GEOTECHNICAL INVESTIGATION
ODOR CONTROL DESIGN AT
11TH STREET FACILITY
WBS NO. R-000020-0010-3
HOUSTON, TEXAS

Report No. 1140200501

Reported to:

ALAN PLUMMER ASSOCIATES, INC.

Houston, Texas

Reported by:

GEOTEST ENGINEERING, INC.

Houston, Texas

Key Map No. 492 A

GEOTEST ENGINEERING, INC.

Geotechnical Engineers & Materials Testing

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Report No. 1140200501
December 1, 2014

Mr. William C. Rackley, P.E.
Alan Plummer Associates, Inc.
3100 Wilcrest Drive, Suite 270
Houston, Texas 77042

Reference: **Geotechnical Investigation**
Odor Control Design at 11th Street Facility
WBS No. R-000020-0010-3
Houston, Texas

Dear Mr. Rackley:

Presented herein is the final report of our geotechnical investigation for the referenced project. The preliminary boring logs were submitted to you on April 29, 2014. A draft report was submitted to you on May 8, 2014. This final report supersedes all previously submitted e-mails, transmittals, etc. for the referenced project. This study was authorized by Agreement for Consulting Services dated February 19, 2014 by accepting our proposal No. 1140343099, dated January 21, 2014.

We appreciate this opportunity to be of service to you. If you have any questions regarding the report or if we can be of further service to you, please call us.

Very truly yours,
GEOTEST ENGINEERING, INC.

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EXECUTIVE SUMMARY

A geotechnical investigation was conducted for Alan Plummer Associates, Inc. for the Odor Control Design at 11th Street Facility in Houston, Texas. This study was authorized by Agreement for Consulting Services, dated February 19, 2014 by accepting our Proposal No. 1140343099 dated January 21, 2014.

The 11th Street Facility is a former lift station that now contains a bio-trickling filter to treat air from the nearby tunnel. The project includes upgrading the odor control facilities at this location, which will include demolition of the existing filter vessels and fans and replacing them. The proposed bio-trickling filter vessels will be 12.5 ft in diameter, 30 ft tall and have an operational weight of 49,100 lbs each (two vessels total).

This study included coring the existing concrete slab at one (1) location, drilling and sampling a total of two (2) soil borings to a depth of 40 feet, performing laboratory tests on samples recovered from borings, performing engineering analyses and preparing a geotechnical report.

The principal findings and conclusions developed from this investigation are summarized below:

- The existing slab at coring C-1 consists of 12.5 inches of concrete.

- The subsurface conditions as encountered in borings B-1 and B-2 consists of medium stiff to hard gray, brown, reddish brown, yellowish brown and gray lean clay, lean clay with sand, sandy lean clay and fat clay to a depth of 40 feet, the termination depth of the borings. Medium dense to dense brown and gray and reddish brown sandy silt and silt was encountered between depths of 31 to 33 feet and 20 to 22 feet in borings B-1 and B-2, respectively. Fill material consisting of medium stiff to stiff lean clay and silty sand was encountered in boring B-1 to a depth of 2 feet below the existing ground.

- Groundwater was encountered at a depth of 40 feet in borings B-1 and B-2. The groundwater level measured 20 minutes after the first water level encountered ranged from 31 to 34 feet in these borings.

- The foundation recommendations for the proposed vessels and fans and the settlement analysis are presented in Section 5.0 of this report.

1.0 INTRODUCTION

1.1 General

The City of Houston selected Alan Plummer Associates, Inc. to perform engineering services for the design and construction of the Odor Control Design at 11th Street Facility in Houston, Texas. Alan Plummer Associates, Inc. retained Geotest Engineering, Inc. as part of design team to perform geotechnical investigation for the above project.

1.2 Authorization

This study was authorized by Alan Plummer Associates, Inc. agreement for consulting services dated February 19, 2014 by accepting our Proposed No. 1140343099 dated January 21, 2014.

1.3 Location and Description of the Project

The project includes upgrading the odor control facilities at this location, which will include demolition of the existing filter vessels and fans and replacing them. The proposed bio-trickling filter vessels will be 12.5 ft in diameter, 30 ft tall and have an operational weight of 49,100 lbs each (two vessels total). Based on the provided information, the new vessels will be supported on existing concrete pad. A Vicinity Map is presented on Figure 1.

1.4 Purpose and Scope

The purposes of this study are to explore the subsurface conditions at the proposed site and develop geotechnical recommendations pertinent to the design and construction of the new vessels placed on existing concrete pad, two larger fans on new concrete pads, duct work and control panel. The scope of work consists of the following tasks:

- Performed coring in the existing concrete slab.

- Drilled and sampled two (2) 40-foot deep borings.

- Performed appropriate laboratory tests including consolidation tests on selected representative soil samples to determine the physical and strength properties and consolidation characteristics of the soils.

- Performed engineering analyses to develop the geotechnical recommendations for the proposed concrete pad foundation and backfill and groundwater control for the duct bank and construction considerations, if any.

- Prepared a geotechnical report including field and laboratory data, and engineering recommendations.

2.0 FIELD EXPLORATION

Subsurface conditions were explored by drilling and sampling two (2) borings designated as B-1 and B-2, each to a depth of 40 feet. The borings were drilled with a truck-mounted rotary drilling rig. The concrete coring was performed in the existing slab to verify the thickness. The approximate locations of borings and coring are shown on Figure 2, Plan of Borings.

