# PRELIMINARY GEOTECHNICAL ASSESSMENT

# BALL ROAD BASIN GENERAL PLAN AMENDMENT AND ZONE CHANGE PROJECT ANAHEIM, CALIFORNIA

Prepared for

**ENVIRONMENTAL ADVISORS**

2390 East Orangewood Avenue, Suite 510
Anaheim, California 92806

Project No. 10113.002

March 18, 2013
(Revised June 13, 2013)

Leighton Consulting, Inc.
A LEIGHTON GROUP COMPANY

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Environmental Advisors
2390 East Orangewood Avenue, Suite 510
Anaheim, California 92806

Attention: Mr. Joshua Haskins

**Subject: Preliminary Geotechnical Assessment**
**Ball Road Basin General Plan Amendment and Zone Change Project**
**Anaheim, California**

In accordance with your request and authorization, Leighton Consulting, Inc. has performed a geotechnical assessment for Ball Road Basin General Plan Amendment and Zone Change Project in Anaheim, California. The Orange County Water District (OCWD) operates the site as a groundwater recharge basin. Since the Ball Road Basin no longer performs well as a groundwater recharge facility, OCWD is pursuing the option of selling or leasing it for commercial development. The purpose of this study was to assess the potential geologic, soils, and seismic impacts that could affect design and construction of future development.

Our review in preparation of this report has incorporated available published geologic and geotechnical information and data from the project site and projects in the site vicinity. This report summarizes our findings and presents possible mitigation measures for potentially significant impacts identified in this report.

During this study, we have not identified any geotechnical impacts within the subject site that cannot be mitigated by proper planning, design and sound construction practices. A geotechnical investigation that includes adequate subsurface exploration and laboratory testing should be performed during future phases of the project.

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We appreciate the opportunity to provide our services for this interesting project. If you have any questions, please contact this office at your convenience.

Respectfully submitted,

LEIGHTON CONSULTING, INC.


Djan Chandra, GE 2376
Senior Principal Engineer

SP/DJC/lr

Distribution: (1) Addressee



Leighton

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# 1.0 INTRODUCTION

## 1.1 Purpose and Scope of Work

The purpose of this study was to evaluate the potential geotechnical and seismic impacts that may affect future development at the Ball Road Basin (Assessor's Parcel Numbers [APNs] 253-473-01, 253-641-39 and 253-631-32), hereafter referred to as the "Project site". The findings presented in this report are preliminary based on the information gained from review of published documents. Field exploration and laboratory testing should be conducted during any future development at the project site to verify these findings. Our scope of work consisted of the following tasks:

- Review of available published documents and geology maps covering geotechnical conditions at the site and its vicinity, including the geotechnical reports for the proposed Burris Pump Station Rehabilitation (Leighton, 2013) and widening of State Route (SR)-57 at Ball Road (Leighton, 2010). A list of references used in preparation of this report is presented in Section 5.0;
- Site reconnaissance to evaluate the current site conditions and to observe potential geologic or geotechnical constraints;
- Seismic analysis for the major active and potentially active faults in the region and a site-specific evaluation of ground motion using the probabilistic approach;
- Geotechnical analysis of the collected data with respect to the proposed project; and
- Preparation of this report presenting the site geotechnical conditions and hazards and preliminary geotechnical recommendations.

## 1.2 Site Location and Description

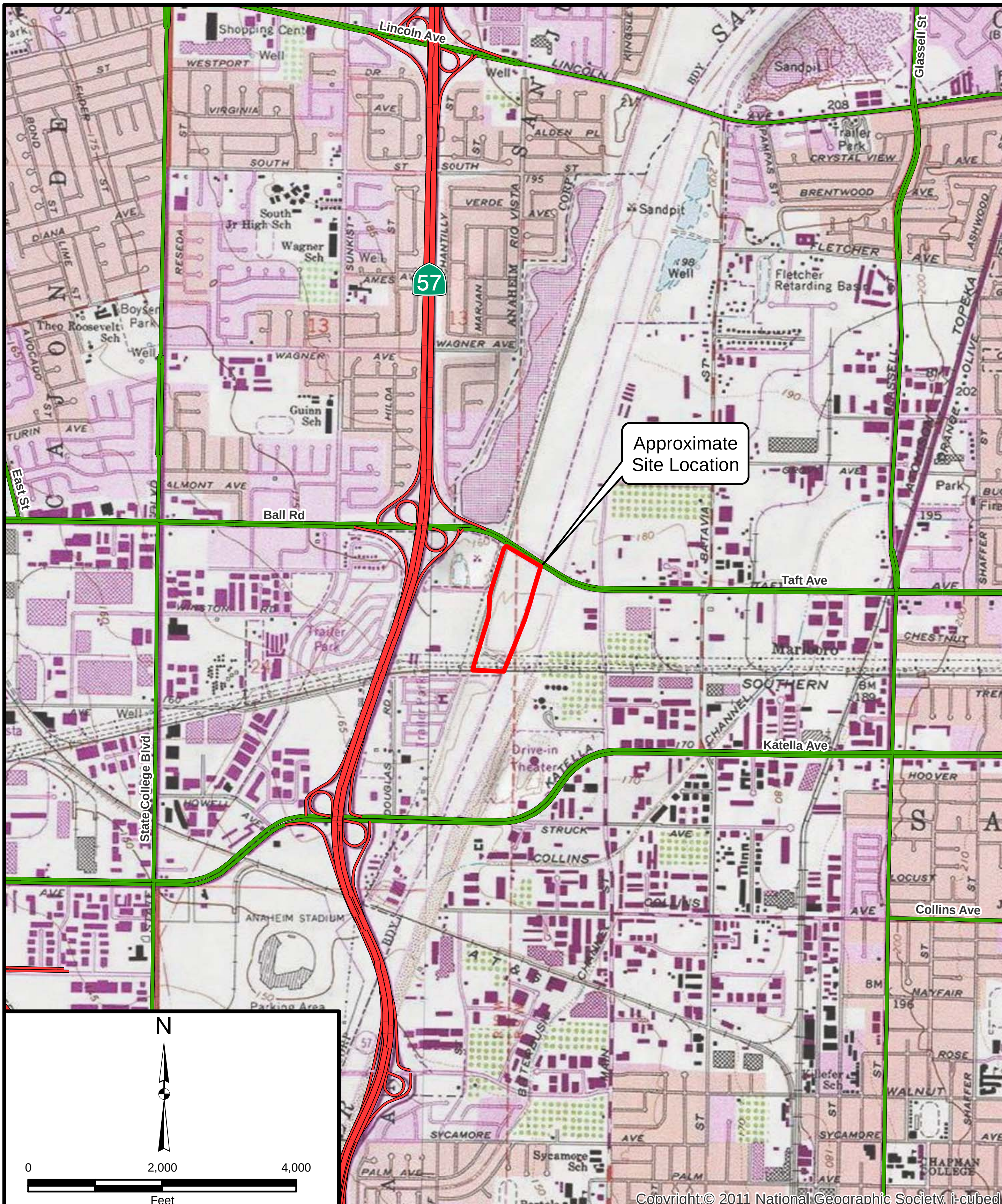
As part of an Orange County Water District (OCWD) groundwater recharge program, several recharge basins were established along the Santa Ana River (River). The Project site, located at the southeast corner of Ball Road and South Phoenix Club Drive in the City of Anaheim (City), is the most down-gradient recharge basin in OCWD's Off-River System. The Project site is approximately

19.5 acres containing a broad, semi-rectangular pit, with a holding capacity of about 220 acre-feet of water and bound by the Santa Ana River Center Levee and the River to the east, Ball Road and the Burris Basin to the north, the Union Pacific Railroad to the south, and South Phoenix Club Drive (also referred to as South Auto Center Drive) to the west (Figure 1, *Site Location Map*). The Project site was purchased in 1943 by OCWD and was separated from the River in the early 1970s with the construction of a levee, called the Center Levee. Elevations on the Project site range from approximately 155 feet at the invert to approximately 180 feet at the top-of-grade. Topography of the general vicinity slopes towards the west. The Project site is unpaved and contains bare soil and weedy vegetation with standing water during rain events. Structures or roads were not observed on the Project site with the exception of unpaved access roads around the perimeter.

## 1.3 Proposed Project

OCWD analyzed the percolation rates of the Project site and its effectiveness as a recharge basin. The site was found to be incapable of significant amounts of recharge due to an extensive clay layer underlying the majority of the basin. OCWD has decided to pursue the option of selling or leasing the site for commercial uses and is in the process of preparing technical documents to support an Environmental Impact Report (EIR) that proposes to amend the City's General Plan Land Use Element Map and Zoning Map for the Project site.

If the map amendments are approved, an approximately 425,000 square foot commercial development, which complies with the development standards of the General Commercial (C-G) Zone (maximum floor area ratio of 0.5), can be constructed on the Project site without further environmental review. It is anticipated that construction and excavation for future construction on-site could include placement of 15 to 25 feet of compacted fill to raise the site grade to the elevations of the surrounding streets.




| Project: 10113.002 | Eng/Geol: DJC/MDC |
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Base Map: ESRI Resource Center 2013
Thematic Info: Leighton
Author: Leighton Geomatics (mmurphy)

# SITE LOCATION MAP

## Ball Road Basin
## Anaheim, California

Figure 1

Leighton

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# 2.0 GEOTECHNICAL CONDITIONS

## 2.1 Regional Geologic Setting

The Project site is located in the Tustin Plain within the southeastern margin of the Los Angeles Basin, a large structural depression within the Peninsular Ranges geomorphic province of California. In general, the Tustin Plain consists of approximately 1,400 feet of unconsolidated to semi-consolidated Quaternary-age alluvial sediments. Underlying the Quaternary alluvial deposits are Tertiary-age bedrock units consisting of sandstone, siltstone, shale and conglomerate on the order of 31,000 feet in thickness.

The site lies near the lower reaches of the River. The surface distribution of Holocene sediments, as recorded in early editions of regional soil survey maps (Eckmann et al., 1916), suggests that the River has recently wandered back and forth across the Orange County coastal plain from Alamitos Bay to Newport Bay. Historical accounts and documents further support the process of widespread sheet flooding being the dominant depositional process associated with the River prior to the construction of Prado Dam in 1941 (California Department of Water Resources, 1957). Currently, the River is located east of the Project site. A geology map of the area is presented on Figure 2, *Regional Geology Map.*

## 2.2 Local Geology

The Project site is underlain by young alluvial soils deposited by the River. Available subsurface explorations at and in the vicinity of the Project site included the borings and Cone Penetration Tests (CPT's) provided by OCWD (Appendix A) and recent borings and CPT's by Leighton (2013) immediately to the north of the site. Review of this available data indicates that the soils in the upper 20 to 25 feet of the Project site are expected to consist generally of sand and silty sand with thin layers of silty clay and silt. A clay layer with interbedded silty clay and silt was encountered below 20 to 25 feet. The clay layer appears to range in thickness from approximately 15 feet to over 30 feet towards the south end of the site. Below the clay layer, the soils consist mainly of sand and gravel.

