ 4/93	12/ 0	3022.9299
52	S28	12/ 4/93	12/ 2	3022.9700
53	S29	12/ 4/93	12/ 5	~~9022.9697~~ CLS 3022.97
54	S30	12/ 4/93	12/10	3022.9600
55	S31	12/ 4/93	12/13	~~9022.9902~~ CLS 3022.99
56	WELL	12/ 4/93	12/28	3023.2800

corrected in computed data

Obs. no.	Station i.d.	Coordinates East-West	North-South	Elevation (feet)	Terrain Corr. (mGals)
1	N34	W 655.64	N 781.37	7.98	.053
2	N32	W 617.08	N 735.4	7.89	.053
3	N30	W 578.51	N 689.44	8.28	.053
4	N28	W 539.94	N 643.48	9.07	.053
5	N26	W 501.37	N 597.51	8.11	.032
6	N24	W 462.81	N 551.55	7.69	.032
7	N22	W 424.24	N 505.59	9.27	.013
8	N20	W 385.67	N 459.63	9.57	.008
9	N18	W 347.11	N 413.66	8.35	.016
10	N16	W 308.54	N 367.7	8.51	.018
11	N14	W 269.97	N 321.74	8.34	.022
12	N12	W 231.4	N 275.78	8.43	.017
13	N10	W 192.84	N 229.81	8.65	.017
14	N8	W 154.27	N 183.85	8.79	.017
15	N6	W 115.7	N 137.89	8.64	.011
16	N4	W 77.13	N 91.93	9.37	.005
17	N2	W 38.57	N 45.96	8.47	.013
18	WELL	E 0	N 0	7.17	.023
19	S1	E 19.28	S 22.98	7.85	.017
20	S2	E 38.57	S 45.96	7.88	.017
21	S3	E 57.85	S 68.94	8.12	.028
22	S4	E 77.13	S 91.93	8.63	.033
23	S5	E 96.42	S 114.91	8.59	.025
24	S6	E 115.7	S 137.89	8.55	.025
25	S7	E 134.99	S 160.87	8.47	.025

Obs. no.	Station i.d.	Coordinates East-West	North-South	Elevation (feet)	Terrain Corr. (mGals)
26	S8	E 154.27	S 183.85	8.55	.025
27	S9	E 173.55	S 206.83	8.64	.025
28	S10	E 192.84	S 229.81	8.64	.025
29	S11	E 212.12	S 252.79	8.6	.025
30	S12	E 231.4	S 275.78	8.19	.025
31	S13	E 250.69	S 298.76	8.06	.028
32	S14	E 269.97	S 321.74	8.07	.028
33	S15	E 289.25	S 344.72	7.89	.028
34	S16	E 308.54	S 367.7	7.91	.032
35	S17	E 327.82	S 390.68	7.82	.032
36	S18	E 347.11	S 413.66	7.91	.032
37	S19	E 366.39	S 436.65	7.76	.032
38	S20	E 385.67	S 459.63	7.72	.023
39	S21	E 404.96	S 482.61	7.59	.023
40	S22	E 424.24	S 505.59	7.53	.023
41	S23	E 443.52	S 528.57	7.68	.023
42	S24	E 462.81	S 551.55	7.69	.021
43	S25	E 482.09	S 574.53	7.49	.021
44	S26	E 501.37	S 597.51	7.69	.02
45	S27	E 520.66	S 620.5	7.77	.02
46	S28	E 539.94	S 643.48	7.77	.02
47	S29	E 559.23	S 666.46	8.06	.02
48	S30	E 578.51	S 689.44	8.21	.02
49	S31	E 597.79	S 712.42	8.12	.02

Obs. no.	Sta. i.d.	Latitude (deg.)	Longitude (deg)	Julian Time (centuries)	Tide (mmGal)	Metered Gravity (mGal)
1	WELL	33.150002	117.279999	0.93925038	4.9	3066.2605
2	N2	33.150128	117.280125	0.93925055	-1.1	3066.2240
3	N4	33.150254	117.280251	0.93925065	-4.4	3066.1598
4	N6	33.150379	117.280378	0.93925072	-7.1	3066.2181
5	N8	33.150505	117.280504	0.93925082	-10.3	3066.1945
6	N10	33.150631	117.280630	0.93925089	-12.9	3066.2021
7	N12	33.150757	117.280756	0.93925095	-14.8	3066.2307
8	N14	33.150883	117.280883	0.93925103	-17.3	3066.2383
9	N16	33.151009	117.281009	0.93925108	-19.1	3066.2263
10	N18	33.151135	117.281135	0.93925116	-21.6	3066.2746
11	N20	33.151261	117.281261	0.93925125	-24.5	3066.1702
12	WELL	33.150002	117.279999	0.93925135	-27.5	3066.2484
13	WELL	33.150002	117.279999	0.93925297	-64.5	3066.2520
14	N22	33.151387	117.281388	0.93925314	-66.8	3066.1685
15	N24	33.151513	117.281514	0.93925321	-67.7	3066.2691
16	N26	33.151639	117.281640	0.93925329	-68.5	3066.1871
17	N28	33.151765	117.281766	0.93925337	-69.2	3066.0950
18	N30	33.151891	117.281893	0.93925344	-69.9	3066.1654
19	N32	33.152017	117.282019	0.93925350	-70.4	3066.1750
20	N34	33.152143	117.282145	0.93925357	-71.0	3066.1643
21	WELL	33.150002	117.279999	0.93925371	-71.8	3066.2548
22	WELL	33.150002	117.279999	0.93925414	-73.1	3066.2536
23	S1	33.149939	117.279936	0.93925422	-73.1	3066.1825
24	S2	33.149876	117.279873	0.93925430	-73.0	3066.1420
25	S3	33.149813	117.279809	0.93925437	-72.9	3066.0914

Obs. no.	Sta. i.d.	Latitude (deg.)	Longitude (deg)	Julian Time (centuries)	Tide (mmGal)	Metered Gravity (mGal)
26	S4	33.149750	117.279746	0.93925451	-72.5	3066.0209
27	S5	33.149687	117.279683	0.93925456	-72.3	3065.9704
28	S6	33.149624	117.279620	0.93925462	-72.0	3065.9605
29	S7	33.149561	117.279557	0.93925466	-71.9	3065.9506
30	S8	33.149498	117.279494	0.93925473	-71.4	3065.9104
31	S9	33.149435	117.279431	0.93925481	-71.0	3065.8906
32	S10	33.149372	117.279367	0.93925487	-70.6	3065.8503
33	S11	33.149309	117.279304	0.93925492	-70.2	3065.8305
34	S12	33.149246	117.279241	0.93925496	-69.9	3065.8409
35	S13	33.149183	117.279178	0.93925502	-69.4	3065.8414
36	S14	33.149120	117.279115	0.93925510	-68.7	3065.8421
37	S15	33.149057	117.279052	0.93925515	-68.2	3065.8325
38	WELL	33.150002	117.279999	0.93925523	-67.4	3066.2795
39	WELL	33.150002	117.279999	0.93925525	-67.2	3066.2188
40	S16	33.148994	117.278989	0.93925540	-65.5	3065.7846
41	S17	33.148931	117.278926	0.93925559	-63.1	3065.7969
42	S18	33.148868	117.278862	0.93925565	-62.4	3065.7878
43	S19	33.148805	117.278799	0.93925570	-61.6	3065.7683
44	S20	33.148742	117.278736	0.93925576	-60.8	3065.7894
45	S21	33.148679	117.278673	0.93925580	-60.2	3065.8100
46	S22	33.148616	117.278610	0.93925586	-59.4	3065.8007
47	S23	33.148553	117.278547	0.93925595	-57.9	3065.7922
48	S24	33.148490	117.278484	0.93925603	-56.7	3065.8236
49	S25	33.148427	117.278421	0.93925608	-55.8	3065.8651
50	S26	33.148364	117.278357	0.93925614	-54.9	3065.8661