Samples were obtained continuously to 20-foot depth and at 5-foot intervals thereafter. Samples of cohesive soils were obtained with a 3-inch diameter thin-walled tube sampler in general accordance with ASTM Method D 1587 and samples of cohesionless soils were obtained with a 2-inch split barrel sampler in general accordance with ASTM D 1586. Each sample was removed from the sampler in the field, carefully examined and logged by an experienced soils technician. Suitable portions of each sample were sealed and packaged for transportation to Geotest's laboratory. The shear strength of cohesive soil samples was estimated by use of a calibrated pocket penetrometer in the field. Driving resistance of split-barrel samples were recorded as "blows per foot" on the boring logs. All the borings were grouted with cement-bentonite grout after completion of drilling and obtaining water level measurements.

Detailed descriptions of the soils encountered in the borings are given on the boring logs presented on Figures A-1 and A-2 in Appendix A. The coring log was presented on Figure A-3 in Appendix A. A key to the symbols and terms used on the boring logs is given on Figure A-4 in Appendix A.

Groundwater level observations were made at each boring location during field investigation. The results of these observations are noted on the boring logs.

3.0 LABORATORY TESTS

The laboratory testing program was designed to evaluate the pertinent physical properties, and shear strength and consolidation characteristics of the subsurface soils. Classification tests were performed on selected samples to aid in soil classification.

The undrained shear strength of selected cohesive samples was estimated by unconsolidated-undrained (UU) triaxial compression (ASTM D2850) tests. The results of UU triaxial compression are plotted on the boring logs as solid squares. The shear strength of cohesive samples was measured in the field with a calibrated hand pocket penetrometer and also in the laboratory with a Torvane. The shear strength values obtained from the penetrometer and Torvane are plotted on the boring logs as open circles and triangles, respectively.

Measurements of moisture content and dry unit weight were taken for each UU triaxial compression test sample. Moisture content (ASTM D 2216) measurements were also made on other samples to define the moisture profile at each boring location. The liquid and plastic limit tests (ASTM D 4318) and percent passing No. 200 sieves (ASTM D 1140) were performed on appropriate samples.

Two (2) one-dimensional consolidation tests, with a hysteresis loop and a measured final rebound, were performed on selected samples in accordance with ASTM D 2435.

The results of these and other applicable classification tests are plotted or summarized on the boring logs presented on Figures A-1 and A-2 in Appendix A. Consolidation tests results are presented on Figures B-1 and B-2 in Appendix B.

4.0 GENERAL SUBSURFACE CONDITIONS

4.1 Geology

The project area lies in the Beaumont Formation. The clays and sands of the Beaumont Formation are over-consolidated as a result of desiccation from frequent rising and lowering of the sea level and the groundwater table. Consequently, clays of this formation have moderate to high shear strength and relatively low compressibility. The sands of the Beaumont Formation are typically very fine and often silty. Further, there is occasional evidence in the Houston area of the occurrence of cemented material (sandstone and siltstone) deposits within the Beaumont Formation.

4.2 General Fault Information

A review of information in the Geotest library, relating to known surface and subsurface geologic faults in the general area of the project site, was undertaken. The information consists of U.S. Geological Survey maps, open file reports and information contained in our files relating to geologic faults in the project area.

Based on the available information, no documented fault crosses the project site. The nearest documented fault is Pecore Fault and is located approximately 4000 feet southeast of the project site. Hence, Phase I Geologic Fault Assessment is not required for the project.

4.3 Existing Concrete Slab

The existing concrete slab, as obtained in coring C-1, is about 12.5 inches.

4.4 Soil Stratigraphy

The subsurface soils as obtained from borings B-1 and B-2 and as shown on boring log profile presented on Figure 3, consists of medium stiff to hard gray, brown, reddish brown, yellowish brown and gray lean clay, lean clay with sand, sandy lean clay and fat clay to a depth of 40 feet, the termination depth of the borings. Medium dense to dense brown and gray and reddish brown sandy silt and silt was encountered between depths of 31 to 33 feet and 20 to 22 feet in borings B-1 and B-2, respectively. Fill material consisting of medium stiff to stiff lean clay and silty sand was encountered in boring B-1 to a depth of 2 feet below the existing ground.

The lean clay, lean clay with sand and sandy lean clay are of medium plasticity with liquid limits ranging from 31 to 39 and plasticity indices ranging from 10 to 19. The fat clay is of very high plasticity with a liquid limit of about 88 and a plasticity index of about 57. The fines content (passing number 200 sieve) of lean clay, lean clay with sand and fat clay ranges from 73 to 100 percent. The percent fines of sandy lean clay is about 65 percent. The percent fines of silt is about 96 percent and percent fines of sandy silt is about 58 percent.

4.5 Groundwater

Groundwater was encountered at a depth of 40 feet in borings B-1 and B-2. The groundwater level measured 20 minutes after the first water level encountered ranged from 31 to 34 feet in these borings.

5.0 GEOTECHNICAL RECOMMENDATIONS

5.1 General

The 11th Street Facility is a former lift station that now contains a bio-trickling filter to treat air from the nearby tunnel. The project includes upgrading the odor control facilities at this location, which will include demolition of the existing filter vessels and fans and replacing them. The proposed bio-trickling filter vessels will be 12.5 ft in diameter, 30 ft tall and have an operational weight of 49,100 lbs each (two vessels total).

5.1.1 Vessel Foundation Recommendations (Existing Concrete Pad). It is our understanding that the proposed vessels are planned to be supported on the existing 24' x 36' concrete pad. Based on the coring obtained from the existing slab, the existing slab thickness is about 12.5 inches.