## 2.3 Groundwater

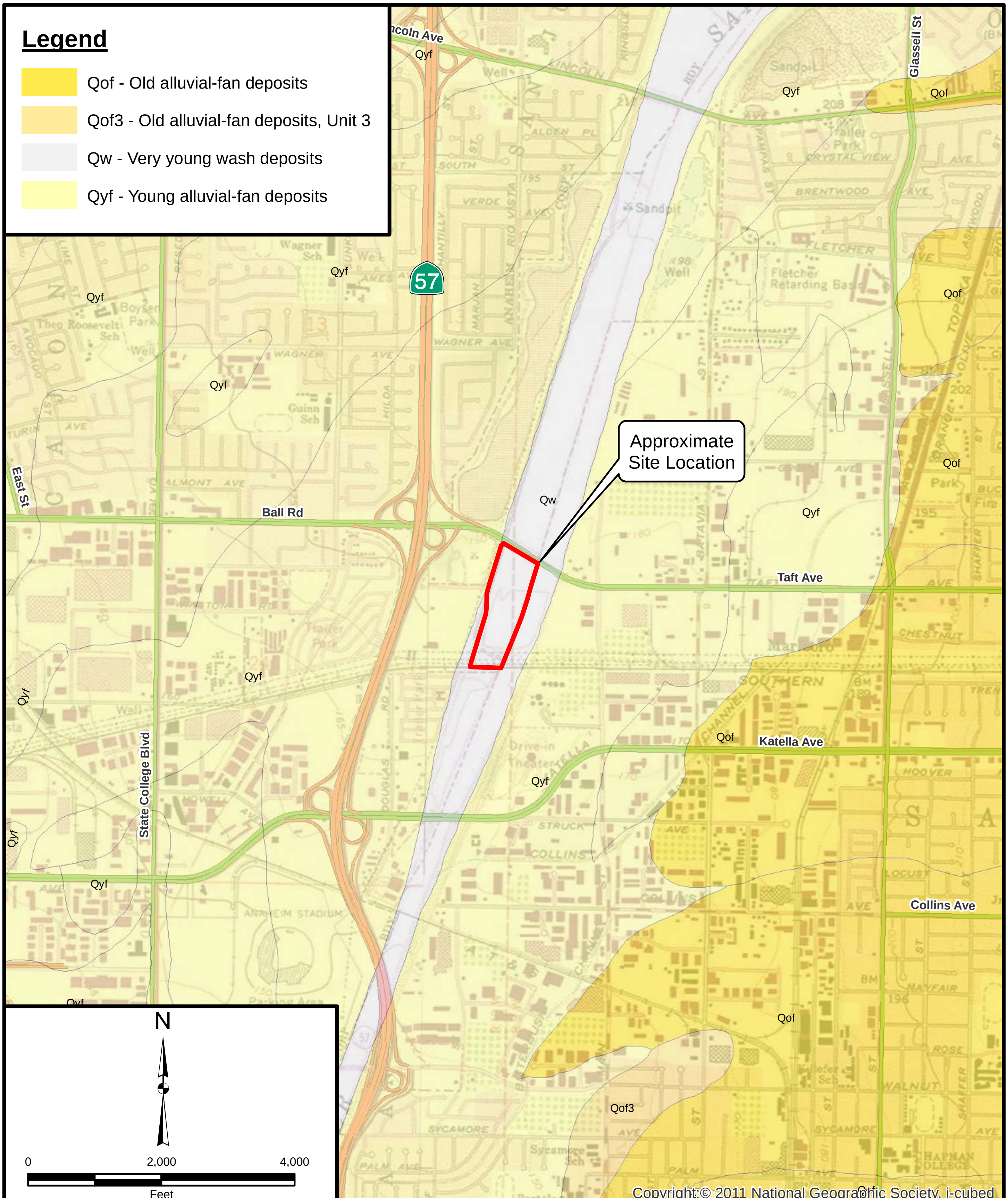
The California Department of Water Resources (2010) has several groundwater monitoring wells in the vicinity of the Project site with readings dating back to 1969. The measured groundwater ranged from Elevations 40 to 125 feet. Our recent borings (Leighton, 2013) at the Burris Basin located north of the Project site encountered groundwater at depths of seven and 25 feet below existing grade, corresponding to approximate Elevations 159 to 164 feet. Groundwater in the area appears to be influenced by the water level in the recharge basins and River. Fluctuations of the groundwater level, localized zones of perched water, and an increase in soil moisture should be anticipated depending on the water level in the basins and during and following the rainy seasons or periods of locally intense rainfall or storm water runoff.

## 2.4 Regional Faulting and Seismicity

Our review of available in-house literature indicates that there are no known active or potentially active faults that have been mapped at the Project site, and the site is not located within an Alquist-Priolo Earthquake Fault Zone (Hart and Bryant, 2007). The principal seismic hazard that could affect the site is ground shaking resulting from an earthquake occurring along one of several major active or potentially active faults in southern California. According to the available fault database by United States Geological Survey (USGS) and the California Department of Transportation (Caltrans), the closest active faults that could affect the site are the Puente Hills Blind Thrust, Elsinore, San Joaquin Hills Blind Thrust, and Newport Inglewood faults located approximately 4.7, 7.6, 8.5 and 11.8 miles, respectively, from the site. A regional fault map (Figure 3, *Regional Fault Map*) is attached to illustrate the proximity of the site to major active faults. The blind thrust faults are expressed as a fold scarp at or just below the ground surface and are, therefore, not shown on Figure 3.

The intensity of ground shaking at a given location depends primarily upon the earthquake magnitude, the distance from the source, and the site response characteristics. Peak Horizontal Ground Accelerations (PHGA) is generally used to evaluate the intensity of ground motion. A probabilistic seismic hazard analysis was performed using the online interactive deaggregation program developed by the United States Geological Survey (USGS, 2008). The analysis was conducted for a two percent probability of exceedance in 50 years (average return period of 2,475 years). The results of the probabilistic seismic hazard analysis indicate the modal seismic event is Moment Magnitude ($M_W$) 7.0 at a distance of 8.1 miles and a PHGA of 0.61g.

Based on review of the *Seismic Hazard Zone Map for the Orange Quadrangle* (California Geological Survey, 1998), the project site is located within a liquefaction hazard zone. Figure 4, *Seismic Hazard Zone Map* shows the region susceptible to liquefaction and the Project site.

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Base Map: ESRI Resource Center 2013
Thematic Info: Leighton
Author: Leighton Geomatics (mmurphy)

# REGIONAL GEOLOGY MAP

Ball Road Basin
Anaheim, California

Figure 2

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Base Map: ESRI Resource Center, 2010
Quaternary and Younger Faults in GIS format from California Fault Activity Map served by California Geological Survey, 2010.
Author: (mmurphy)

# REGIONAL FAULT MAP

## Ball Road Basin
## Anaheim, California

Figure 3

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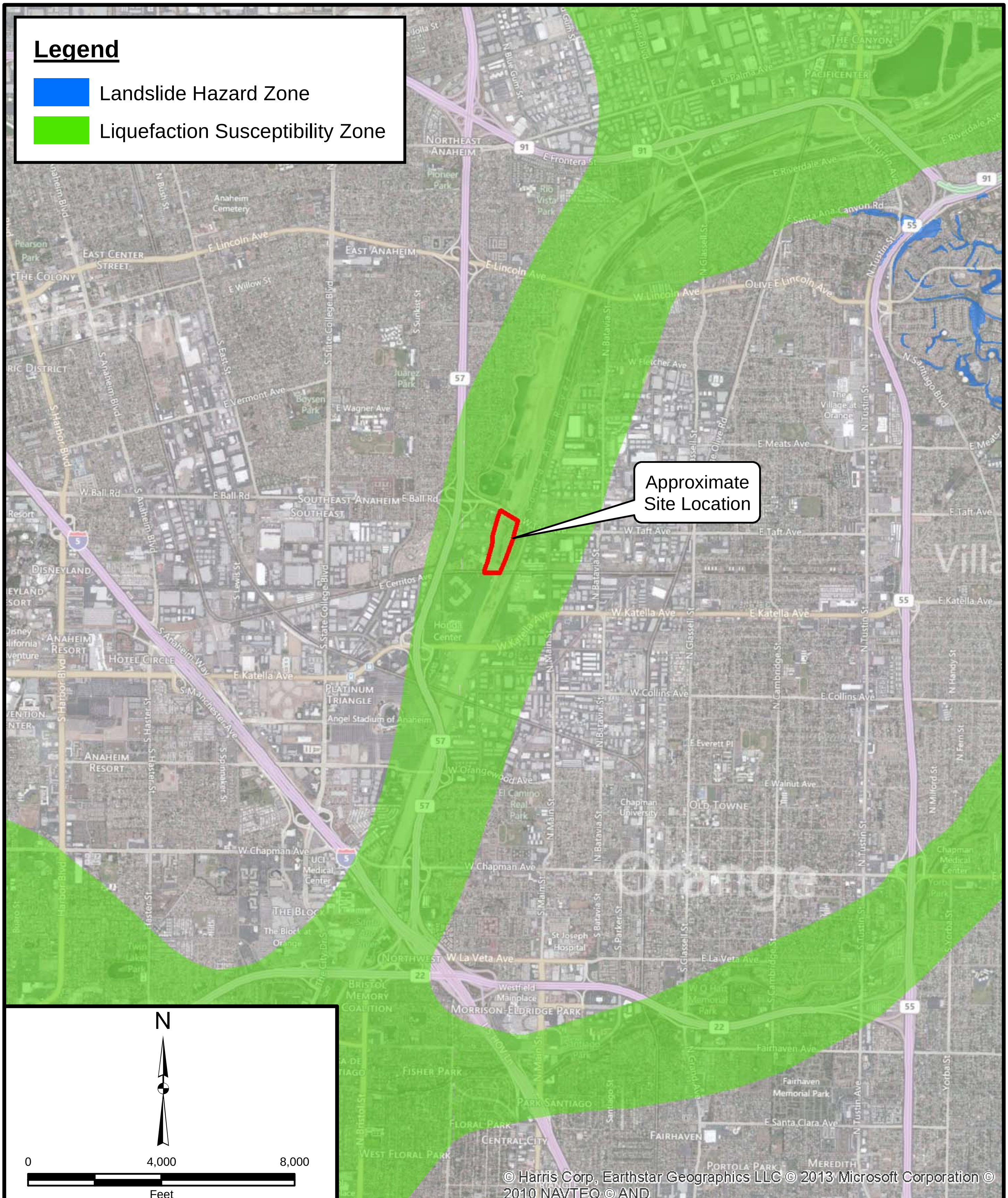


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| Scale: 1 " = 4,000 ' | Date: March, 2013 |

Base Map: ESRI Resource Center 2013
Thematic Info: Leighton, CGS, Seismic Hazards Zonation Program. Anaheim, California Quadrangle, 2001
Author: Leighton Geomatics (mmurphy)

# SEISMIC HAZARD MAP

## Ball Road Basin
## Anaheim, California

Figure 4

Leighton

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# 3.0 POTENTIAL GEOTECHNICAL HAZARDS

This section presents the principal geological and geotechnical conditions at the Project site. The potential constraint and impact that each condition may have on the site is subjectively rated as less than significant or potentially significant. Table 1 summarizes the potential geotechnical hazards at the project site. Where the impact is less than significant, no mitigation measures are considered necessary. Where the impact is potentially significant, measures to mitigate the hazard are required. Discussion of these hazards and measures to mitigate these hazards are presented in the following subsections.

**Table 1 – Summary of Potential Geotechnical Hazards**

| Potential Geotechnical Hazard | | Hazard Level |
|---|---|---|
| Earthquake Damage | Fault Displacement/Ground Rupture | Less than significant |
| | Seismic Shaking | Potentially significant |
| | Liquefaction | Potentially significant |
| | Lateral Spreading | Potentially significant |
| | Seismically Induced Settlement | Potentially significant |
| | Seismically Induced Landslides | Potentially significant |
| | Ground Lurching | Less than significant |
| | Seismically Induced Inundation | Potentially significant |
| | Tsunami | Less than significant |
| Land Subsidence | Extraction | Less than significant |
| | Hydroconsolidation | Less than significant |
| | Compressible Soils | Potentially significant |
| Slope Stability | Unstable Slopes | Potentially significant |
| | Landslides and Mudflows | Less than significant |
| Flooding | | Potentially significant |
| Grading Impacts | | Potentially significant |
| Volcanic Hazards | | Less than significant |

## 3.1 Earthquake Damage

### 3.1.1 Fault Displacement/Ground Rupture

Surface slip along a fault plane can damage structures that cross the fault trace by surface rupture and offset. No active or sufficiently active faults are known to cross the Project site. The Project site is not located within an Alquist-Priolo Earthquake Fault Zone (Bryant and Hart, 2007). The nearest active or sufficiently active faults are Puente Hills Blind Thrust and Elsinore faults located approximately 4.7 and 7.6 miles, respectively, from the site. The geotechnical hazard posed by ground surface rupture from direct fault offset is considered to be low. Therefore, this impact is **less than significant**.

**Mitigation Measures**: No special precautions or restrictions are considered necessary.

3.1.2 Seismic Ground Shaking

The site is expected to experience ground shaking resulting from an earthquake occurring along several major active or sufficiently active faults in southern California. The intensity of ground shaking at a given location depends on several factors, but primarily on the earthquake magnitude, the distance from the epicenter to the site of interest, and the response characteristics of the soils or bedrock units underlying the site. The peak horizontal ground accelerations at the Project site are estimated to be on the order of 0.61g for an earthquake event with a return period of 2,475 years. Therefore, within the Project site, the hazard posed by seismic shaking is considered to be high, due to the proximity of known active faults and the nature of the materials underlying the site. This is a **potentially significant** impact.

**Mitigation Measures**: There is no realistic way in which the seismic shaking hazard can be avoided due to the nature of earthquakes; however, design and construction of the project in accordance with current regulations and codes are expected to mitigate the effects of ground shaking to **less than significant**.

3.1.3 Secondary Effects of Seismic Shaking

Secondary effects generally associated with strong seismic shaking include liquefaction, lateral spreading, seismically-induced settlement, seismically-induced landslides and inundation, ground lurching, and tsunami. Each of these phenomena is discussed below.

*Liquefaction*: Liquefaction is a seismic phenomenon in which loose, saturated, fine-grained granular soils behave similarly to a fluid when subjected to high-intensity ground shaking. Liquefaction occurs when three general conditions exist: 1) shallow groundwater; 2) low density, fine, clean sandy soils; and 3) high-intensity ground motion. Effects of liquefaction on level ground can include sand boils, settlement, and bearing capacity failures below structural foundations. Effects of liquefaction on pile foundations include reduction in pile's lateral capacities and downdrag or negative friction due to settlement of a liquefied layer and the layers above it.

The project site is located within a liquefaction hazard zone based on the *Seismic Hazard Zone Map for the Orange Quadrangle* (California Geological Survey, 1997). The effects of liquefaction are expected to be a **potentially significant** impact.