Obs. no.	Sta. i.d.	Latitude (deg.)	Longitude (deg)	Julian Time (centuries)	Tide (mmGal)	Metered Gravity (mGal)
51	S27	33.148301	117.278294	0.93925622	-53.6	3065.8572
52	S28	33.148238	117.278231	0.93925626	-53.0	3065.8984
53	S29	33.148175	117.278168	0.93925631	-52.0	3065.8994
54	S30	33.148112	117.278105	0.93925641	-50.3	3065.8909
55	S31	33.148049	117.278042	0.93925646	-49.3	3065.9224
56	WELL	33.150002	117.279999	0.93925675	-44.1	3066.2217

Obs. no.	Sta. i.d.	Drift corr.	Abs.Grav. +980000mGal	Free -air	Bouguer Gravity (mGal) 1.60	1.80	2.00	2.20
1	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744
2	N2	-0.002	-0.034	423.000	422.840	422.818	422.797	422.775
3	N4	-0.003	-0.097	423.011	422.825	422.801	422.777	422.753
4	N6	-0.004	-0.038	422.991	422.826	422.804	422.782	422.760
5	N8	-0.006	-0.060	422.973	422.810	422.788	422.765	422.743
6	N10	-0.006	-0.052	422.958	422.798	422.776	422.754	422.732
7	N12	-0.007	-0.023	422.956	422.801	422.779	422.757	422.736
8	N14	-0.008	-0.014	422.945	422.797	422.776	422.754	422.733
9	N16	-0.009	-0.025	422.940	422.784	422.762	422.740	422.719
10	N18	-0.010	0.024	422.963	422.809	422.788	422.766	422.745
11	N20	-0.011	-0.079	422.965	422.777	422.753	422.728	422.704
12	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744
13	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744
14	N22	0.001	-0.084	422.921	422.745	422.721	422.697	422.674
15	N24	0.001	0.016	422.862	422.737	422.718	422.698	422.678
16	N26	0.001	-0.066	422.809	422.675	422.655	422.634	422.613
17	N28	0.002	-0.159	422.797	422.664	422.641	422.618	422.595
18	N30	0.002	-0.089	422.782	422.666	422.645	422.623	422.602
19	N32	0.002	-0.079	422.744	422.636	422.616	422.596	422.576
20	N34	0.002	-0.090	422.732	422.622	422.601	422.581	422.560
21	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744
22	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744
23	S1	0.002	-0.073	422.919	422.775	422.755	422.735	422.715
24	S2	0.004	-0.115	422.884	422.740	422.720	422.700	422.680
25	S3	0.005	-0.168	422.860	422.722	422.701	422.680	422.660

Obs. no.	Sta. i.d.	Drift corr.	Abs.Grav. +980000mGal	Free -air	Bouguer Gravity (mGal) 1.60	1.80	2.00	2.20
26	S4	0.009	-0.241	422.839	422.696	422.674	422.652	422.630
27	S5	0.010	-0.293	422.789	422.638	422.617	422.595	422.573
28	S6	0.011	-0.305	422.779	422.629	422.607	422.586	422.564
29	S7	0.012	-0.315	422.766	422.618	422.596	422.575	422.553
30	S8	0.014	-0.357	422.737	422.587	422.565	422.543	422.521
31	S9	0.016	-0.379	422.729	422.577	422.555	422.533	422.511
32	S10	0.017	-0.421	422.692	422.540	422.518	422.496	422.474
33	S11	0.019	-0.442	422.672	422.522	422.500	422.478	422.456
34	S12	0.020	-0.432	422.648	422.506	422.485	422.464	422.443
35	S13	0.021	-0.433	422.641	422.504	422.483	422.463	422.442
36	S14	0.023	-0.434	422.646	422.509	422.488	422.467	422.447
37	S15	0.024	-0.445	422.623	422.490	422.470	422.450	422.429
38	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744
39	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744
40	S16	0.000	-0.434	422.641	422.511	422.491	422.471	422.451
41	S17	0.001	-0.423	422.650	422.522	422.502	422.482	422.462
42	S18	0.001	-0.432	422.654	422.524	422.504	422.484	422.464
43	S19	0.001	-0.451	422.626	422.499	422.479	422.459	422.440
44	S20	0.001	-0.430	422.648	422.513	422.493	422.474	422.454
45	S21	0.001	-0.410	422.662	422.530	422.510	422.491	422.471
46	S22	0.001	-0.419	422.652	422.521	422.502	422.482	422.463
47	S23	0.001	-0.428	422.662	422.529	422.509	422.489	422.470
48	S24	0.002	-0.397	422.700	422.563	422.544	422.524	422.505
49	S25	0.002	-0.355	422.728	422.595	422.576	422.557	422.538
50	S26	0.002	-0.355	422.752	422.615	422.595	422.576	422.556

Obs. no.	Sta. i.d.	Drift corr.	Abs.Grav. +980000mGal	Free -air	Bouguer Gravity (mGal) 1.60	1.80	2.00	2.20
51	S27	0.002	-0.363	422.756	422.617	422.597	422.578	422.558
52	S28	0.002	-0.322	422.802	422.663	422.644	422.624	422.604
53	S29	0.002	-0.321	422.836	422.691	422.670	422.650	422.629
54	S30	0.002	-0.330	422.846	422.698	422.677	422.657	422.636
55	S31	0.002	-0.299	422.875	422.729	422.708	422.687	422.666
56	WELL	0.000	0.000	422.922	422.799	422.781	422.762	422.744