Based on the surficial soil conditions revealed by the soil borings, an allowable soil bearing pressure for the existing 24-ft by 36-ft concrete pad placed at ground surface was estimated to be 1,800 psf for total dead and live loads and 1,200 psf for dead and sustained live loads. The allowable bearing pressures contain a safety factor of 2 for total loads and 3 for dead and sustained live loads.

5.1.2 Subgrade Preparation (New Slab for Fans). Based on the subsurface conditions revealed by the borings B-1 and B-2, the existing soils consists of essentially medium stiff to hard and medium plasticity lean clays. Based on the soil conditions, it is recommended that the fan slabs may be supported on lime stabilized compacted fill material.

The site preparation for the proposed new slab for fans should consist of stripping, proof-rolling, and stabilization. The following procedures for the site preparation are recommended:

Strip the surficial soils to a suitable depth to remove all surficial vegetation. In isolated areas where soft, compressible, or very loose soils are encountered, additional stripping may be required.

Stripping should extend to a minimum of 6 feet beyond the edge of the proposed tank.

1. After stripping, the exposed surface should be proof-rolled with a minimum of 3 passes of a 30-ton pneumatic-tired roller or a partially loaded truck utilizing a tire pressure of approximately 90 psi. If rutting develops, the tire pressure should be reduced. The purpose of the proof-rolling operation is to identify any underlying zones or pockets of soft soils so these weak materials can be removed and replaced.

   The upper 6 inches of the exposed soils should be stabilized with at least 5% hydrated lime (by dry soil weight) and place it back in compacted lifts. Lime stabilization of select fill subgrade should be performed in accordance with City of Houston Standard Specification Section 02336, “Lime-Stabilized Subgrade”. The actual percentage of lime should be determined by laboratory tests at the time of construction.

5.1.3 Concrete Pad Supporting Fans (New Slab). Based on subsurface conditions revealed by borings (B-1 and B-2), the site soils consist of medium plasticity lean clays. The foundation for fans may be supported on a concrete pad on a lime stabilized subgrade. The concrete pad may be designed for an allowable (net) bearing pressure 1,800 psf for total loads or 1,000 psf for dead and sustained live loads, whichever results in a larger pad area. The allowable bearing pressures contain a safety factor of 2 for total loads and 3 for dead and sustained live loads.

5.1.4 Foundation Settlement. The settlement of a foundation for any structure depends on its size, shape, depth, and more particularly on the magnitude of the sustained load imposed at the base of the concrete pad and on the compressibility of the foundation soils. Based on the loading conditions (approximately 650 psf contact pressure over the 24-ft by 36-ft container pad including the operation weight of 100,000 lb) and consolidation characteristics of very stiff clays, settlements were estimated for the vessel foundation ranging from 0.4 to 0.8 inches.

Should the piping of the tanks not be able to accommodate the estimated settlement, flexible pipe connections should be used to withstand the anticipated settlements.

It should be pointed out that the performance of the foundation system will be sensitive to construction quality as well as soil-structure interaction. Care should be taken to insure that the soils at bearing depths are not disturbed during excavation operations. Actual settlements can vary as much as 20% of the estimated values.

5.1.5 Site Preparation and Structural Fill Requirements. It is recommended that any equipment and material loads should be kept away at a minimum clear distance of 20 feet from the existing tank at all times.

After site clearing, stripping and grubbing to remove vegetation, trees and tree stumps (if any) and topsoil and performing over excavation to remove weak sandy clay soils as mentioned in previous section. The exposed surface should be proof-rolled to detect excessively moist, soft or otherwise unsuitable soil conditions. Proof-rolling should be done after a suitable period of dry weather to avoid degrading otherwise acceptable subgrade.

The select fill should consist of sandy lean clay or lean clay with a plasticity index between 8 and 20 and a liquid limit of less than 40. The onsite medium plasticity lean clay soils, which meet above criteria, are suitable for structural fill.

All excavated areas should be adequately protected from surface run-off water and appropriate measures of providing positive surface drainage should be adopted to prevent ponding of water in and around the excavations. Additional measures, such as temporary ditches lead to a sump pit with pumps, may be provided to prevent softening of exposed soils due to ponded water. Excavations should be sloped, shored or braced in accordance with OSHA's excavation safety standard, and applicable City of Houston requirements.

The finished grade around the tank should be properly graded to prevent ponding of water.

<u>5.1.6 Foundation Construction.</u> When forming the foundation, the steel should be placed and the footing pored the same day of excavation. Seepage into excavation due to high groundwater level is not expected except during significant rainfall and where surface soils are sandy.

Minor variation in soil stratigraphy is known to occur in this area. It is recommended that the footing excavation be inspected by a geotechnical engineer or experienced engineering technician or owner's representative prior to placing concrete. The excavation should be checked to verify that (a) the footing has been constructed to the specified dimensions and is placed at the correct depth and into appropriate stratum with adequate bearing capacity as recommended in this report, and (b) the loose cuttings, and any soft-compressible materials have been removed from the bottom of the excavation. A seal slab of lean concrete should be placed if concrete placement is delayed for more than 6 hours after excavation or sooner if rain is forecasted. No footing concrete should be placed without the prior approval of the Project Engineer or Owner's Representative.

<u>5.1.7 Filling Test.</u> It is recommended that the tank be filled in the stages of 25% full, 50% full, 75% full and then 100% full. Each stage should be left for a period of about 24 to 48 hours and the settlement should be monitored for each stage. After 100% full, the tank should remain filled with water for about 4 to 5 days.

<u>5.1.8 Performance Monitoring.</u> It is recommended that the performance of the foundation system be monitored whenever practical during the water testing. A minimum of four monitoring stations should be established on the edges of the footing and elevations be checked during initial water loading. If settlements are in excess of expected magnitudes or if differential movements are higher than specified values, the geotechnical engineer should be consulted along with the tank manufacturer as to the next course of action. Geotest should be retained to assist you in the monitoring effort.