**Mitigation Measures**: Geotechnical field explorations during future design phase should include Standard Penetration Tests (SPT) and CPT's to evaluate and quantify the extent of liquefaction. Future placement of 15 to 25 feet of compacted fill on the Project site will increase overburden pressures that tend to reduce liquefaction potential and the associated surface manifestation. Mitigation measures are likely to include removal and recompaction of near-surface, loose earth material and design of the proposed structures to accommodate liquefaction-induced settlement. If the liquefaction potential and its resulting effects are found to be significant, the mitigation measures may include in-place ground improvements, such as compaction grouting, deep dynamic compaction or stone columns to reduce the effects of liquefaction to **less than significant**.

*Lateral Spreading*: Lateral spreading is a phenomenon where large blocks of soil translate laterally along or through a layer of liquefied soil. The mass moves downslope toward an unconfined area, such as a descending slope or river, and is known to move on slope gradients as gentle as one degree. For lateral spreading to occur, the layer of liquefied soil needs to be continuous. The east side of the Project site is bordered by the Center Levee that is maintained by U.S. Army Corps of Engineers (USACE). The levee slopes down into the River Channel. As mentioned in the liquefaction section above, the site is located in an area susceptible to liquefaction. If the liquefiable layer is continuous, lateral spreading could potentially occur.  As such, the effects of lateral spreading are expected to be a **potentially significant** impact**.**

**Mitigation Measures**: It is recommended that future geotechnical investigation includes review of stability analysis of the Center Levee for potential lateral spreading.  If the potential exists, analysis should be performed to determine appropriate stability measures that may include one of the ground improvement techniques mentioned above or structural setback from top of the levee.  Incorporation of this mitigation is expected to reduce the effects of lateral spreading to **less than significant**.

*Seismically Induced Settlements*:  These settlements, consisting of dynamic settlement (above groundwater) and liquefaction settlement (below groundwater), occur primarily in loose sandy soils due to reduction in volume during or after an earthquake event.  These settlements are caused by strong ground shaking that allows the soil particles to become more tightly packed, thereby reducing pore space.  Poorly compacted artificial fills and poorly consolidated wash deposits are especially susceptible to this phenomenon. Seismically induced settlement is a **potentially significant** impact.

**Mitigation Measures**:  Removal and recompaction of low-density, near-surface soils should reduce this potential hazard.  Additionally, the proposed structures may be designed, as necessary, to account for the settlements**.** Incorporation of this mitigation is expected to reduce the effects of seismically induced settlements to **less than significant**.

*Seismically Induced Landslides*: Marginally stable slopes, including existing landslides, may be subject to landsliding caused by seismic shaking.  In most cases, this is limited to relatively shallow soil failures on steep slopes, especially where the soil is relatively thick and loose.  The Project site is not located in an area shown to be susceptible to seismically induced landslides by the California Geological Survey (1997). However, the site is bordered by a descending slope to the River.  As such, the potential hazard from seismically induced landslides is considered to be **potentially significant**.

**Mitigation Measures**: The USACE has an ongoing evaluation and monitoring program of existing levees.  Additional slope stability analysis should be performed to evaluate stability against seismic shaking during future design phase. Mitigation measures, if required, may consist of construction of shear keys, flattening of the existing slope, or building setback from top of the slope. Incorporation of these mitigation measures is expected to reduce the effects of seismically induced landslides to **less than significant**.

*Ground Lurching:* Ground lurching occurs when soil or rock masses move at right angles to a cliff or steep slope in response to seismic waves. Structures built on these masses can experience significant lateral and vertical deformations if ground lurching occurs. The existing slope descending to the River on the Project site is relatively flat. This impact is **less than significant.**

**Mitigation Measures**: None required.

*Seismically Induced Inundation*: Strong seismic ground motion can cause dams and levees to fail, resulting in damage to structures and properties located downstream. The Project site is located approximately 15 miles downstream of Prado Dam and flood control basin. Failure of the dam during a strong seismic event may cause inundation at the site. This impact is **potentially significant**.

**Mitigation Measures**: The USACE has recently completed upgrades that increase the dam's level of protection to low lying facilities downstream of the dam. The USACE continuously monitors the dam for safety against failure from potential seismic events, reducing this impact to **less than significant**.

*Tsunami*: Tsunamis are waves generated in large bodies of water by fault displacement or major ground movement. Based on the inland location of the site, tsunami risks at the site are considered **less than significant**.

**Mitigation Measures**: None required.

## 3.2 Land Subsidence

### 3.2.1 Extraction

Ground subsidence has been caused by the extraction of subsurface fluids such as petroleum or groundwater. Subsidence has also been caused by the oxidation of organic material such as peat. No oil fields or peat deposits are known in the area of the proposed project. Groundwater is not being heavily pumped from the project area. Therefore, this potential hazard is considered **less than significant**.

**Mitigation Measures**: None required.

3.2.2 Hydroconsolidation

Hydroconsolidation is caused by the addition of water to loose, dry soils in a semi-arid climate. The earth materials most susceptible to hydroconsolidation are silty sands and sands with relatively low moisture content. The soils encountered in the available borings nearby the Project site are not considered to have the potential for hydroconsolidation. The hazard for hydroconsolidation at the site, therefore, is considered **less than significant**.

**Mitigation Measures**: None required.

3.2.3 Compressible Soils

When a load, such as a fill or a structure, is placed on alluvial soils, the underlying soil layers can undergo a certain amount of compression. This compression is due to the deformation of the soil particles, the relocation of soil particles, expulsion of water or air from the void spaces, and other reasons. This settlement occurs both immediately after a load is applied and over a period of time after placement of the load. For engineering applications, it is important to estimate the total amount of settlement that will occur upon placement of a given load and the rate of consolidation.

The near-surface soils within the upper five to 10 feet in the Project site and the clay layers mentioned in Section 2.2 are potentially compressible. Compacted fill on the order of 15 to 25 feet will be placed for the Project. Therefore, compressible soils are considered to be **potentially significant**.

**Mitigation Measures**: To minimize the potential for settlement of the fills and the improvements on top of the fills, the near-surface compressible layers should be densified or removed and replaced with compacted fill. This is normally achieved by excavation and recompaction during grading operations. Removal and recompaction of the compressible layers may not be feasible as they are located at depths below 20 feet. After completion of grading, the fill should be monitored for settlement. A waiting period may be required between completion of fill placement and construction of improvements. Improvements should only be constructed after the settlement stabilizes and the projected long-term settlement is tolerable to the proposed improvements. Incorporation of these mitigation measures is expected to reduce the effects of compressible soils to **less than significant**.

## 3.3 Slope Stability

### 3.3.1 Unstable Slopes

The slope of the Center Levee that descends to the River is subject to the water flow in the river that may cause erosion and scour. The slope is also subject to a rapid drawdown condition where the water level in the river drops rapidly while the slope remains saturated. The potential for slope instability is considered **potentially significant**.

**Mitigation Measures**: The USACE has an ongoing evaluation and monitoring program of existing levees. Additional slope stability analysis should be performed during future design phase. Mitigation measures, if required, may consist of construction of shear keys, flattening of the existing slope, or building setback from top of the slope. This is expected to reduce the effects of unstable slopes to **less than significant**.

### 3.3.2 Landslides and Mudflows

There are no known or mapped landslides at or near the Project site. The potential for landslides or mudflows is considered **less than significant.**

**Mitigation Measures**: None required.

## 3.4 Flooding

The River, located immediately east of the Project site, had been known to cause widespread flooding in the area downstream of the river, including the project site. Construction of Prado Dam by the USACE in 1941 has alleviated the flooding hazard. The dam is located approximately 15 miles east and upstream of the site. The potential for inundation exists should Prado dam fail. If this occurs, the potential impact on the site will be **potentially significant**.

**Mitigation Measures**: The Prado Dam has been actively maintained and improved by the USACE, including raising the existing embankment and spillway crest, installation of a new outlet and construction of new levees and dikes. The segment of Santa Ana River immediately downstream of the dam is also constantly improved by the USACE. This is expected to reduce the effects of flooding to **less than significant**.

3.5 Grading Impacts

Development of the site will require significant fill placement to backfill the existing basin. The fill soils will require moisture conditioning and adequate compaction to provide proper support for the proposed improvements. Transportation of the import material may affect traffic in the vicinity. Grading operations will also generate dust and noise. This impact is considered **potentially significant**.

**Mitigation Measures**: Sources for the import material should be identified prior to construction, sampled and tested to verify that the material is suitable for the intended use at the project site. Routes and schedule for importing should be established to minimize disruption to traffic. Sufficient water should be added to the soils during grading to reduce generation of dust. Noise barriers may be erected around the site to reduce noise and/or grading operations should be maintained during normal working hours to reduce the noise impact to the surrounding neighborhood. This will reduce the impact to **less than significant**.

3.6 Volcanic Hazards

No volcanoes have been mapped or are known to exist near the proposed site. The potential for any lava flow or ash fall is negligible. Therefore, the potential for these hazards is **less than significant**.

**Mitigation Measures**: None required.

## 4.0 FUTURE GEOTECHNICAL INVESTIGATION

Geotechnical evaluations presented in this report are preliminary based on the review of subsurface soil conditions from the projects in the vicinity and information gained from review of historic data as well as our understanding of the current proposed Project. The nature of many sites is such that differing geotechnical or geological conditions can occur within small distances and under varying climatic conditions. Changes in subsurface conditions can and do occur over time.

Exploratory borings and CPT's should be performed during future geotechnical investigation(s) to evaluate the subsurface conditions at the Project site and collect soil samples for laboratory testing. SPT's should be conducted in the exploratory borings for assessing consistency of the soils and liquefaction evaluation. Laboratory testing should be performed to determine in-place moisture and density, gradation, soil plasticity, strength and consolidation characteristics, and corrosivity. Project site-specific recommendations for design and construction of the proposed project should be developed based on geotechnical analyses of the borings, CPT's and laboratory test results.

Design of the Project in accordance with standard engineering practice, including requirements of California Building Code (CBC), City, OCWD and USACE, and the recommendations of the project civil and structural engineers, geotechnical consultant and others will reduce the potential for adverse geotechnical conditions impacting the proposed Project.

## 5.0 REFERENCES


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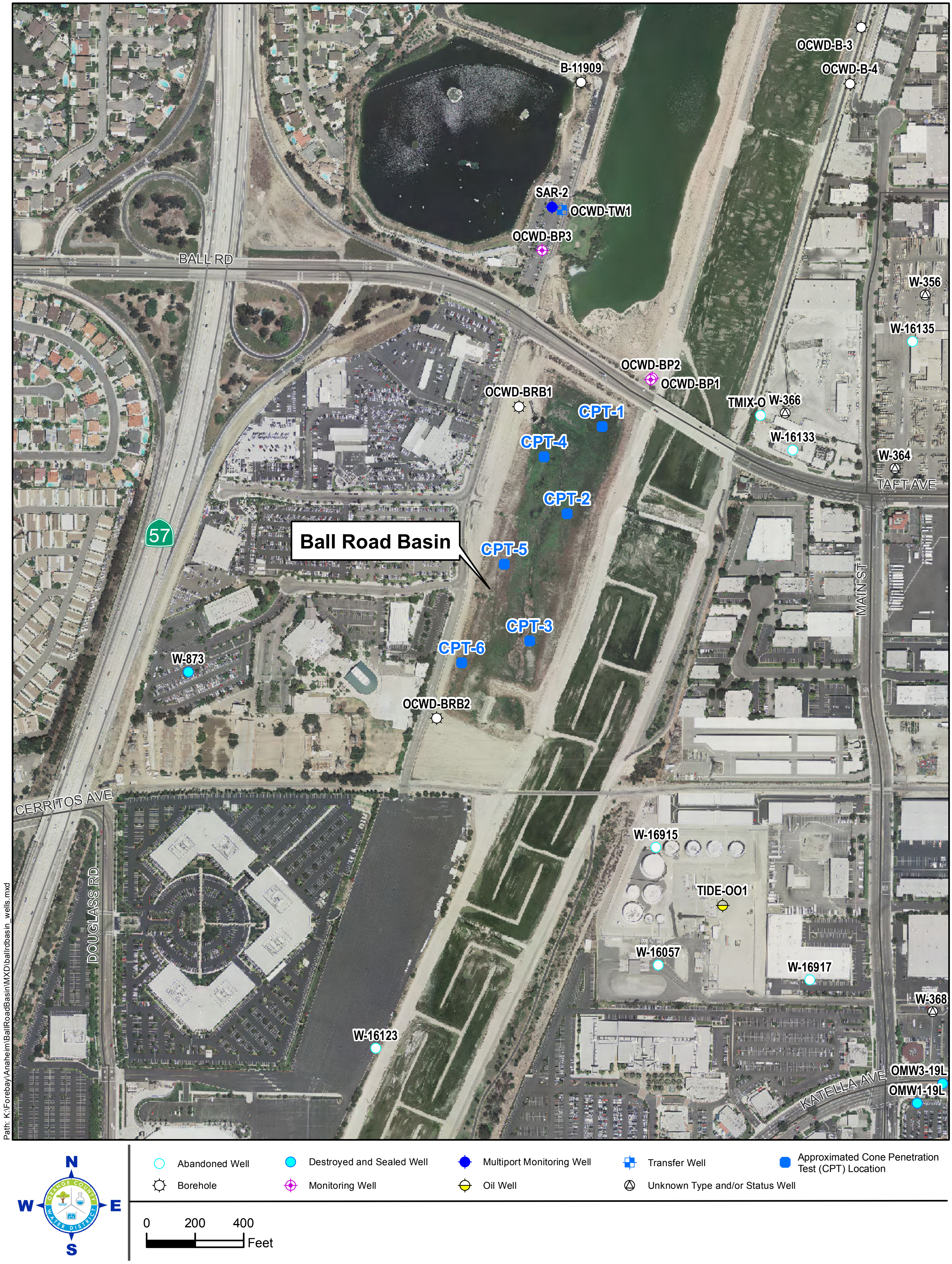
# APPENDIX A