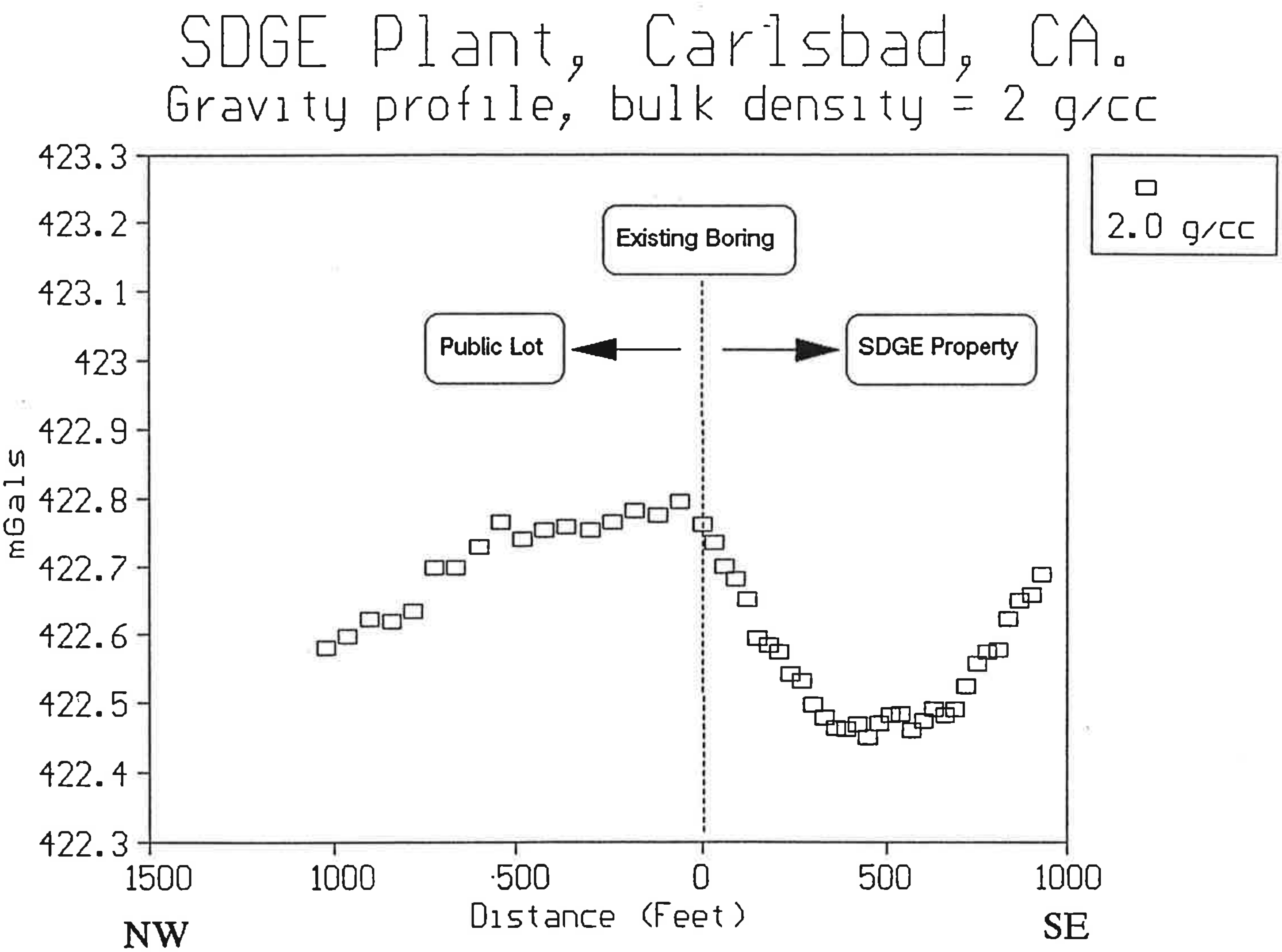


Figure #1 - Relative gravity profile calculated for a bulk density of 2.0 g/cc.
Data has been corrected for elevation, drift, and nearby terrain.

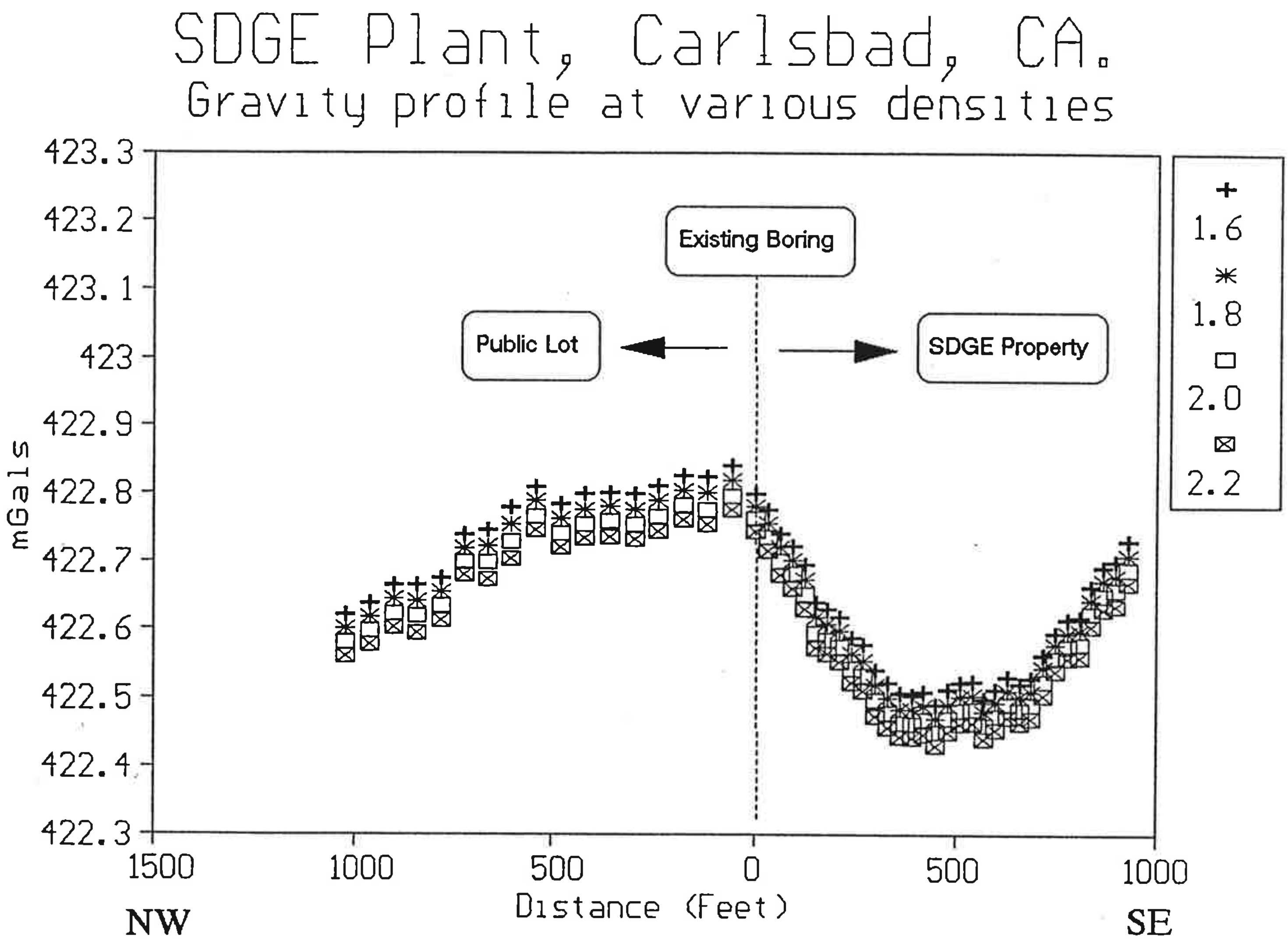


Figure #2 - Relative gravity profile calculated for a bulk density range from 1.6 g/cc to 2.2 g/cc. data has been corrected for elevation, drift, and nearby terrain.