5.2 Proposed Duct Bank

We understand that the proposed duct bank will be constructed by open cut method of construction. The maximum depth of the duct bank will be less than 10 feet. The recommendations for the geotechnical parameters for open-cut trench excavations were developed and are provided in Table 2. For design, the groundwater should be assumed at surface, since this condition will exist after a heavy rainfall or flooding.

5.2.1 Trench Stability. For trench excavation, it is essential to maintain the stability of the sides and base and not to disturb the soil below the excavation grade. This is necessary to prevent any damage to adjacent facilities as a result of either vertical or lateral movements of the soil. In addition, a satisfactory excavation procedure must include an adequate construction dewatering system to lower and maintain the water level at least 3 to 5 feet below the lowest excavation grade. This will minimize the potential for softening or “boiling” of the base support soil.

The trench excavation may be shored, laid back to a stable slope (as recommended by OSHA) or some other equivalent means used to provide safety for workers and adjacent structures. The excavating and trenching operations should be in accordance with OSHA Standards, OSHA 2207, Subpart P (latest revision).

- Excavation Shallower Than 5 Feet – Protection may not be required when excavations that are less than 5 feet deep and an examination of the ground by a competent person provides no indication of potential cave-in. When any indication of hazardous ground movement or potential cave-in is anticipated during construction, adequate. protective system should be provided for all excavation even that excavations are shallower than 5 feet.

- Excavation Deeper Than 5 Feet – Excavations that are deeper than 5 feet (regardless of the type of soil encountered) should be sloped, shored, shielded or provided with some other appropriate means of protection where workers might be exposed to moving ground or cave-ins. The slopes and shoring should be in accordance with OSHA requirements. The following items provide design criteria for trench stability.

(i) OSHA Soil Type. Based on the soil conditions revealed by the geotechnical borings, OSHA's soil type "C" should be used for the determination of allowable maximum slope and/or the design of a shoring system. For shoring deeper than 20 feet, an engineering evaluation is required.

(ii) Trench Support Earth Pressure. Trench support earth pressure diagram was developed based on the subsurface conditions indicated by our field and laboratory investigations. The earth pressure diagram developed for trench support is presented on Figure 5. The pressure diagram can be used for the design of temporary trench bracing. Design of trench boxes for resisting lateral earth pressures can be based on an equivalent fluid pressure of 91 pcf. The effects of any surcharge loads at the ground surface should be added to the computed lateral earth pressures. A surcharge load, q, will typically result in a lateral load equal to 0.5q. The computation of the equivalent fluid pressure assumes that water level is at ground surface, since these conditions may exist after a heavy rain or flooding.

(iii) Bottom Stability. In braced cuts, if tight sheeting is terminated at the base of the cut, the bottom of the excavation can become unstable under certain conditions. The stability of the trench bottom is governed by the shear strength of the soils and by the differential hydrostatic head. For cuts in cohesive soils (such as lean clays) as encountered in all the borings, stability of the bottom can be evaluated in accordance with the procedure outlined on Figure 6.

5.2.2 Lateral Earth Pressure Diagram. The pressure diagram provided on Figure 5 can be used for the design of braced excavation.

5.2.3 Excavation Dewatering. Excavations for the utilities along the proposed alignment may encounter groundwater seepage depending upon groundwater conditions at the time of construction and the location and depth of excavation. For cohesive soils such as lean clay and lean clay with sand as encountered in borings, groundwater may be managed by collection in trench bottom sumps for pumped disposal. It is recommended that the contractor should verify groundwater level at the time of construction and should provide an adequate groundwater control, where required.

5.2.4 Bedding and Backfill for Duct Bank. In general, excavation and backfill for the proposed duct bank should be designed and constructed in accordance with the City of Houston Standard Specification Section 02317, "Excavation and Backfill for Utilities."

6.0 PROVISIONS

The subsurface conditions and the foundation recommendations information contained in this report are based on the test borings made at the time of drilling at specific locations. However, some variation in soil conditions may occur between the boring locations. Should any subsurface conditions other than those described in our boring logs be encountered, Geotest should be immediately notified so that further investigation and supplemental recommendations can be provided. The depth of the groundwater level can be expected to vary with environmental variations such as frequency and magnitude of rainfall.

The analysis and recommendations submitted in this report are based upon the data obtained from subsurface explorations made at the time test borings were drilled at specific locations and the results of laboratory tests on selected soil samples from the test borings. The stratification lines on the log of borings represent the approximate boundaries between soil types; however, the transition between soil types may be more gradual than depicted.

This report has been prepared for the exclusive use of Alan Plummer Associates, Inc., specifically for the design and construction of the Odor Control Design at 11th Street Facility in Houston, Texas. This report shall not be reproduced in whole or part without written permission of Geotest Engineering, Inc., Alan Plummer Associates, Inc. or City of Houston.