Ball Road Basin
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OCWD-B-4
B-11909
SAR-2
OCWD-TW1
OCWD-BP3
BALL RD
W-356
W-16135
OCWD-BP2
OCWD-BP1
OCWD-BRB1
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CPT-4
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OMW3-19L
KATELLA AVE
OMW1-19L
Path: K:\Forebay\Anaheim\BallRoadBasin\MXD\ballrdbasin_wells.mxd
N
W
E
S
ORANGE COUNTY WATER DISTRICT
Abandoned Well
Destroyed and Sealed Well
Multiport Monitoring Well
Transfer Well
Approximated Cone Penetration Test (CPT) Location
Borehole
Monitoring Well
Oil Well
Unknown Type and/or Status Well
0
200
400
Feet

04S|10W-13R
24A

**Ball Road Basin B-1**

**LITHOLOGY LOG**

***ROJECT:*** Ball Road Basin Exploratory Borehole Drilling.
***OCATION:*** Northwest corner of Ball Road Basin near concrete channel.
***DATE DRILLED:*** 11/17/2005
***HOLE DIAMETER:*** 8" borehole.
***TOTAL DEPTH:*** 109 ft. bgs.

| DEPTH (ft) | SAMPLE DESCRIPTION | NOTES |
|---|---|---|
| 0 - 4 | SAND. 95% sand, 5% silt, light olive brown (2.5Y/5/4), <1/16 to 2mm, 8 to 16mm, very fine to very coarse sand, moderately sorted, subrounded, high sphericity. Predominantly very fine to medium sand, trace gravel and plant roots. | Dry |
| 4 - 9 | SAND WITH GRAVEL. 80% sand, 20% gravel, light olive brown (2.5Y/5/4), <1/16 to 32mm, very fine sand to coarse pebble gravel, very poorly sorted, subangular to well rounded, low to high sphericity, trace silt. | Dry |
| 9 – 11 ½ | SAND. 100% sand, light yellowish brown (2.5Y/6/3), 1/16 to 8mm, very fine to very coarse sand, poorly sorted, subangular to rounded, high sphericity, trace gravel. | Dry |
| 11 ½ - 14 | SAND. 90% sand, 10% gravel, light yellowish brown (2.5Y/6/3), 1/16 to 16mm, very fine sand to medium pebble gravel, very poorly sorted, subangular to rounded, moderate to high sphericity. | Dry |
| 14 – 19 | SAND. 100% sand, light yellowish brown (2.5Y/6/3), 1/16 to 8mm, very fine to very coarse sand, poorly sorted, subangular to rounded, moderate to high sphericity, trace gravel. | Dry |
| ) – 21 ½ | SAND WITH GRAVEL. 85% sand, 15% gravel, light yellowish brown (2.5Y/6/3), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, subangular to rounded, moderte to high sphericity. | Dry |
| 21 ½ - 23 ½ | SAND WITH GRAVEL. 70% sand, 30% gravel, light yellowish brown (2.5Y/6/3), 1/16 to 32mm, very fine sand to coarse pebble gravel, very poorly sorted, subangular to rounded, low to high sphericity. | Dry |
| 23 ½ - 24 | SAND. 90% sand, 10% silt, olive brown (2.5Y/4/3), <1/16 to 1mm, very fine to coarse sand, well sorted, subangular to subrounded, high sphericity. | Moist |
| 24 - 24 ½ | CLAY. 90% clay, 10% sand, olive brown (2.5Y/4/3), 1/16 to 1mm, very fine to coarse sand, moderately sorted, subangular to subrounded, high sphericity. | Wet |
| 24 ½ - 26 ½ | SAND WITH CLAY. 80% sand, 20% clay, olive brown (2.5Y/4/3), 1/16 to 2mm, very fine to very coarse sand, poorly sorted, subangular to subrounded, high sphericity. | Tagged WL @ 26.15 ft bgs |
| 26 ½ - 28 | SAND. 100% sand, grayish brown (2.5Y/5/2), <1/16 to 2mm, very fine to very coarse sand, poorly sorted, subangular to subrounded, moderate to high sphericity, trace clay and silt. | Wet |
| 28 - 31 ½ | SAND. 95% sand, 5% gravel, grayish brown (2.5Y/5/2), 1/16 to 8mm, very fine sand to fine pebble gravel, moderately sorted, subrounded, moderate to high sphericity. | Heaving sand |
| 31 ½ - 34 | SAND. 100% sand, light olive brown (2.5Y/5/3), 1/16 to 2mm, very fine to very coarse sand, poorly sorted, subangular to subrounded, moderate to high sphericity. | Heaving sand |
| , - 36 ½ | SAND. 95% sand, 5% gravel, light olive brown (2.5Y/5/3), 1/16 to 4mm, very fine sand to very fine pebble gravel, poorly sorted, subangular to subrounded, moderate to high sphericity. | Heaving sand |

## Ball Road Basin B-1

| DEPTH (ft) | SAMPLE DESCRIPTION | NOTES |
|---|---|---|
| 36 ½ - 39 ½ | SAND. 100% sand, light olive brown (2.5Y/5/3), 1/16 to 1mm, very fine to coarse sand, moderately sorted, subangular to subrounded, moderate to high sphericity. | Heaving sand |
| 39 ½ - 41 ½ | CLAY WITH SAND. 70% clay, 30% sand, dark grayish brown (2.5Y/4/2), 1/16 to 1mm, very fine to coarse sand, moderately sorted, subrounded, high sphericity, trace plant fragments. | |
| 41 ½ - 51 ½ | CLAY. 95% clay, 5% sand, brown (10YR/4/3). | |
| 51 ½ - 54 | CLAY. 90% clay, 10% sand, brown (10YR/4/3), trace gravel. | |
| 54 -56 ½ | SAND WITH GRAVEL. 80% sand, 20% gravel, dark yellowish brown (10YR/3/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, subrounded to well rounded, low to high sphericity. | |
| 56 ½ - 59 | GRAVEL AND SAND. 60% gravel, 40% sand, dark yellowish brown (10YR/3/4), 1/16 to 256mm, very fine sand to cobble gravel, very poorly sorted, angular to well rounded, low to high sphericity. | Cobble in drive shoe |
| 59 - 61 ½ | GRAVEL AND SAND. 60% gravel, 40% sand, dark yellowish brown (10YR/3/4), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, subangular to well rounded, moderate to high sphericity. | |
| 61 ½ - 64 | CLAY AND GRAVEL and SAND. 50% clay, 30% gravel, 20% sand, dark yellowish brown (10YR/4/4), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, angular to subrounded, moderate sphericity. | |
| 64 - 66 ½ | GRAVEL WITH SAND. 80% gravel, 20% sand, dark yellowish brown (10YR/3/6), <1/16 to 256mm, very fine sand to cobble gravel, very poorly sorted, subangular to well rounded, low to high sphericity, trace silt. | |
| 66 ½ - 69 | GRAVEL WITH SAND. 70% gravel, 30% sand, dark yellowish brown (10YR/4/4), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, subround to well rounded, low to moderate sphericity. | |
| 69 - 71 ½ | CLAY. 80% clay, 10% sand, 10% gravel, yellowish brown (10YR/5/4), 1/16 to 16mm, very fine sand to medium pebble gravel, very poorly sorted, moderate sphericity. | |
| 71 ½ - 75 | CLAY. 100% clay, yellowish brown (10YR/5/4), trace very fine sand. | |
| 75 - 76 ½ | SAND. 95% sand, 5% clay, dark yellowish brown (10YR/4/4), 1/16 to 1mm, very fine to coarse sand, moderately sorted, subangular to subrounded, high sphericity. | |
| 76 ½ - 79 | CLAY. 90% clay, 10% sand, yellowish brown (10YR/5/4). 2 to 3 inches of 100% fine to coarse sand in drive shoe. | |
| 79 - 81 ½ | NO RECOVERY | |
| 81 ½ - 83 | CLAY WITH SAND. 80% clay, 20% sand, yellowish brown (10YR/5/4), 1/16 to 1mm, very fine to coarse sand, moderately sorted, subangular to subrounded, high sphericity. | |
| 83 - 84 | SAND WITH CLAY. 80% sand, 20% clay, brown (10YR/4/3), 1/16 to 1mm, very fine to coarse sand, moderately sorted, subangular to subrounded, high sphericity. | |
| 84 - 86 | CLAY. 90% clay, 5% sand, 5% gravel, brown (10YR/4/3). | |
| 86 - 86 ½ | CLAY WITH SAND. 70% clay, 20% sand, 10% gravel, brown (10YR/4/3), 1/16 to 8mm, very fine sand to fine pebble gravel, very poorly sorted, subangular to subrounded, high sphericity. | |
| 86 ½ - 89 | GRAVEL and SAND WITH CLAY. 45% gravel, 40% sand, 15% clay, brown (10YR/4/3), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, angular to well rounded, low to high sphericity. | Heaving sand |

## Ball Road Basin B-1

| DEPTH (ft) | SAMPLE DESCRIPTION | NOTES |
|---|---|---|
| 89 - 91 ½ | GRAVEL AND SAND. 60% gravel, 40% sand, dark yellowish brown (10YR/3/4), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, subround to well rounded, moderate to high sphericity. | Heaving sand |
| 91 ½ - 94 | SAND AND GRAVEL. 50% sand, 50% gravel, dark yellowish brown (10YR/3/4), 1/16 to 32mm, very fine sand to coarse pebble gravel, very poorly sorted, subround to well rounded, moderate to high sphericity. | Heaving sand |
| 94 - 99 | GRAVEL WITH SAND. 70% gravel, 30% sand, dark yellowish brown (10YR/3/4), 1/16 to 32mm, very fine sand to coarse pebble gravel, very poorly sorted, subround to well rounded, moderate to high sphericity. | Heaving sand |
| 99 - 104 | SAND AND GRAVEL. 60% sand, 40% gravel, dark yellowish brown (10YR/3/4), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, subangular to rounded, moderate to high sphericity. | Heaving sand |
| 104 - 109 | SAND WITH GRAVEL. 70% sand, 30% gravel, dark yellowish brown (10YR/3/4), 1/16 to 32mm, very fine sand to coarse pebble gravel, very poorly sorted, subangular to well rounded, moderate to high sphericity. | Heaving sand |
| | **BOREHOLE TERMINATED AT 109 FT BGS DUE TO HEAVING SAND** | |

04S-10W-244

# OCWD-B2

## LITHOLOGY LOG

***PROJECT:*** Ball Road Basin Borehole Project.
***LOCATION:*** In the southwest corner of Ball Road Basin.
***DATE DRILLED:*** 1/17 to 1/18/2006.
***HOLE DIAMETER:*** 6" borehole.
***TOTAL DEPTH:*** Borehole to 171 ft. bgs.

| DEPTH (ft) | SAMPLE DESCRIPTION | NOTES |
|---|---|---|
| 0 - 5 | N/A | No recovery |
| 5 - 9 | SAND. 100% sand, trace gravel, brown (10Y 5/3), 1/16 to 1mm, 32 to 64mm, very fine sand to coarse sand and very coarse pebble gravel, poorly sorted, subangular to rounded, moderate to high sphericity. | Low recovery 30 |
| 9 - 13 | SAND. 95% sand, 5% gravel, brown (10Y 5/3), 1/16 to 1mm, very fine to coarse sand, 32mm to 64mm, very coarse pebble gravel, poorly sorted, subangular to rounded, moderate to high sphericity. | Low recovery 30 |
| 13 - 17 | SAND. 90% sand, 10% gravel, brown (10Y 5/3), 1/16 to 32mm, very fine sand to very coarse pebble gravel, very poor sorting, angular to subrounded, moderate sphericity. | Low recovery 30 |
| 17 - 19 | SAND. 95% sand, 5% gravel, brown (10Y 5/3), 1/16 to 8mm, very fine sand to fine pebble gravel, poorly sorted, subangular to subrounded, moderate sphericity. | Low recovery 30 |
| - 21 | SAND. 85% sand, 15% gravel, brown (10Y 5/3), 1/16 to 16mm, very fine sand to coarse pebble gravel, poorly sorted, subangular to subrounded, moderate sphericity. | 30 |
| 21 - 24 | SAND. 90% sand, 10% gravel, brown (10Y 5/3), 1/16 to 8mm, very fine sand to very coarse gravel, poorly sorted, subangular to subrounded, moderately sphericity. | 30 |
| 24 - 27 | SAND. 100% sand, trace clay and gravel, brown (10Y 5/3), 1/16 to 8mm, very fine sand to fine pebble gravel, poorly sorted, subrounded, moderate to high sphericity. | 30 |
| 27 - 28 | SAND. 95% sand. 5% sand, brown (10Y 5/3), 1/16 to 1mm, very fine to coarse sand, well sorted, subangular to subrounded, high sphericity. | 30 |
| 28 - 30 | SAND. 95% sand. 5% silt, brown (10Y 5/3), <1/16 to 1mm, very fine to coarse sand, well sorted, subangular to subrounded, high sphericity. | 30 |
| 30 - 33 | SAND. 100% sand, trace clay, brown (10Y 5/3), 1/16 to 32mm, very fine to coarse sand, moderately sorted, very angular to subrounded, moderate to high sphericity. | 30 |
| 33 - 36 | SAND. 100% sand, trace silt, brown (10Y 5/3), <1/16 to 2mm, very fine to very coarse sand, well sorted, subangular to subrounded, moderate sphericity. | 30 |
| 36 - 39 | SAND. 95% sand, 5% clay, brown (10Y 5/3), 1/16 to 2mm, very fine to fine pebble gravel, poorly sorted, subrounded, moderately sphericity. | Low recovery 30 |