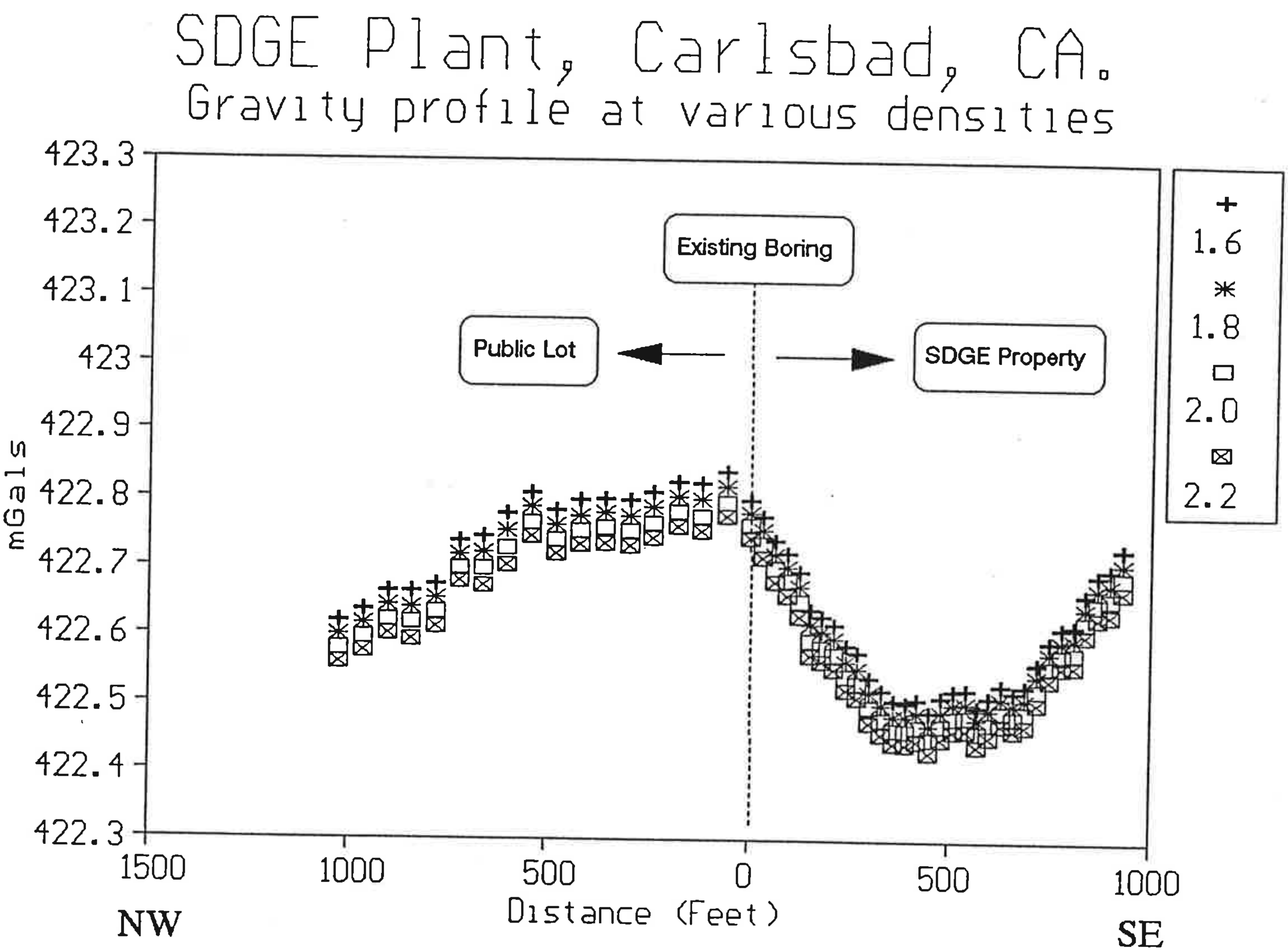
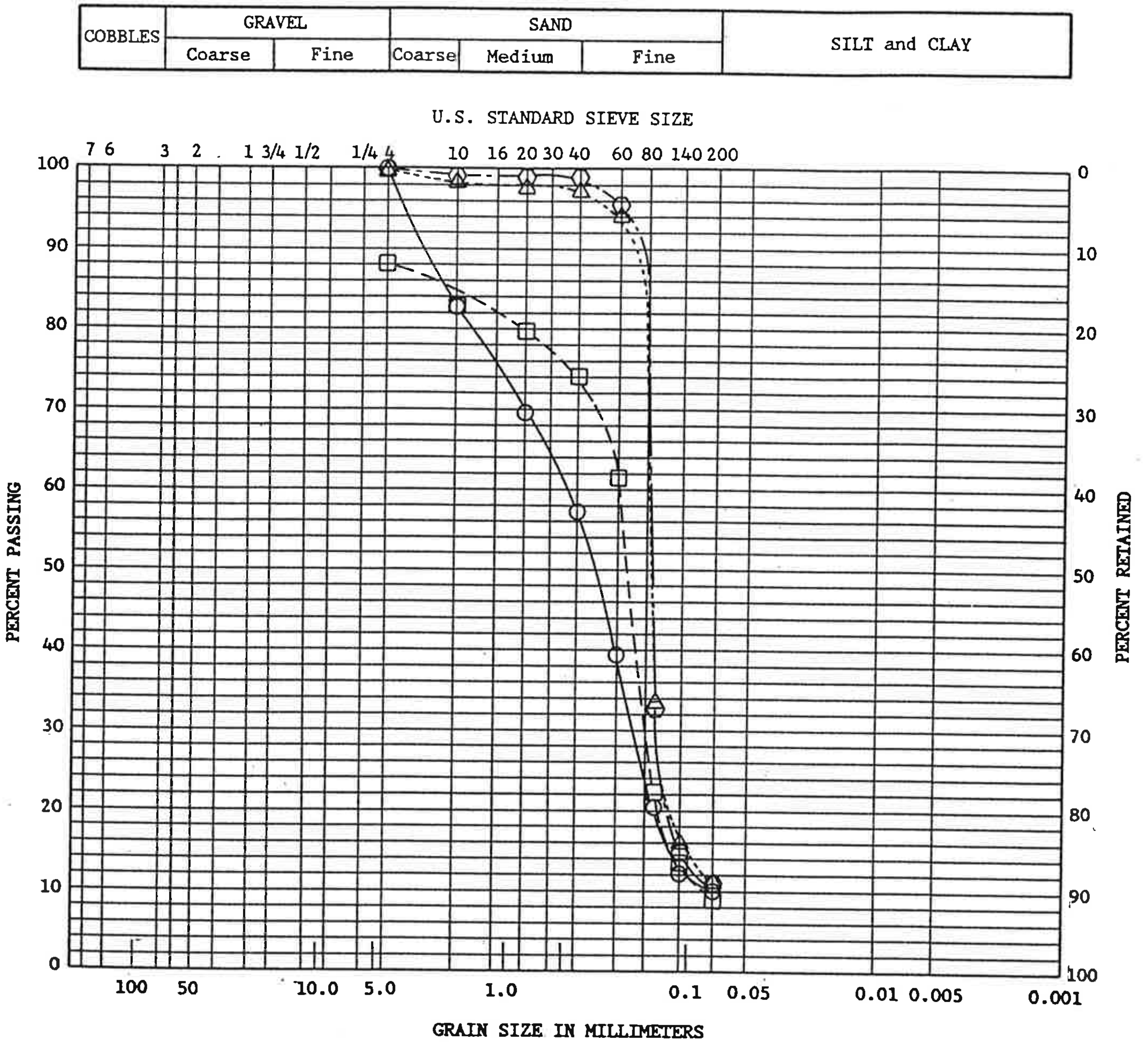


Figure #2 - Relative gravity profile calculated for a bulk density range from 1.6 g/cc to 2.2 g/cc. data has been corrected for elevation, drift, and nearby terrain.