TABLES

TABLE 1
SUMMARY OF BORING INFORMATION

Boring No.	Boring Depth (feet)	Northing	Easting	Ground Surface * Elevation (feet)
B-1	40	13852327.09	3104193.69	51.3
B-2	40	13852364.10	3104192.68	51.60

Notes:

1. Survey information was provided by Alan Plummer Associates, Inc.

TABLE 2

GEOTECHNICAL DESIGN PARAMETER SUMMARY
OPEN-CUT EXCAVATION

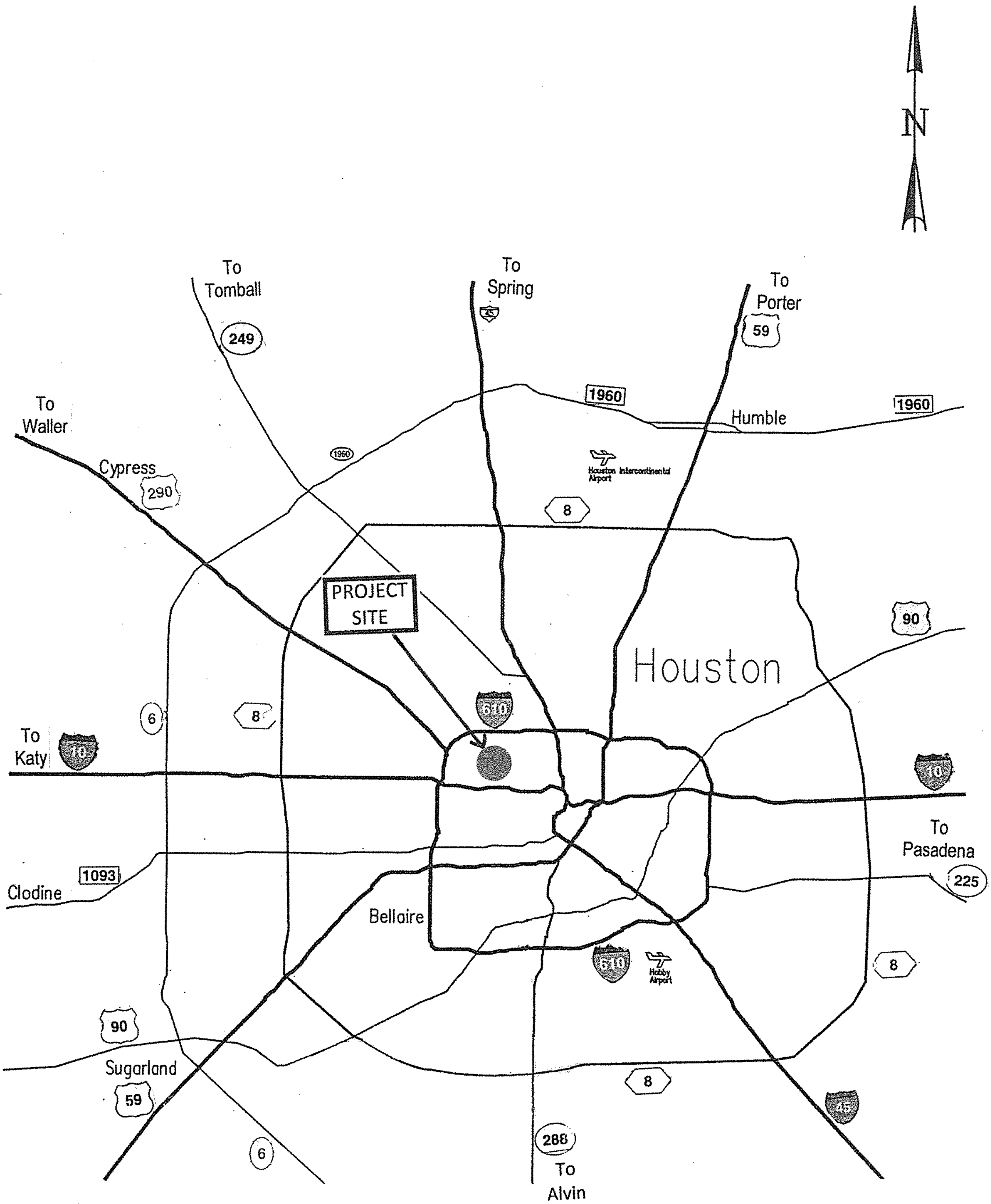
Alignment	Boring Nos.	Stratigraphic Unit	Range of Depths, ft	Wet Unit Weight, γ, pcf	Submerged Unit Weight, γ′, pcf	Undrained Cohesion, C, psf	Internal Friction Angle, ϕ, degree
Proposed Duct Bank	B-1 and B-2	Cohesive	0-10	120	60	1,200	--

Notes:

1. Cohesive soils include lean clay with sand.

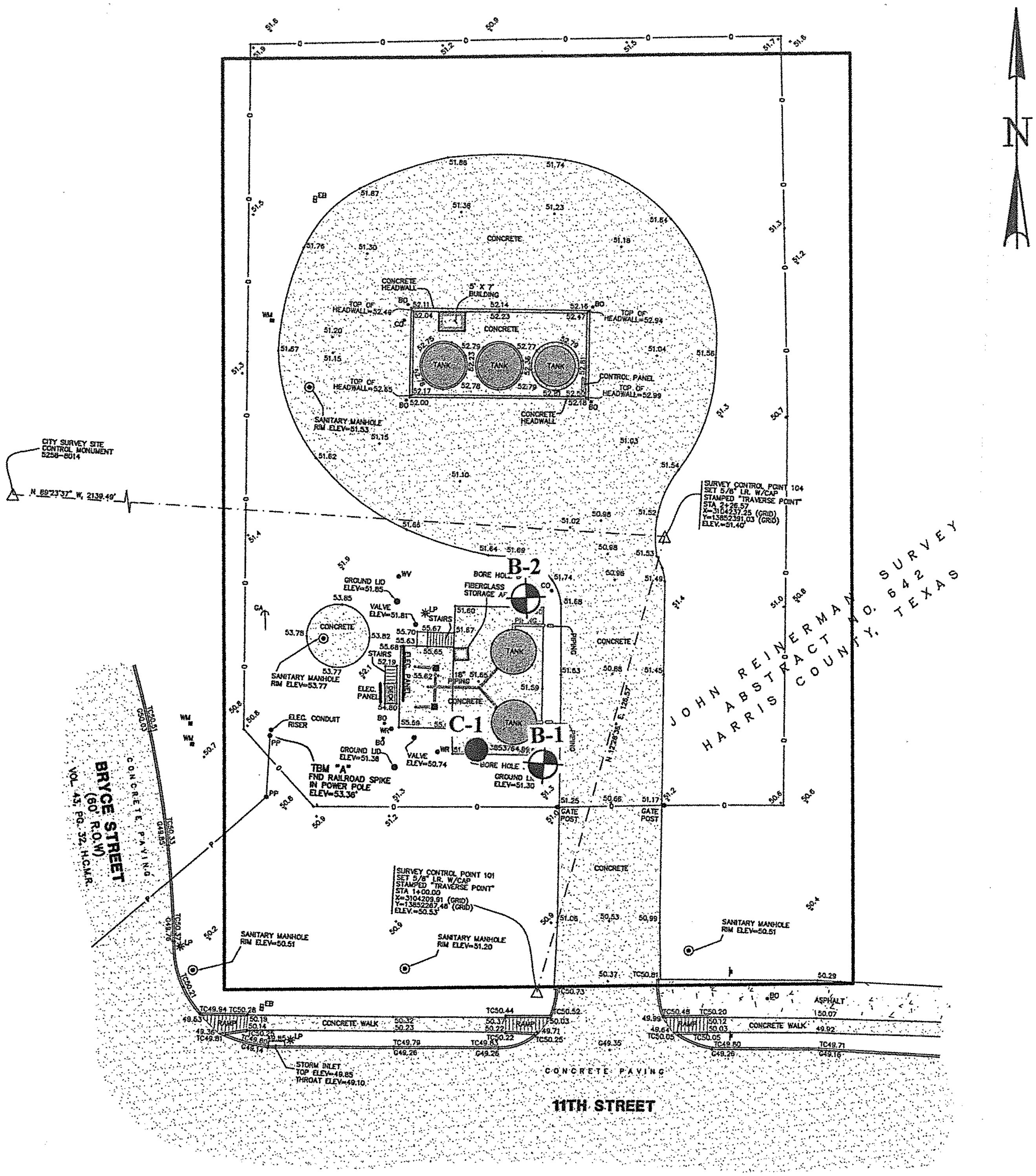
ILLUSTRATIONS

Job No. 1140200501



VICINITY MAP
(NOT TO SCALE)