## OCWD-B2

| DEPTH (ft) | SAMPLE DESCRIPTION | NOTES |
|---|---|---|
| 39 - 42 | SAND and CLAY. 60% sand, 40% clay, trace gravel, brown (10Y 5/4), 1/16 to 1mm, 16mm to 32mm, very fine to coarse sand and coarse pebble gravel, moderately sorted, subangular to subrounded, high sphericity. | 30+10 |
| 42 - 45 | SAND with SILT. 80% sand, 20% silt, brown (10Y 4/4), <1/16 to 1mm, very fine to coarse sand, moderately sorted, subangular to subrounded, moderate sphericity. | 30/20 |
| 45 - 50 | CLAY. 90% clay, 10% sand, brown (10Y 4/4). | 10 |
| 50 - 53 | CLAY. 100% clay, trace sand and gravel, red-brown (7.5Y 4/4). | 10 |
| 53 - 56 | CLAY. 90% clay, 10% sand, red-brown (7.5Y 4/4). | Low recovery 10 |
| 56 - 59 | CLAY. 90% clay, 10% sand, red-brown (7.5Y 4/4). | Low recovery 10 |
| 59 - 62 | SAND and CLAY. 60% sand, 40% clay, brown (10Y 4/4), <1/16 to 2mm, very fine to coarse sand, moderately sorted, subrounded, high sphericity. | 30+20 |
| 62 - 65 | CLAY. 100% clay, trace sand, red-brown (7.5Y 4/6). | 10 |
| 65 - 68 | CLAY. 100% clay, trace sand, red-brown (7.5Y 4/6). | 10 |
| 68 - 72 | CLAY with SAND. 80% clay, 20% sand, trace gravel, red-brown (7.5Y 4/6), 1/16 to 4mm, very fine sand to very fine pebble gravel, poorly sorted, subrounded, high sphericity. | 10/30 |
| 72 - 76 | CLAY. 100% clay, trace sand, red-brown (7.5Y 4/6). | 10 |
| 76 - 80 | CLAY with SAND. 70% clay, 30% sand, red-brown (7.5Y 4/6), 1/16 to 4mm, very fine sand to very fine pebble gravel, well sorted, subangular to subrounded, moderate sphericity. | 10/30 |
| 80 - 84 | CLAY and SAND. 60% clay, 30% sand, 10% silt, trace gravel, red-brown (7.5Y 4/6), <1/16 to 1mm, 8 to 16mm, very fine sand to very fine pebble gravel, well sorted, angular to subrounded, moderate sphericity. | 10+30 |
| 84 - 86 | CLAY. 100% clay, trace sand, red-brown (7.5Y 4/6). | 10 |
| 86 - 88 | CLAY and SAND. 55% clay, 40% sand, 5% silt, brown (10Y 4/4), <1/16 to 1/2mm, very fine to medium sand. | 10+30 |
| 88 - 90 | CLAY and SAND. 55% clay, 40% sand, 5% silt, brown (10Y 4/4), <1/16 to 1/2mm, very fine to medium sand. | 10+30 |
| 90 - 91 | SAND. 100% sand, brown (10Y 4/4), 1/16 to 1/2mm, very fine to medium sand, very well sorted, subrounded, high sphericity. | 30 |
| 91 - 94 | SAND. 100% sand, trace clay, brown (10Y 4/4), 1/16 to 1/2mm, very fine to medium sand, very well sorted, subrounded, high sphericity. | 30 |
| 94 - 97 | CLAY. 100% clay, trace fine gravel, red-brown (7.5Y 4/6). | 10 |
| 97 - 100 | SAND and CLAY. 60% sand, 40% clay, brown (7.5Y 4/6), 1/16 to 1/2mm, very fine to medium sand, poorly sorted, subangular to rounded, moderate sphericity. | 30+10 |
| 100 - 102 | N/A | No recovery Rig chatter |

## OCWD-B2

| DEPTH (ft) | SAMPLE DESCRIPTION | NOTES |
|---|---|---|
| 102 - 103 | GRAVEL with SAND. 80% gravel, 20% sand, yellow brown (10Y 5/6), 1/16 to 164mm, very fine sand to very coarse pebble gravel, very poorly sorted, angular to rounded, low sphericity. | Rig chatter 40+10 |
| 103 - 105 | GRAVEL. 90% gravel, 10% sand, yellow brown (10Y 5/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, angular to rounded, low to high sphericity. | Rig chatter 40 |
| 105 - 107 | N/A | No recovery |
| 107 - 109 | SAND. 100% sand, trace gravel, brown (10Y 5/3), 1/16 to 1mm, very fine sand to coarse sand, moderately sorted, subangular to subrounded, moderate sphericity. | 30 |
| 109 - 110 | SAND and CLAY. 60% sand, 40% clay, trace gravel red brown (7.5Y 4/6), 1/16 to 1mm, very fine sand to coarse sand, moderately sorted, subangular to subrounded, moderate sphericity. | 30+10 |
| 110 - 113 | SAND with CLAY. 75% sand, 20% clay, 5% gravel, red brown (7.5Y 4/6), 1/16 to 32mm, very fine to coarse pebble gravel, poorly sorted, subangular to rounded, low to moderate sphericity. | 30/10 |
| 113 - 116 | CLAY with SAND. 70% clay, 20% sand, 10% gravel, yellow brown (10Y 5/6), 1/16 to 8mm, very fine sand to fine pebble gravel, poorly sorted, angular to subrounded, moderate sphericity. | 10+30 |
| 116 - 119 | SAND and CLAY. 55% sand, 40% clay, 5% gravel, yellow brown (10Y 5/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, poorly sorted, subangular to subrounded, moderate sphericity. | 30+10 |
| 119 - 122 | CLAY with SAND. 80% clay, 20% sand, yellow brown (10Y 5/6), 1/16 to 1mm, very fine to coarse sand, well sorted, subangular to subrounded, high sphericity. | 10/30 |
| 122 - 125 | CLAY with GRAVEL. 80% clay, 15% gravel, 5% sand, yellow brown (10Y 5/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, poorly sorted, angular to subrounded, moderate sphericity. | 10/40 |
| 125 - 128 | CLAY AND SAND and GRAVEL. 60% clay, 20% sand, 20% gravel, yellow brown (10Y 5/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, poorly sorted, subangular to rounded, moderate sphericity. | 10+30, 40 |
| 128 - 131 | SAND. 100% sand, trace gravel, brown (10Y 5/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, poorly sorted, subangular to subrounded, moderate sphericity. | 30 |
| 131 - 133 | SAND and GRAVEL. 50% sand, 50% gravel, yellow brown (10Y 5/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, angular to rounded, low to moderate sphericity. | Rig Chatter 30+40 |
| 133 - 134 | N/A | No recovery |
| 134 - 136 | GRAVEL with SAND. 70% gravel, 30% sand, yellow brown (10Y 66), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, angular to subrounded, low to high sphericity. | Rig Chatter 40/30 |
| 136 - 139 | N/A | No recovery, hard drilling |

## OCWD-B2

| DEPTH (ft) | SAMPLE DESCRIPTION | NOTES |
|---|---|---|
| 139 - 142 | SAND. 100% sand, trace gravel, brown (10Y 5/4), 1/16 to 2mm, 8 to 16mm, very fine to very coarse sand and coarse pebble gravel, moderately sorted, subangular to subrounded, high sphericity. | Low recovery 30 |
| 142 - 145 | SAND and GRAVEL. 70% sand, 30% gravel, trace clay, yellow brown (10Y 5/3), 1/16 to 64mm, very fine sand to very coarse pebble gravel, very poorly sorted, subangular to well rounded, low to moderate sphericity. | 30+40 |
| 145 - 148 | SAND. 90% sand, 10% gravel, yellow brown (10Y 5/4), 1/16 to 32mm, very fine sand to coarse pebble gravel, poorly sorted, subangular to rounded, moderate sphericity. | Low recovery 30 |
| 148 - 150 | N/A | No recovery |
| 150 - 153 | SAND. 100% sand, trace gravel and clay, brown (10Y 4/4), 1/16 to 1mm, 64 to 256mm, very fine to medium sand and cobble gravel, moderately sorted, subangular to rounded, moderate sphericity. | 30 |
| 153 - 155 | CLAY. 90% clay, 5% silt, 5% sand, brown (10Y 4/4). | 10 |
| 155 - 156 | SAND. 90% sand, 10% gravel, yellow brown (10Y 5/6), 1/16 to 256mm, very fine sand to cobble gravel, poor to moderately sorted, angular to subangular, moderate sphericity. | 30 |
| 156 - 159 | CLAY with GRAVEL. 70% clay, 30% gravel, yellow brown (10Y 5/6), 16 to 64mm, coarse pebble to very coarse pebble gravel, very poorly sorted, subangular to subrounded, moderate sphericity. | 10/40 |
| 9 - 162 | SAND with GRAVEL. 70% sand, 30% gravel, trace clay, dark yellow brown (10Y 4/6), 1/16 to 64mm, very fine sand to very coarse pebble gravel, poorly sorted, angular to subrounded, moderate sphericity. | Low recovery 30/40 |
| 162 - 163 | SAND with GRAVEL. 80% sand, 20% gravel, trace clay, yellow brown (10Y 5/6), 1/16 to 16mm, very fine sand to medium pebble gravel, poorly sorted, angular to subangular, moderate sphericity. | 30/40 |
| 163 - 165 | CLAY with SAND. 80% clay, 20% sand, dark yellow brown (10Y 4/4), 1/16 to 4mm, very fine sand to medium pebble gravel, very poorly sorted, angular to subangular, moderate sphericity. | 10/30 |
| 165 - 168 | CLAY with SAND. 70% clay, 30% sand, trace gravel, brown (10Y 5/4), 1/16 to 16mm, very fine sand to coarse pebble gravel, very poorly sorted, angular to subangular, moderate sphericity. | 10/30 |
| 168 - 171 | SAND and GRAVEL. 45% sand, 45% gravel, 10% clay, brown (10Y 5/4), 1/16 to 256mm, very fine sand to cobble gravel, very poorly sorted, very angular to subrounded, low sphericity. | Rig Chatter 30+40 |

**FUGRO GEOSCIENCES, INC.**

6105 Rookin
Houston, TX 77074
Phone : 713-778-5580
Fax : 713-778-5501

October 19, 1998
Report Number 0303-0253-2

Orange County Water District
10500 Ellis Avenue
Fountain Valley, California 92708

Attention: Mr. Greg Woodside

**REPORT FOR**
**CONE PENETRATION TESTING (CPT)**
**AND RELATED SERVICES**
**SANTA ANA RIVER RECHARGE**
**SANTA ANA CANYON**
**CALIFORNIA**

(BALL Road BASIN)

Dear Mr. Woodside:

Please find enclosed herewith the final results of the cone penetration tests (C1-C6) conducted at the above referenced location. Cone penetration tests were carried out under the supervision of Orange County Water District's personnel.

For your information, the soil stratigraphy was identified using Campanella and Robertson's Simplified Soil Behavior Chart. Please note that because of the empirical nature of the soil behavior chart, the soil identification should be verified locally.

Fugro Geosciences appreciates the opportunity to be of service to your organization. If you should have any questions, or if we can be of further assistance, please do not hesitate to contact us. We look forward to working with you in the future.