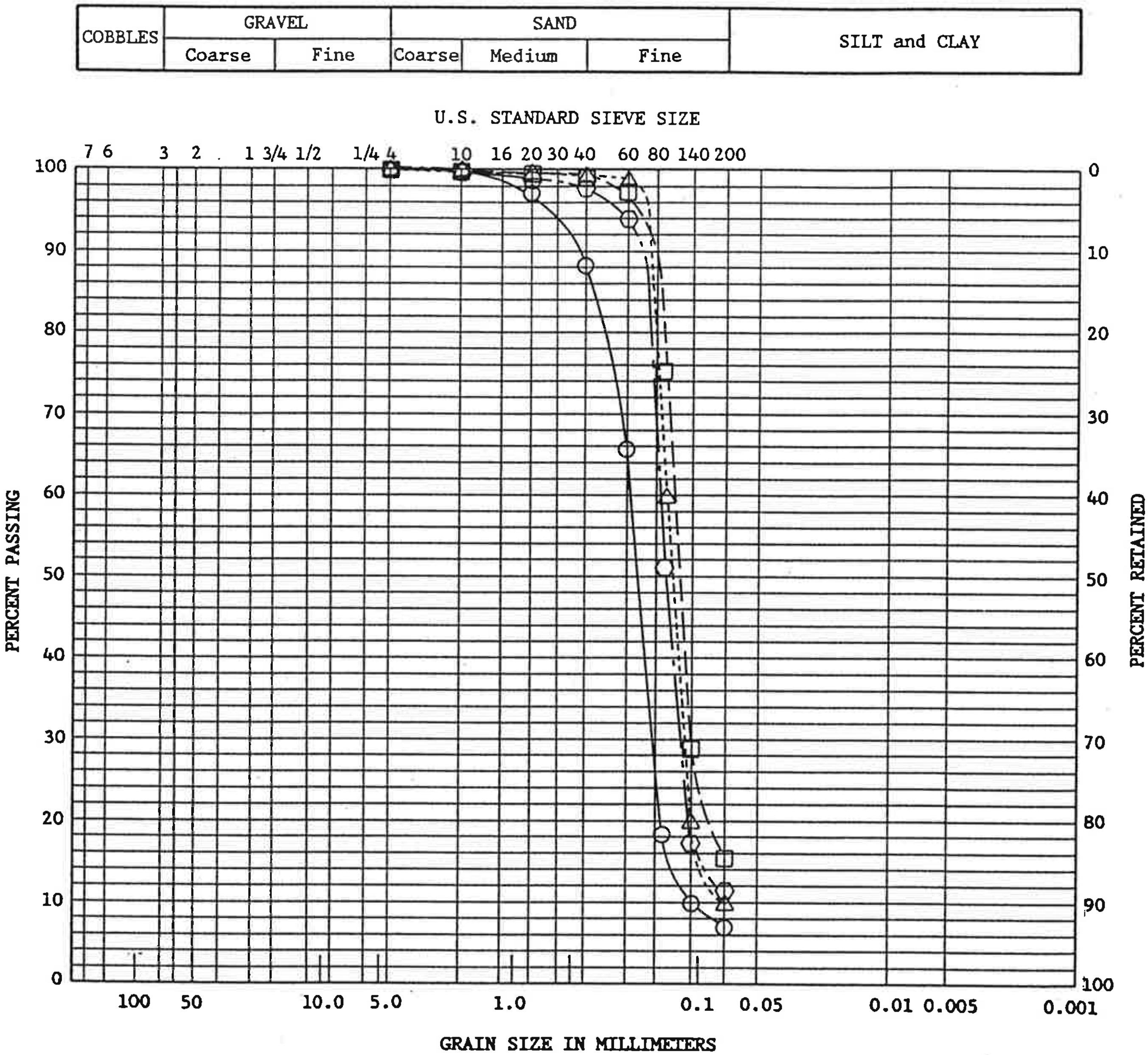
APPENDIX C
LABORATORY TESTING



SAMPLE	DEPTH	SYMBOL	CLASSIFICATION	LL	PI
B4-3	29'-30'	--□--	GRAY POORLY GRADED SAND WITH SILT AND 12% GRAVEL (SP-SM)		
B4-4	34'-35.5'	—○—	GRAY WELL-GRADED SAND WITH SILT (SW-SM)		
B4-6	44'-45'	--△--	GRAY POORLY GRADED SAND WITH SILT (SP-SM)		
B4-8	54'-55.5'	-·-○-·-	GRAY POORLY GRADED SAND WITH SILT (SP-SM)		

GRAIN SIZE DISTRIBUTION

PROJECT: 1555	SDG&E ENCINA POWER PLANT	FIGURE: C-1



SAMPLE	DEPTH	SYMBOL	CLASSIFICATION	LL	PI
B4-10	64'-65'	—○—	GRAY POORLY GRADED SAND WITH SILT (SP-SM)		
B4-12	74'-75.5'	- -□- -	GRAY SILTY SAND (SM)		
B4-14	84'-85.5'	---△---	GRAY POORLY GRADED SAND WITH SILT (SP-SM)		
B4-16	94'-95.5'	-·-○·-	GRAY POORLY GRADED SAND WITH SILT (SP-SM)		

GRAIN SIZE DISTRIBUTION

PROJECT: 1555	SDG&E ENCINA POWER PLANT	FIGURE: C-2

APEX GEOTECHNOLOGY, INC., *in association with*
GROUP DELTA CONSULTANTS, INC., *A Joint-Venture Partnership*

APPENDIX D
PRODUCTION WELL DESIGN

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PRODUCTION WELL DESIGN

The design of Production Well W-1 was based on the geologic log of Boring B-4, grain-size analyses of samples collected during the drilling of Boring B-4, and geophysical logs of Production Well W-1 performed immediately after completion of drilling. The well screen slot-size and gravel-pack design was based entirely on grain-size analyses of samples collected from Boring B-4. Grain-size analyses, presented in Appendix C, were performed on eight samples collected from Boring B-4. Evaluation of the grain-size data for design of the gravel pack is presented in Table D-1. The D_{50}, D_{60}, and D_{10} were interpolated from the grain-size distribution plots and used to calculate the uniformity coefficient, defined as D_{60}/D_{10}, of the samples (Table D-1).

Table D-1
Calculation of Gravel-Pack from Sediment Grain-Size Analyses

Depth (ft)	D_{50} (mm)	D_{60} (mm)	D_{10} (mm)	C_u	6 x D_{50} (mm)	9 x D_{50} (mm)
29 - 30	0.2	0.25	0.106	2.4	1.2	1.8
34 - 35.5	0.35	0.55	0.075	7.3	2.1	3.2
44 - 45	0.18	0.18	0.075	2.4	1.1	1.6
54 - 55.5	0.15	0.15	0.075	2.0	0.9	1.4
64 - 65	0.2	0.23	0.088	2.6	1.2	1.8
74 - 75.5	0.11	0.15	0.06	2.5	0.64	0.95
84 - 85.5	0.15	0.15	0.075	2.0	0.9	1.4
94 - 95.5	0.15	0.15	0.075	2.0	0.9	1.4

For unconsolidated sediments, we recommend that a gravel-pack be selected such that the D_{50} of the gravel-pack be six to nine times the D_{50} of the sediment. The results of this analysis suggests that the gravel-pack should have a D_{50} of between 1.0 and 1.7 mm. Review of grain size distribution curves from commercially-available gravel-packs indicates that Lone Star #3 best meets this criteria. The D_{50} of Lone Star #3 ranges between 1.2 and 1.7 mm. The next two larger gravel-packs, Lone Star "8 mesh" and Lone Star

"6 x 12" have a mean grain-size (D_{50}) of 1.7 and 2.4 mm, respectively, which could potentially allow significant quantities of finer-grained formation into the well.

Well screen slot size is generally recommended to be selected such that no more than 10% of the gravel pack is able to pass through the slots. One to thirteen percent of Lone Star #3 is reported to be finer than 0.85 mm (0.033 inch), so a 0.03-inch slot size well screen was selected. The next available slot size, 0.04 inch, could potentially allow as much as 30% to 40% of Lone Star #3 through the screen.

Intervals for placement of slotted screen were selected on the basis of the geologic and geophysical logs of Production Well W-1. Both electric and gamma logging were performed as part of the geophysical surveying of the borehole. The electric log provided very little information because of the very high salinity (low resistivity) of the groundwater in the alluvial sediments. Significant increases in gamma emissions, which are often associated with clays, were seen from 86 to 90 feet, from 107 to 111 feet, from 113 to 120 feet, and from 137 to 146 feet. The gamma log is shown on Figure 2. A medium-grained sand was also logged and sampled by the site geologist from 145 to 180 feet. The geologic log also suggests that the Santiago Formation (a low-permeability, consolidated sandstone) was encountered at about 182 feet. These observations were confirmed by the natural gamma log, which shows relatively low emissions from 145 to 180 feet and a significant increase in gamma-ray emissions at 182 feet. Blank casing was set opposite those zones showing increased gamma emissions as much as possible within reasonable constraints of practical well construction.