Job No. 1140200501



ODOR CONTROL DESIGN AT 11TH STREET FACILTY WBS NO. R-000020-0010-3 HOUSTON, TEXAS

PLAN OF BORINGS

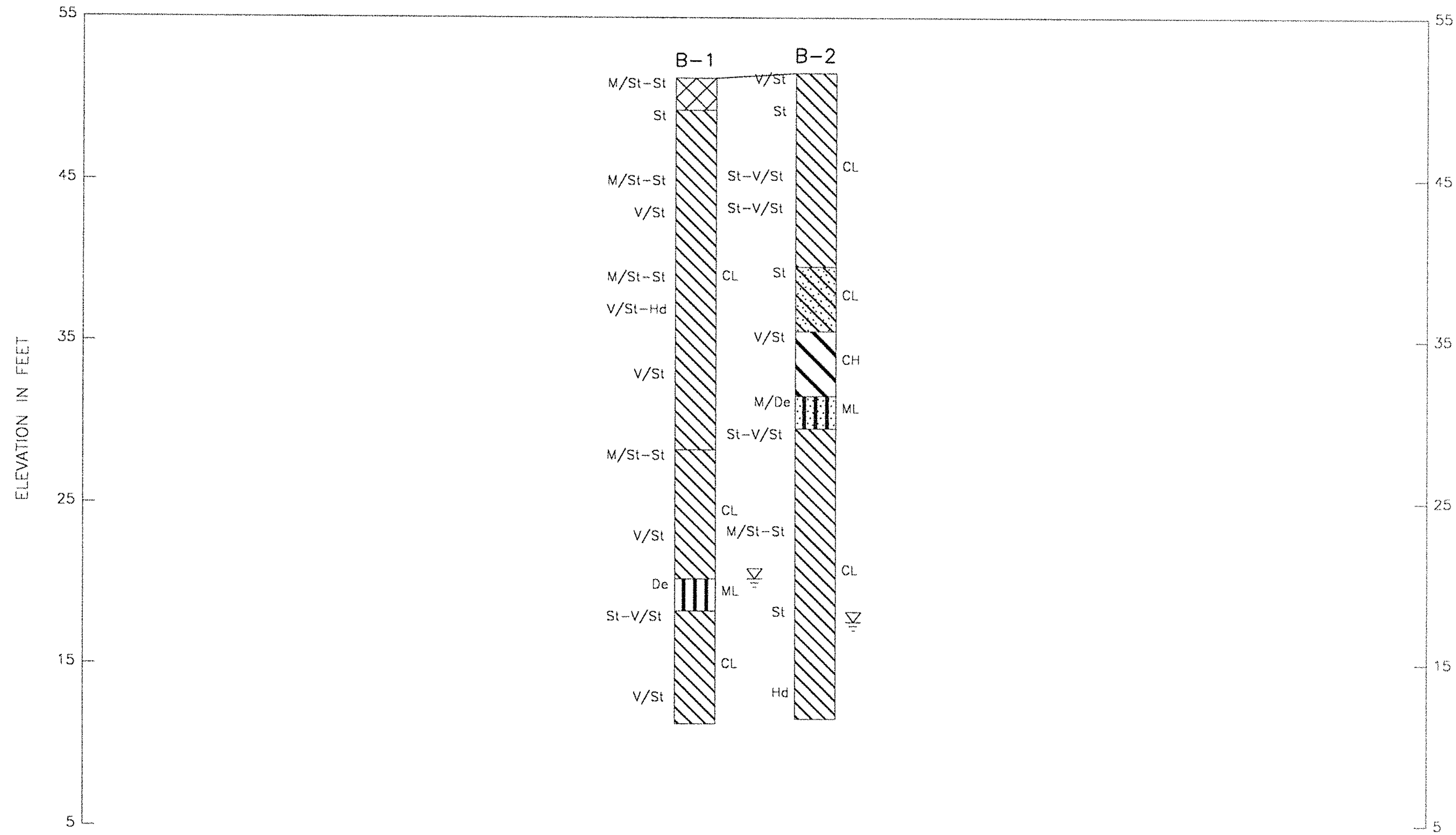
0 30 60 90 120

SCALE IN FEET

LEGEND

Boring

Coring



GENERAL NOTES:

1. See Figure 2 for approximate location of borings and profile section.
2. Data concerning subsurface conditions have been obtained at boring locations only. Actual conditions between borings may differ from the profile shown here.
3. See logs of boring for detailed description of soils encountered in each borehole.
4. See Figure 4 for symbols and abbreviations used on this profile.
5. Ground surface elevation at each boring location was based on survey data provided to us by Alan Plummer Associates, Inc.

BORING LOG PROFILE

ODOR CONTROL DESIGN AT 11TH STREET FACILITY

0 25 50 75 100

HORIZONTAL SCALE IN FEET

Job No. 1140200501

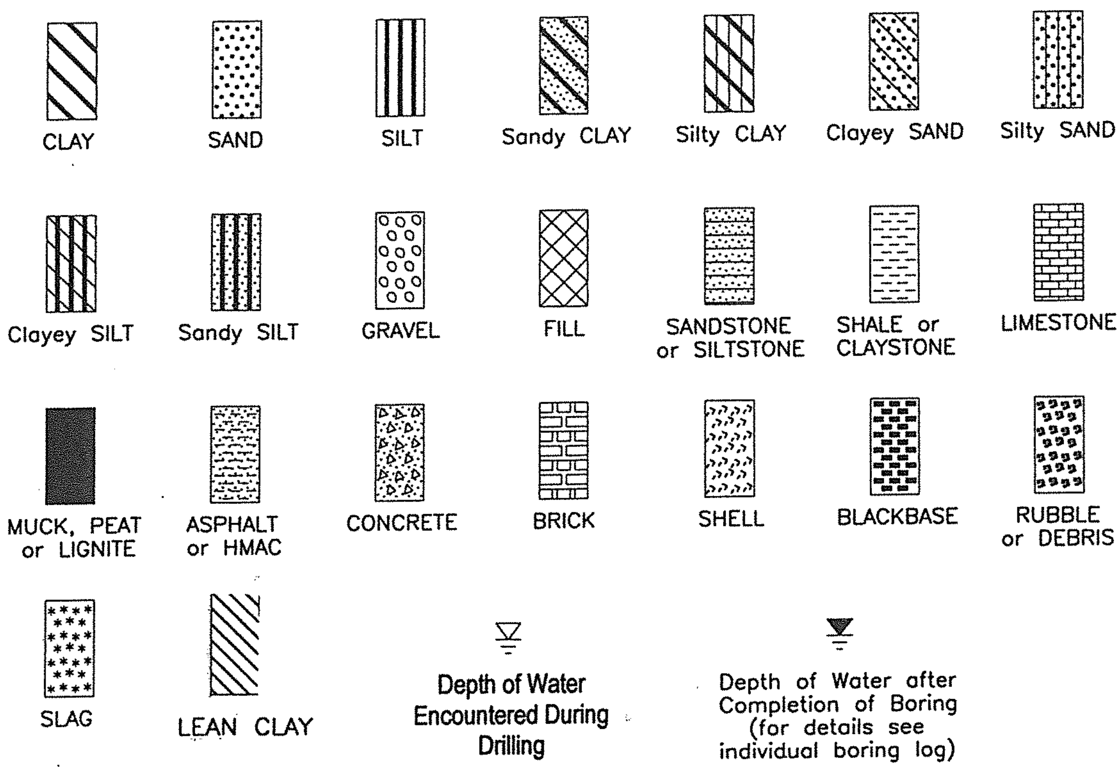
Geotest Engineering, Inc.