Very truly yours,
**FUGRO GEOSCIENCES, INC.**

Recep Yilmaz
President

RY/mw

1 Diskette Enclosed

# Key to Soil Classification and Symbols

**SOIL TYPE** (Shown in Symbol Column) | **SAMPLE TYPE** (Shown in Samples Column)

Sand Silt Clay

Fill | Sandy | Silty | Clayey | Undisturbed | Rock Core | Split Spoon | No Recovery

Predominant type shown heavy

## TERMS DESCRIBING CONSISTENCY OR CONDITION

**COARSE GRAINED SOILS** (Major portion Retained on No. 200 Sieve)

Includes (1) clean gravels & sand described as fine, medium or course, depending on distribution of grain sizes (2) silty or clayey gravels & sands & (3) fine grained low plasticity soils (P1 < 10) such as sandy silts. Condition is rated according to relative density, as determined by lab tests or estimated from resistance to sampler penetration.

| Descriptive Term | Penetration Resistance* | Relative Density |
|---|---|---|
| Loose | 0-10 | 0 to 40% |
| Medium Dense | 10-30 | 40 to 70% |
| Dense | 30-50 | 70 to 90% |
| Very Dense | Over 50 | 90 to 100% |

*Blows/Ft., 140# hammer, 30" drop

**FINE GRAINED SOILS** (Major Portion Passing No. 200 Sieve)

Includes (1) inorganic & organic silts & clays, (2) sandy, gravelly or silty clays, & (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings or by unconfined compression tests for soils with P1 ≥ 10.

| Descriptive Term | Cohesive Shear Strength Tons/Sq. Ft. |
|---|---|
| Very Soft | Less Than 0.125 |
| Soft | 0.125 to 0.25 |
| Firm | 0.25 to 0.50 |
| Stiff | 0.50 to 1.00 |
| Very Stiff | 1.00 to 2.00 |
| Hard | 2.00 and Higher |

Note: Slickensided and fissured clay may have lower unconfined compressive strengths than shown above because of planes of weakness or shrinkage cracks; consistency ratings of such soils are based on hand penetrometer readings.

## TERMS CHARACTERIZING SOIL STRUCTURE

**Parting:** paper thin in size

**Seam:** 1/8"-3" thick

**Layer:** greater than 3"

**Fissured:** containing shrinkage cracks, frequently filled with fine sand or silt, usually more or less vertical

**Sensitive:** pertaining to cohesive soils that are subject to appreciable loss of strength when remolded

**Interbedded:** composed of alternate layers of different soil types

**Laminated:** composed of thin layers of varying color and texture

**Calcareous:** containing appreciable quantities of calcium carbonate

**Well Graded:** having wide range in grain sizes and substantial amounts of all intermediate particle sizes

**Poorly Graded:** predominately of one grain size, or having a range of sizes with some intermediate size missing

**Flocculated:** pertaining to cohesive soils that exhibit a loose knit or flakey structure

**Slickensided:** having inclined planes of weakness that are slick and glossy in appearance.

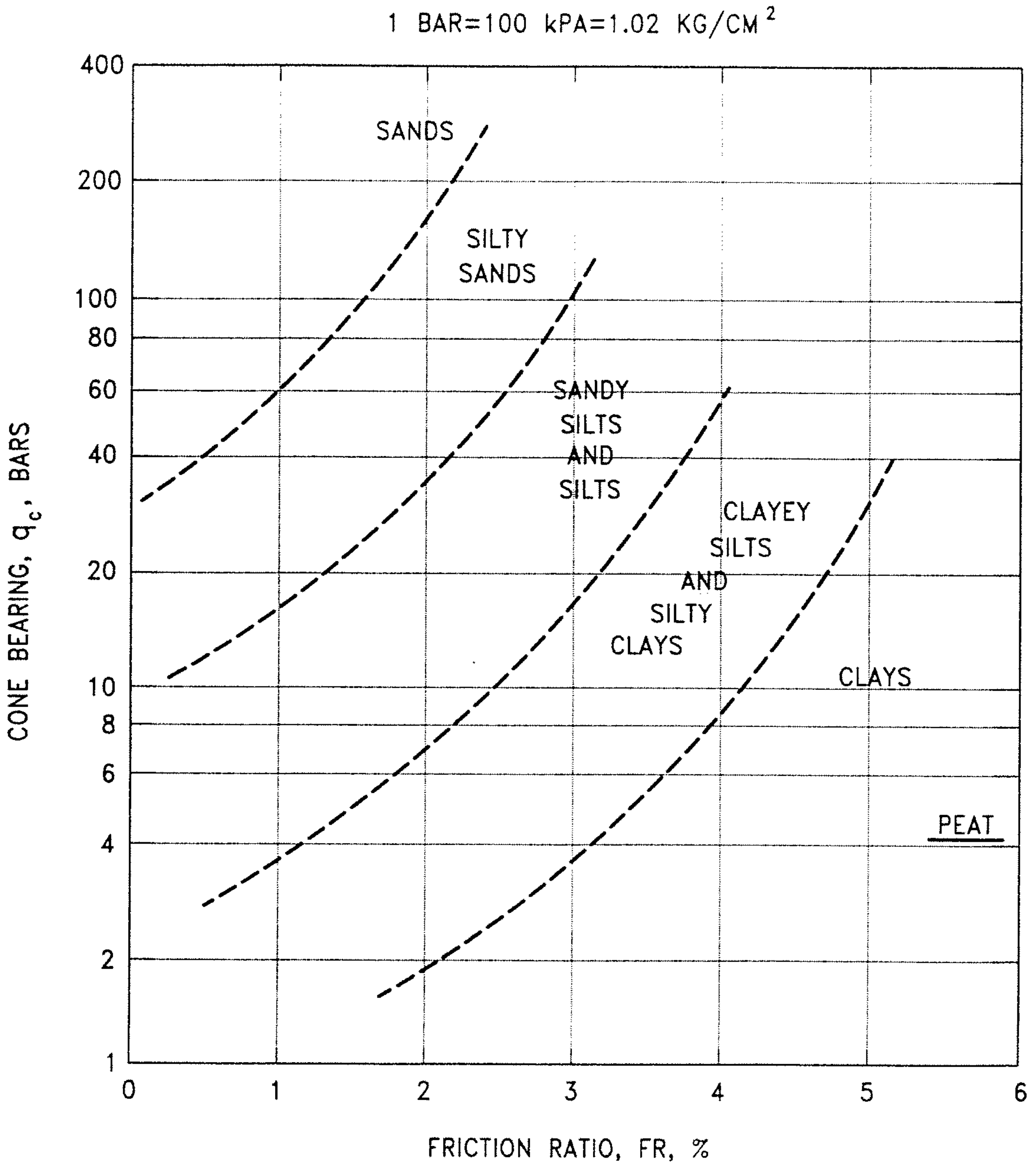
Degree of Slickensided Development

Slightly Slickensided: slickensides present at intervals of 1'-2', soil does not easily break along these planes

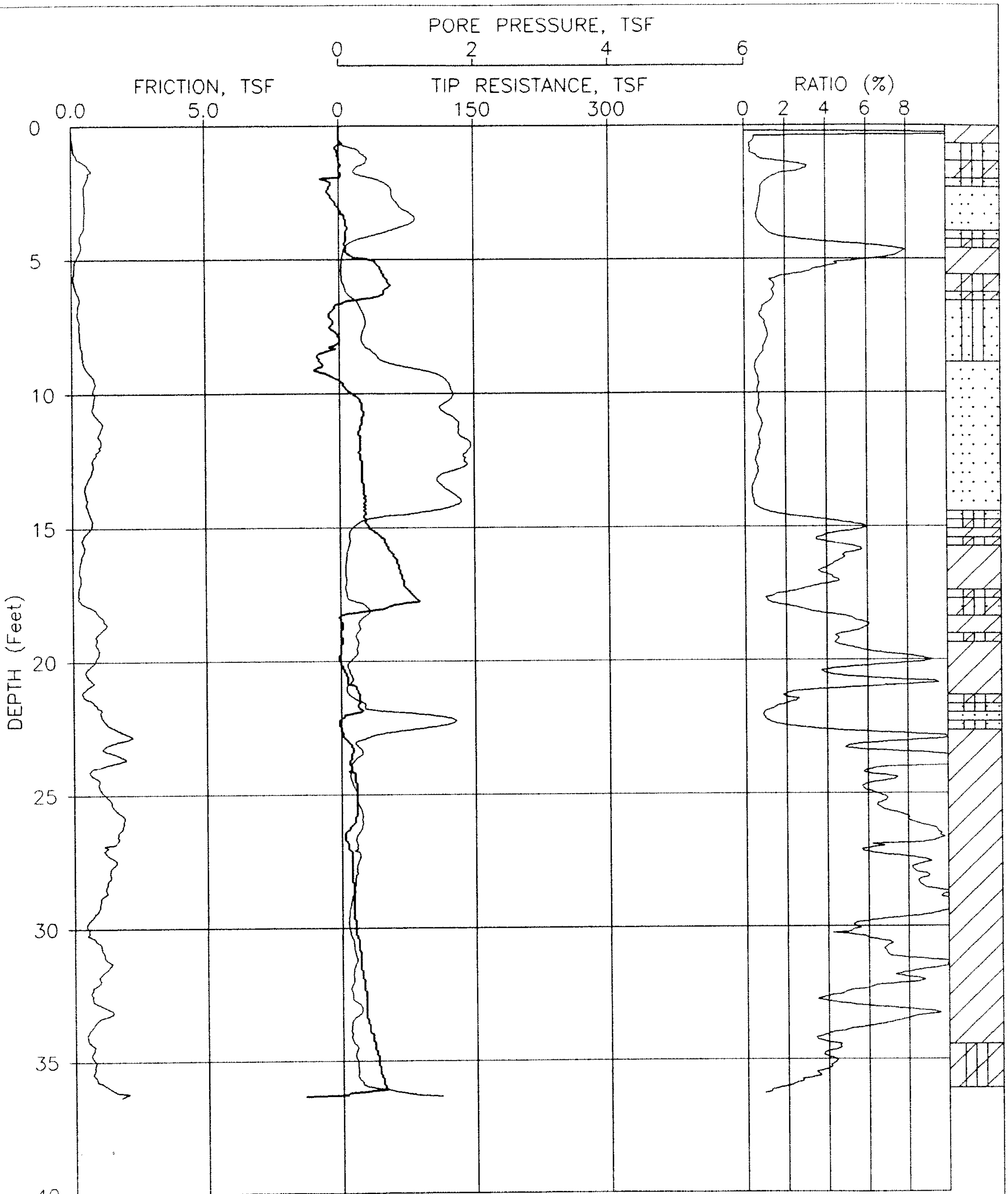
Moderately Slickensided: slickensides spaced at intervals of 1'-2', soil breaks easily along these planes

Extremely Slickensided: continuous and interconnected slickensides spaced at intervals of 4"-12", soil breaks along the slickensides into pieces 3"-6" in size

Intensely Slickensided: slickensides spaced at intervals of less than 4", continuous in all directions; soil breaks down along planes into nodules 1/4"-2" in size



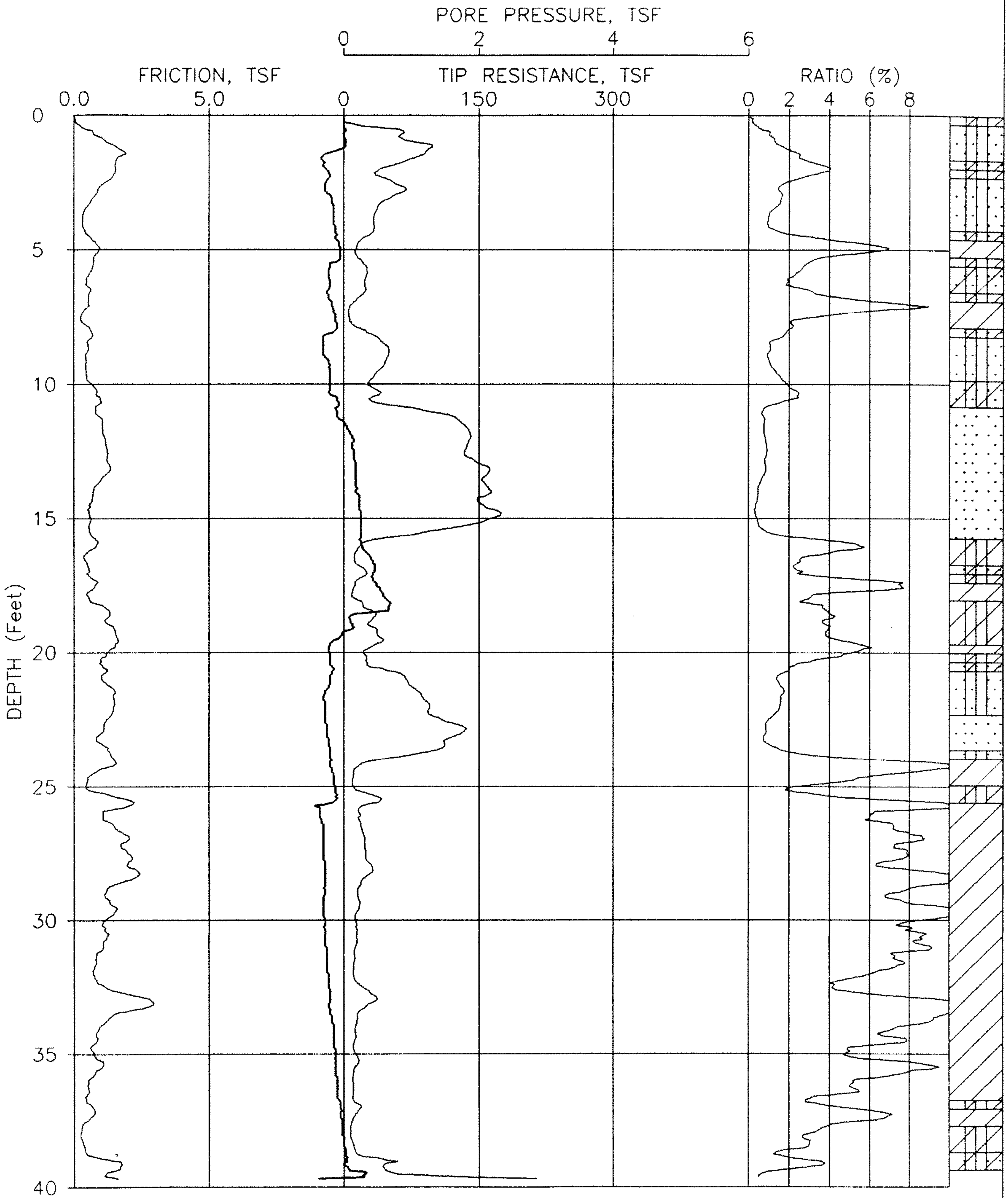

**CAMPANELLA AND ROBERTSON CLASSIFICATION CHART (1983)**




JOB NUMBER: 0303-0253 CPT NUMBER: C1 DATE: 10-09-1998

ELEVATION: 0.00 CONE NUMBER: F7.5CKEW966 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC




JOB NUMBER: 0303-0253 CPT NUMBER: C2 DATE: 10-09-1998

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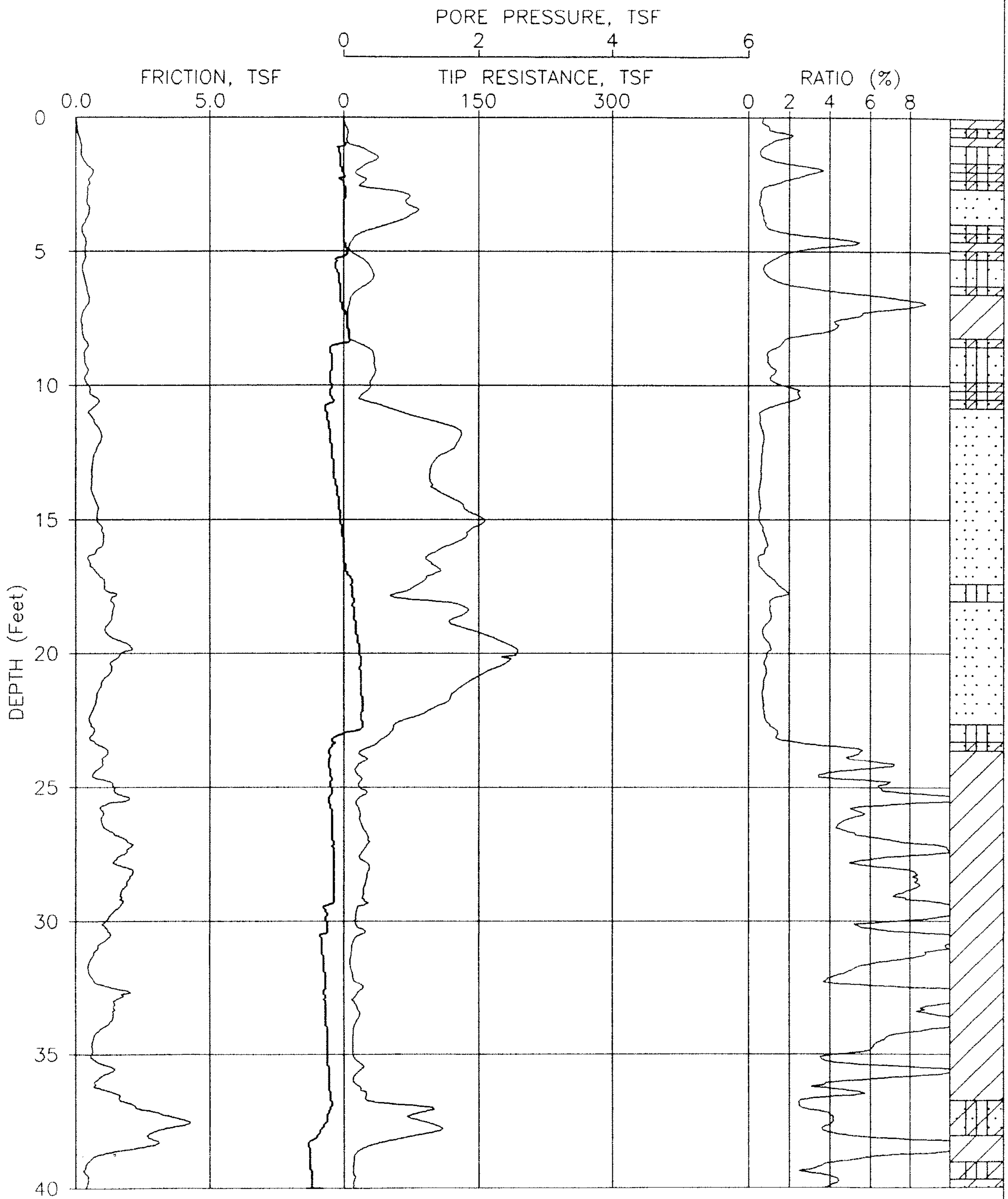
FUGRO GEOSCIENCES,INC




JOB NUMBER: 0303-0253 CPT NUMBER: C3 DATE: 10-09-1998
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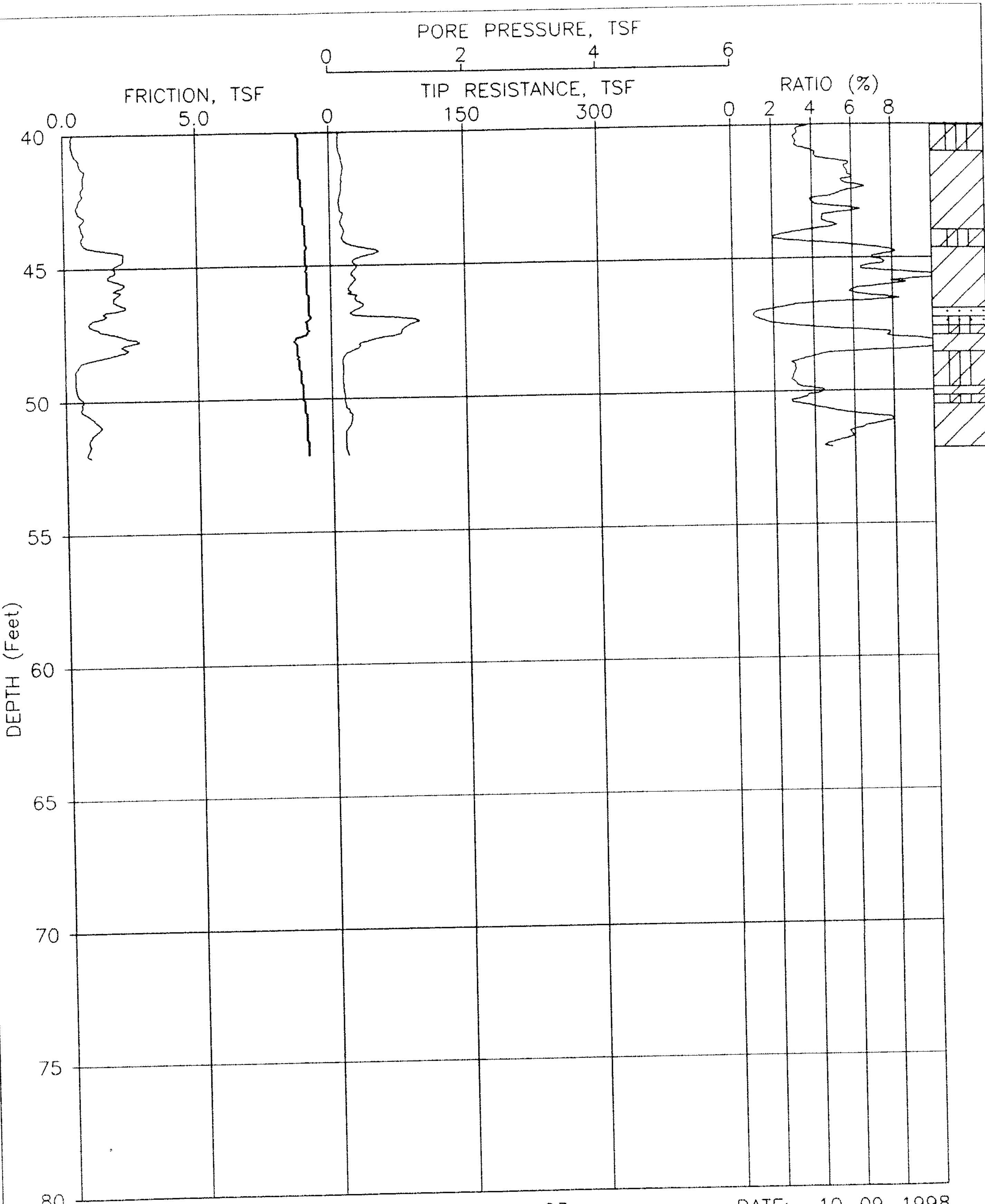


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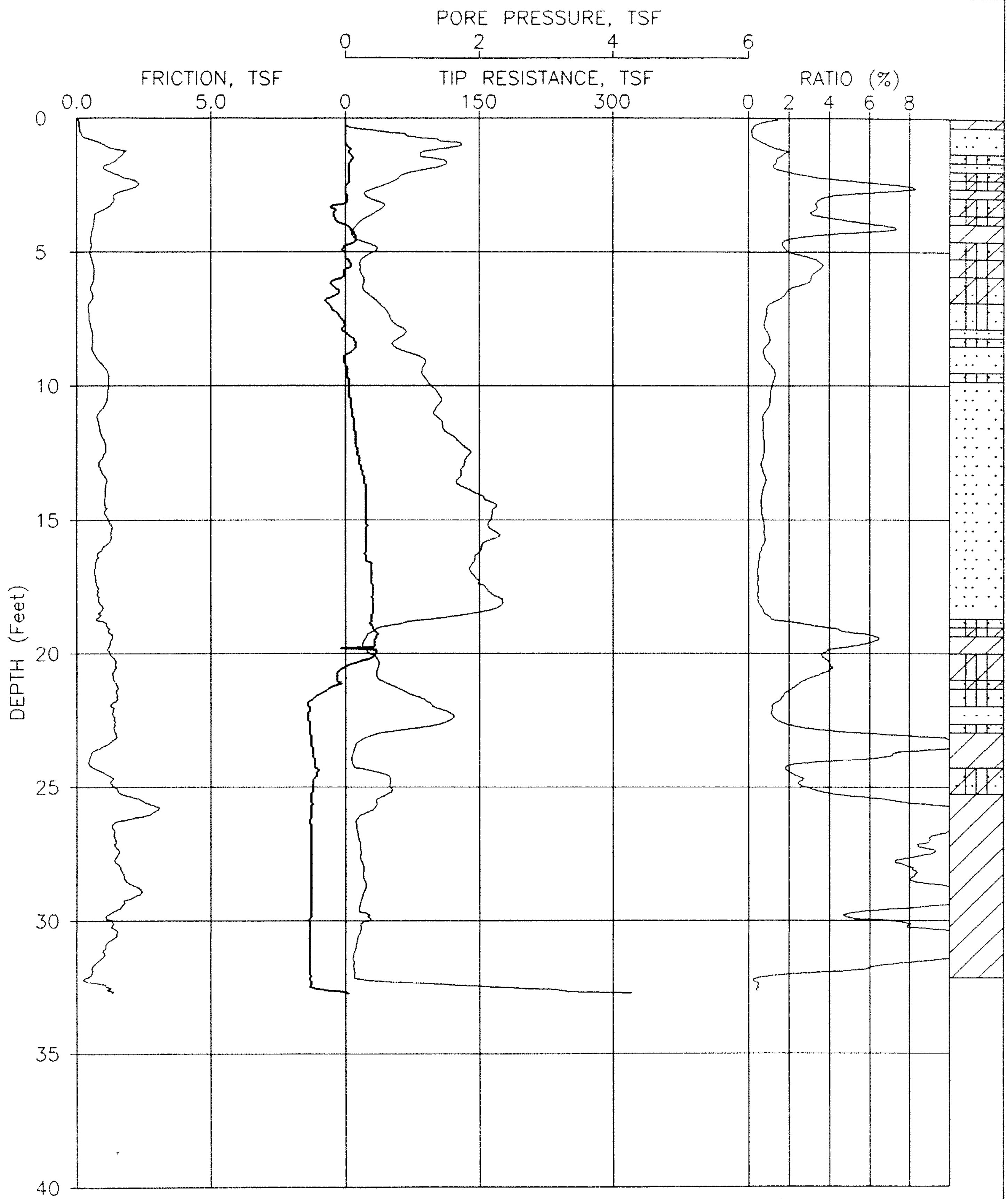
DATE: 10-09-1998