APPENDIX E
TIDAL INFLUENCE CORRECTIONS

APPENDIX E
TIDAL INFLUENCE CORRECTIONS

A step-drawdown test was conducted on Production Well W-1 between February 2 and 4, 1994. Because of the proximity to the estuary and the ocean, ocean tidal effects in the production and monitoring wells were expected to be significant. Monitoring Well B-2, located approximately 900 feet from Production Well W-1 (Figure 1, Site Plan), was monitored from January 18, 1994, until February 4, 1994, to assess background variations due to ocean tidal influences. These influences are quite marked, with the well showing up to 4 feet of variation in water level in direct response to ocean tidal influences. Both the major and minor ocean tide cycles are clearly seen on the hydrograph of Monitoring Well B-2 (Figure E-1). In addition, there appears to be no deviation from this during the pumping test at Production Well W-1, indicating that Monitoring Well B-2 was too far from the production well to be influenced by pumping.

Monitoring Well B-3 was less-influenced by ocean tidal cycles (Figure E-2), though a 0.1 to 0.2 foot variation in water level was seen prior to the pumping test. Only the major tidal cycle is seen on the hydrograph of Monitoring Well B-3, due to the greater distance from the estuary and the attenuation of the tidal influence with distance from the estuary and ocean. A trend of increasing depth to water was seen in Monitoring Well B-3 prior to the pumping test. The cause of this decline is unknown. Monitoring Well B-3 was not monitored during the pumping test because of the need to use the data-logging equipment in Monitoring Well B-4, located closer to the production well. It is our opinion that Monitoring Well B-3 did not respond during the pumping test since Monitoring Well B-2, located closer to the production well, did not exhibit a response during the pumping test.

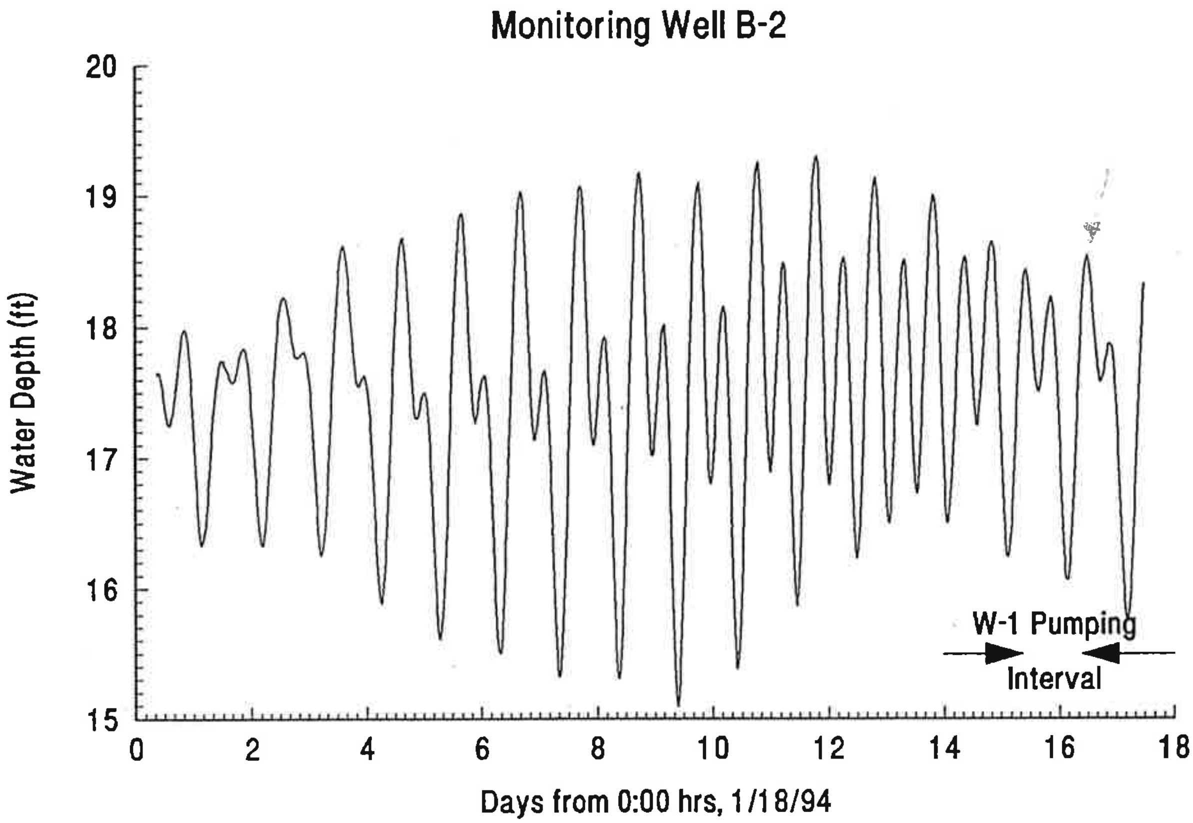
Water-level changes in response to the pump test were seen in both Production Well W-1 and nearby Monitoring Well B-4. The background response of Production Well W-1 to ocean tidal influences was monitored for approximately 12 hours before pumping began (Figure E-3). Figure E-3 shows both the water elevation changes measured in Production Well W-1 and the ocean tide changes at Scripps Pier in La Jolla, California. Ocean tide changes propagate through soil from both the estuary and the ocean. As these tide changes propagate through the soil, they are both damped (decreased in amplitude) and delayed (shifted in time). To correct groundwater level data for tidal influences, we must calculate both the time shift and the tidal efficiency, which is defined as;

$$EFF_{tide} = \frac{A_{gw}}{A_{tide}}$$

where Eff_{tide} is the tidal efficiency, A_{gw} is the amplitude of the tidal variation in the well, and A_{tide} is the tidal amplitude.

Ocean tide data were calculated at 15 minute intervals using the computer program TIDE.1, a tide prediction program available from Micronautics, Inc. (Rockport, Maine). These ocean tidal variations were plotted on the same graph as the groundwater elevations and shifted in time until the peaks of the groundwater elevation variations matched in time with the ocean tidal peaks (Figure E-3). For Production Well W-1, the groundwater level peaks were delayed by 25 minutes from the ocean tidal peaks, which is taken into account by the plot. The scales of the groundwater hydrograph and the ocean tide hydrograph were then adjusted to produce a best-match between the groundwater and tide hydrographs. For Production Well W-1, it can be seen that an ocean tide variation of approximately 4 feet produces a groundwater elevation change of only 2.6 feet (Figure E-3), resulting in a tidal efficiency of 0.650. Once the tidal efficiency and the time shift are known, measured groundwater elevations during the aquifer test can be corrected for the predicted ocean tidal fluctuations.

Comparison of Figures E-4 and E-5 shows the effect of this correction. Figure E-4 is an uncorrected plot of water-level change in Production Well W-1 during both the pumping and recovery portions of the step-drawdown test. Though the first 400 minutes of the test is dominated by water-level fluctuations due to changes in discharge in the production well, the period from about 400 minutes to 1500 minutes shows a 2- to 3-foot fluctuation in water level due to ocean tidal variation superimposed on the changes in water level associated with pumping 330 gpm. Similarly, after pumping ceased, at about 1500 minutes, the tidal fluctuations are evident in the water levels as the well recovers. Correction of these data for the ocean tidal influences (Figure E-5) results in a plot that is smooth for both the 330 gpm step and for the recovery after pumping.



WATER LEVEL MONITORING, MONITORING WELL B–2

Project No. 1555	SDG&E ENCINA POWER PLANT	Figure E–1

APEX GEOTECHNOLOGY, INC., *in association with*
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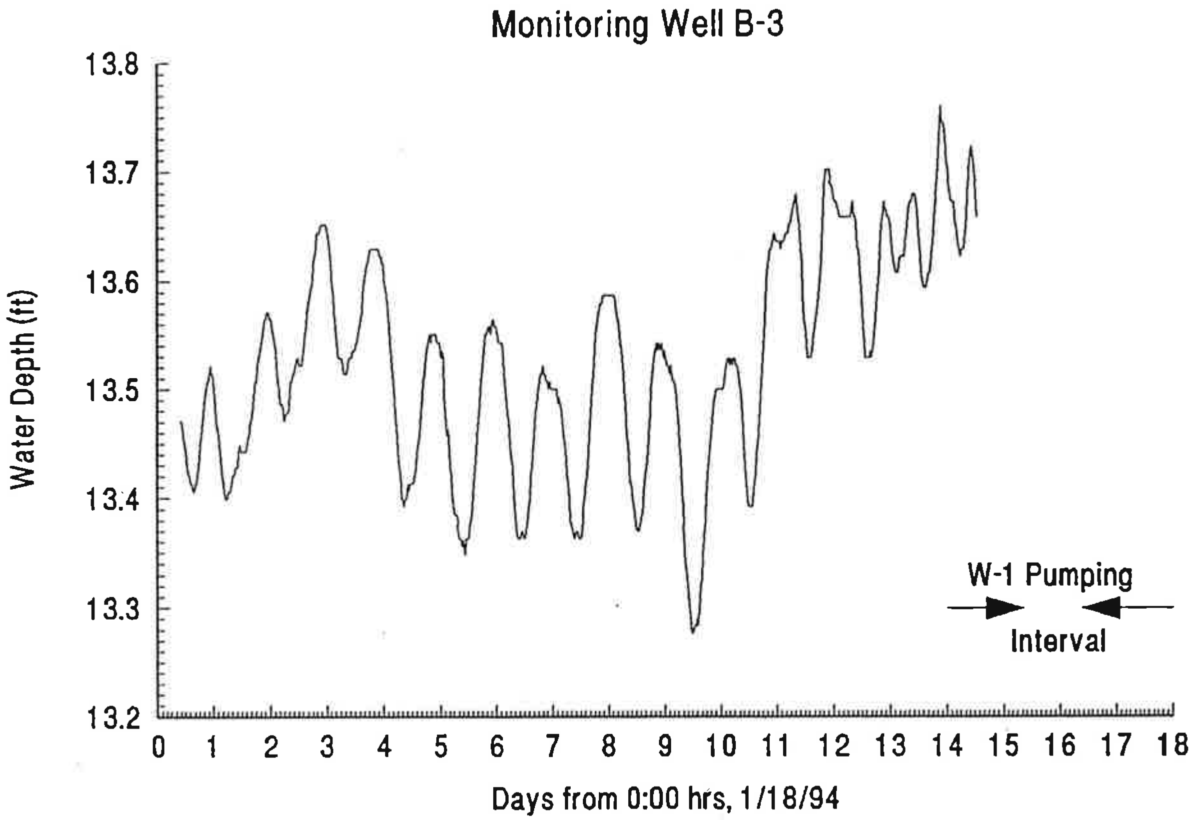

WATER LEVEL MONITORING, MONITORING WELL B-3

Project No. 1555	SDG&E ENCINA POWER PLANT	Figure E-2

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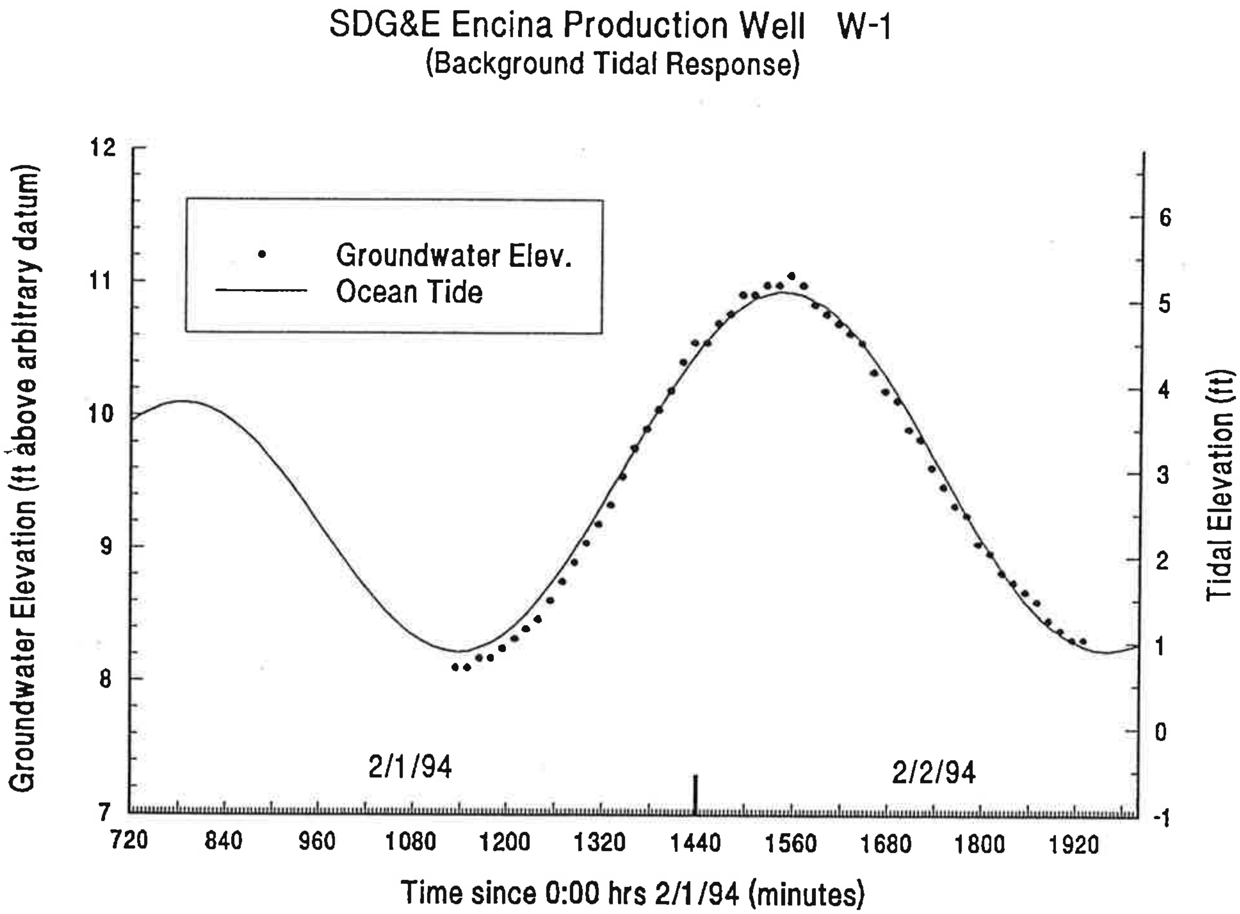
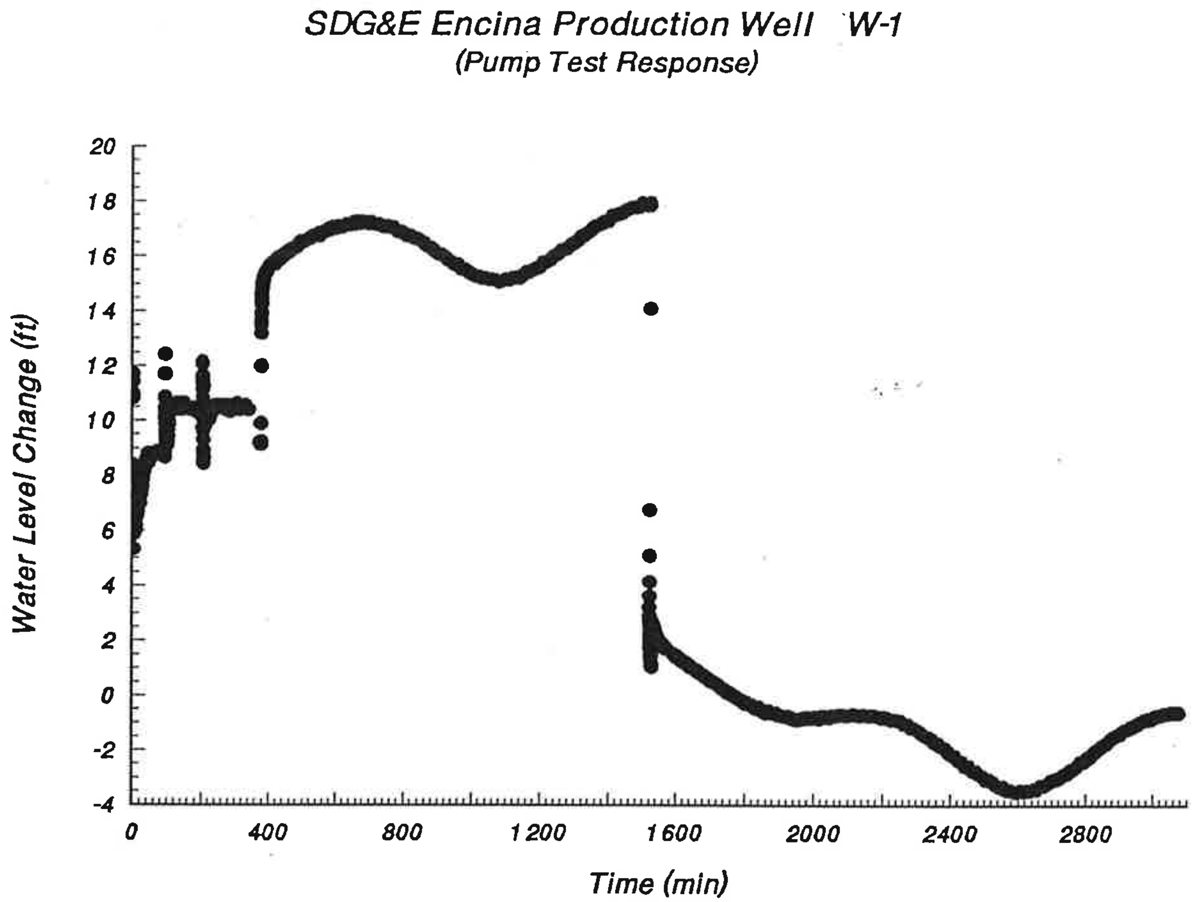