PLATE: 2 OF 2

FUGRO GEOSCIENCES, INC




JOB NUMBER: 0303-0253 CPT NUMBER: C4 DATE: 10-09-1998
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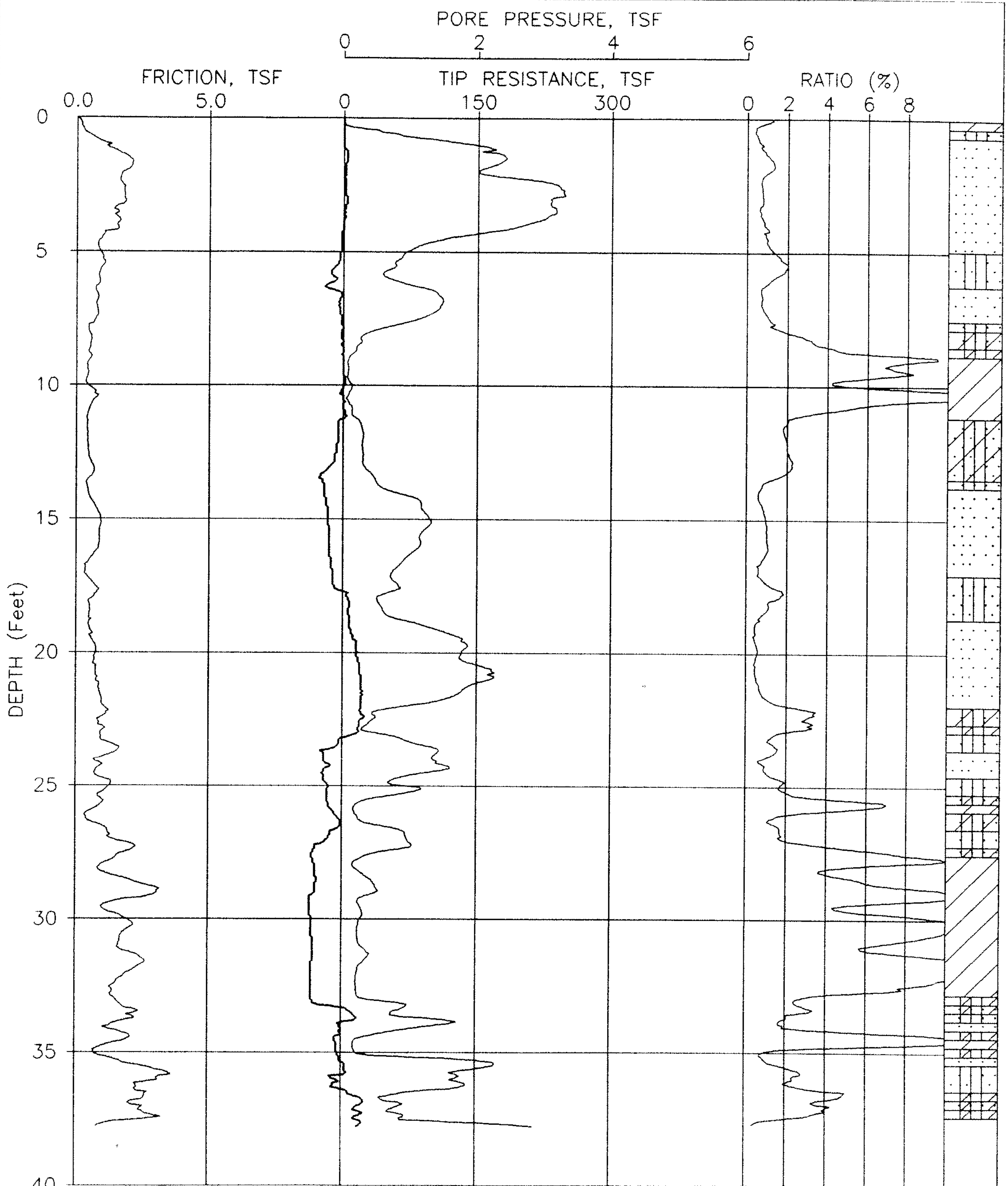
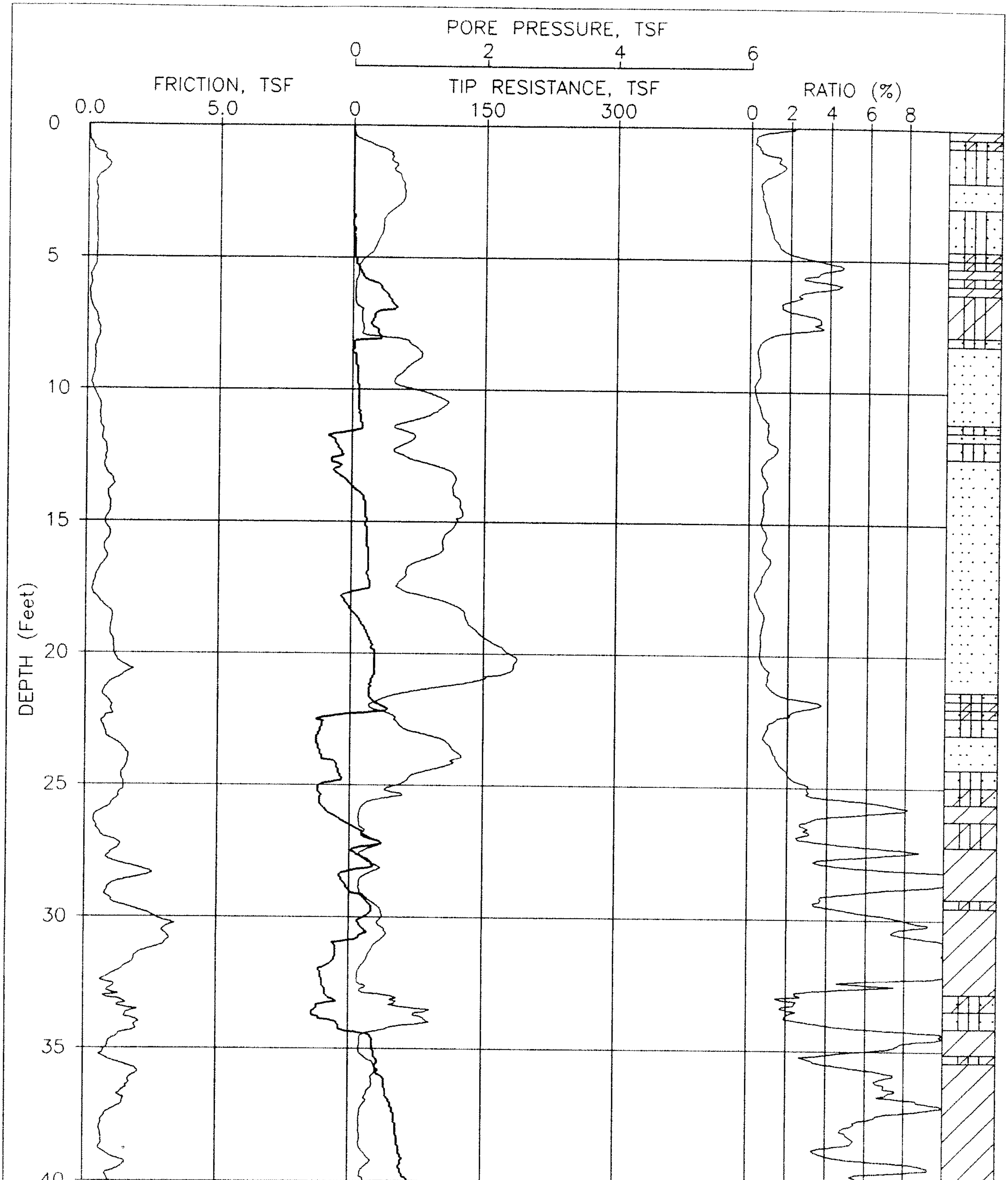



JOB NUMBER: 0303-0253 CPT NUMBER: C5 DATE: 10-09-1998
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW966 PLATE: 1 OF 1

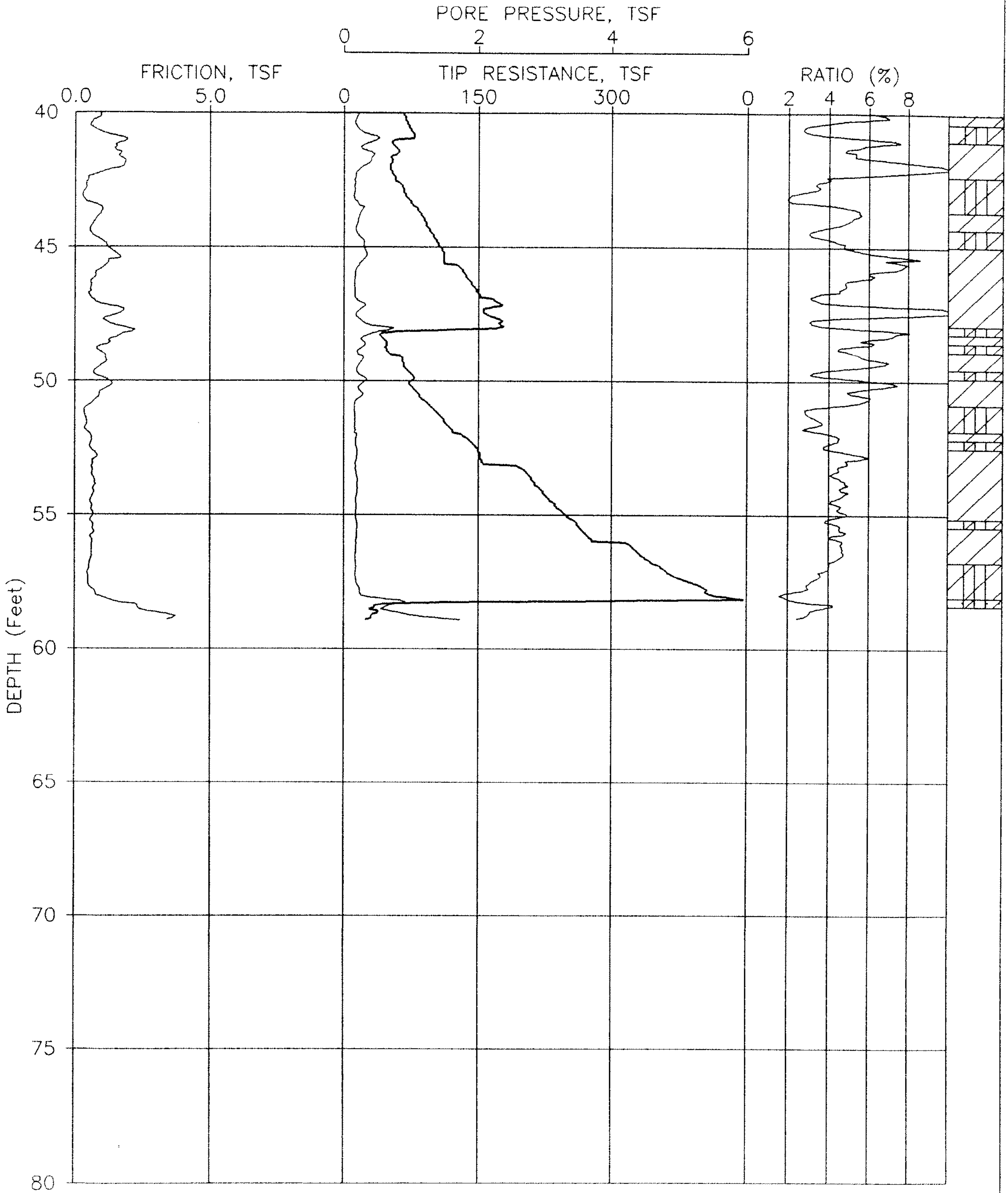
FUGRO GEOSCIENCES,INC




JOB NUMBER: 0303-0253 CPT NUMBER: C6 DATE: 10-09-1998

ELEVATION: 0.00 CONE NUMBER: F7.5CKEW966 PLATE: 1 OF 2

FUGRO GEOSCIENCES,INC




JOB NUMBER: 0303-0253 CPT NUMBER: C6 DATE: 10-09-1998
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW966 PLATE: 2 OF 2

FUGRO GEOSCIENCES,INC

March 17, 2017

Project No. 10113.002

Environmental Advisors
2390 East Orangewood Avenue, Suite 510
Anaheim, California 92806

Attention: Mr. Joshua Haskins

**Subject: Addendum to Preliminary Geotechnical Assessment Ball Road Basin Redevelopment, Anaheim, California**

Reference: Leighton Consulting, Inc., 2013, Preliminary Geotechnical Assessment Ball Road Basin Redevelopment, Anaheim, California, dated March 18, 2013.

Based on our review of the referenced geotechnical report, it is our professional opinion that the conclusions, findings and recommendations in the referenced geotechnical report remain applicable.

We appreciate the opportunity to be of continued service on this project. If you have any questions regarding this addendum, please contact the undersigned at ***(866) LEIGHTON***; specifically at the phone extensions or e-mail as listed below.

Respectfully submitted,

LEIGHTON CONSULTING, INC.

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JR/DJC/lr

Distribution: (1) Addressee