TIDAL DATA HAS BEEN SHIFTED TO ACCOUNT FOR A 25-MINUTE TIME LAG BETWEEN PREDICTED TIDAL PEAKS AT SCRIPPS PIER AND THE OBSERVED PEAKS IN PRODUCTION WELL W-1

BACKGROUND WATER LEVEL MONITORING IN PRODUCTION WELL W-1		
Project No. 1555	SDG&E ENCINA POWER PLANT	Figure E-3



RESPONSE OF PRODUCTION WELL P-1 TO STEP-DRAWDOWN TEST (UNCORRECTED FOR TIDAL FLUCTUATIONS)

Project No. 1555	SDG&E ENCINA POWER PLANT	Figure E-4

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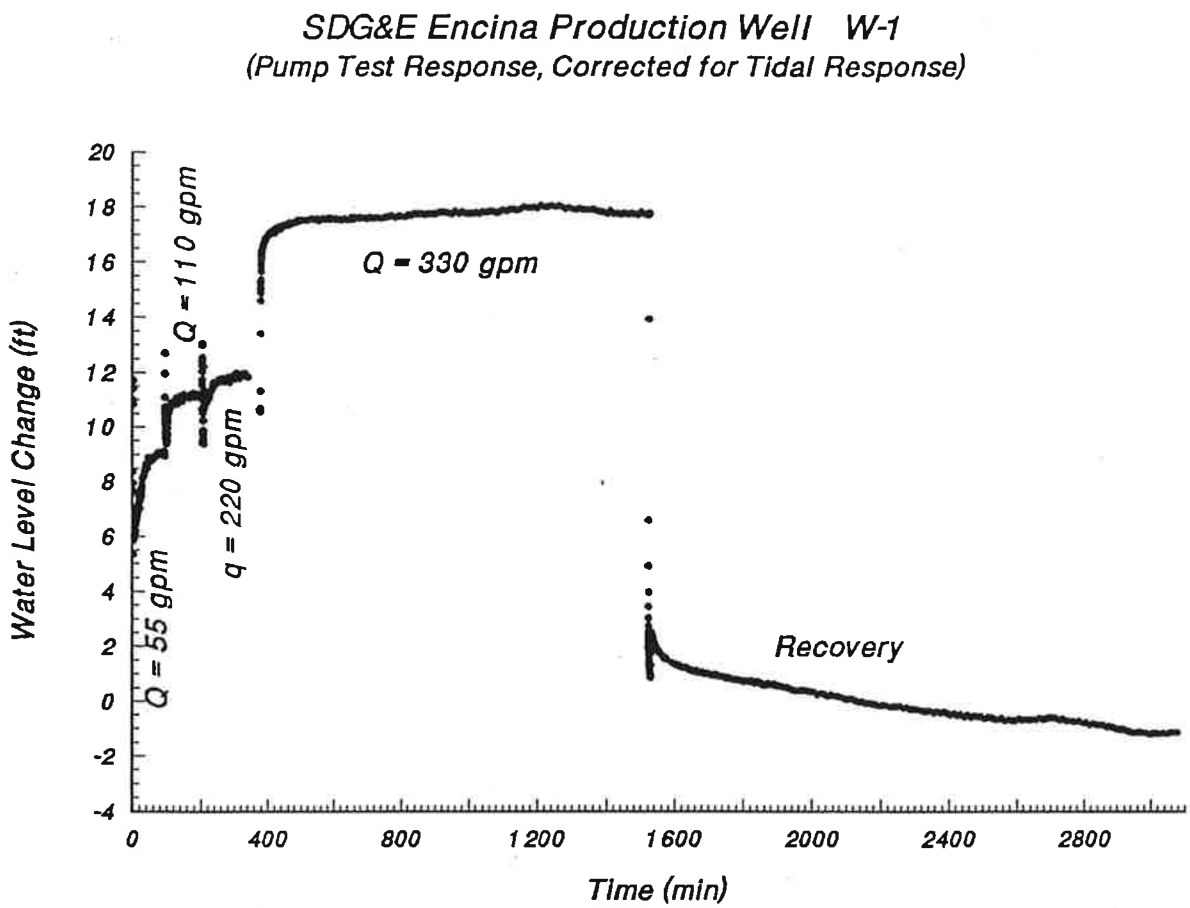

RESPONSE OF PRODUCTION WELL P-1 TO STEP-DRAWDOWN TEST (CORRECTED FOR TIDAL FLUCTUATIONS)

Project No. 1555	SDG&E ENCINA POWER PLANT	Figure E-5

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