FIGURE 3

Job No. 1140200501

SYMBOLS AND ABBREVIATIONS USED ON BORING LOG PROFILE

LEGEND



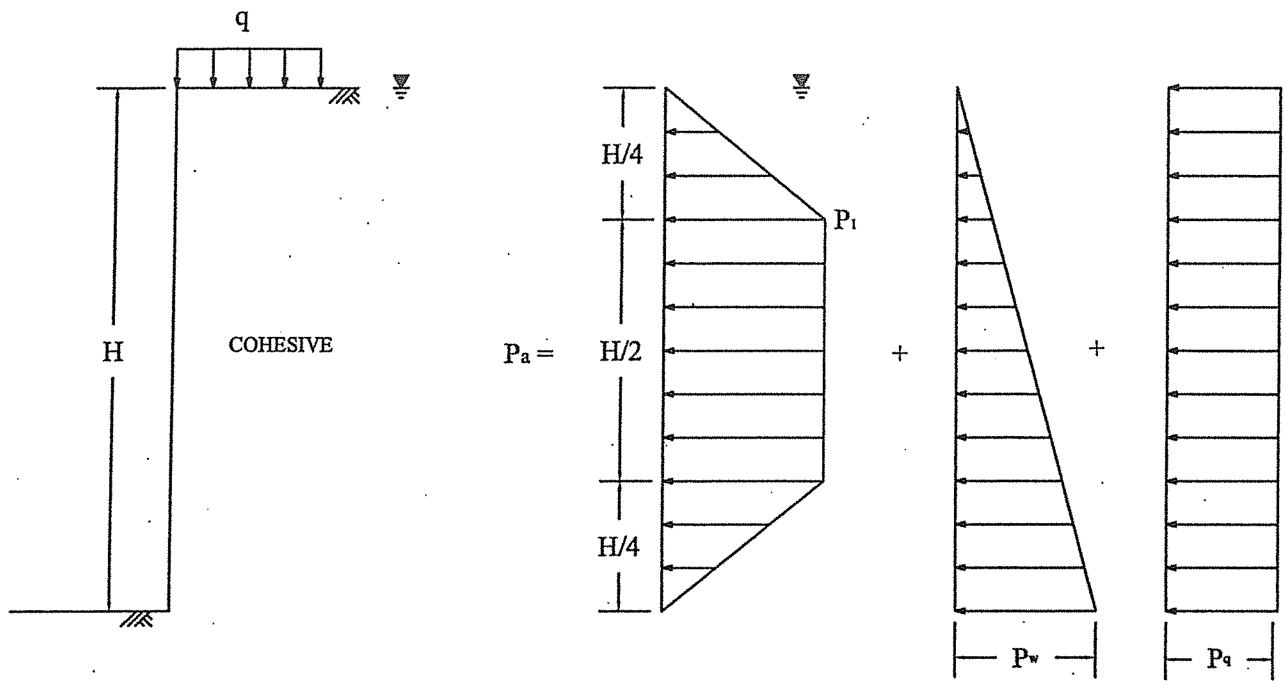
ABBREVIATIONS USED FOR CONSISTENCY/DENSITY

COHESIVE SOILS

V/So : Very Soft
So : Soft
Fm : Firm
M/St : Medium Stiff
St : Stiff
V/St : Very Stiff
Hd : Hard
V/Hd : Very Hard

COHESIONLESS SOILS

V/Lo : Very Loose
Lo : Loose
S/Co : Slightly Compact
Co : Compact
M/De : Medium Dense
De : Dense
V/De : Very Dense



TYPICAL SOIL PARAMETERS

See Table 2 for typical values of soil parameters

BRACED WALL

For $\gamma H/c \leq 4$

$P_1 = 0.3\ \gamma_c'\ H$
$P_w = \gamma_w\ H = 62.4\ H$
$P_q = 0.5\ q$

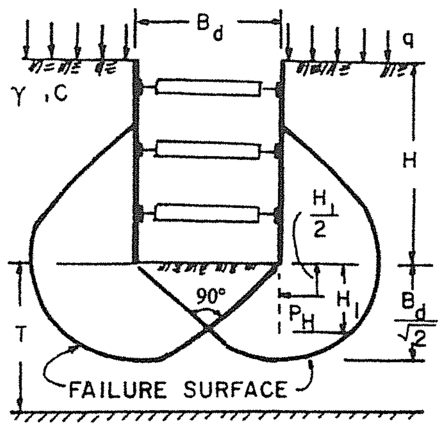
Where:

γ_c' = Submerged unit weight of cohesive soil, pcf;
γ_w = Unit weight of water, pcf;
q = Surcharge load at surface, psf;
P_a = Lateral pressure, psf;
P_1 = Active earth pressure, psf;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Depth of braced excavation, feet
c = Shear strength of cohesion soil, psf;

TRENCH SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL

CUT IN COHESIVE SOIL,
DEPTH OF COHESIVE SOIL UNLIMITED ($T > 0.7\ B_d$)
L = LENGTH OF CUT



If sheeting terminates at base of cut:

$$\text{Safety factor, } F_S = \frac{N_C C}{\gamma H + q}$$

N_C = Bearing capacity factor, which depends on dimensions of the excavation : B_d, L and H (use N_C from graph below)

C = Undrained shear strength of clay in failure zone beneath and surrounding base of cut

γ = Wet unit weight of soil (see Table 2)

q = Surface surcharge (assume q = 500 psf)

If safety factor is less than 1.5, sheeting or soldier piles must be carried below the base of cut to insure stability - (see note)

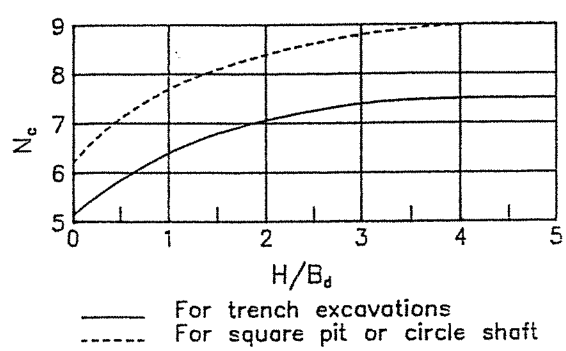
$$H_1 = \text{Buried length} = \frac{B_d}{2} \geq 5 \text{ feet}$$

Note : If soldier piles are used, the center to center spacing should not exceed 3 times the width or diameter of soldier pile .

Force on buried length, P_H:

If $H_1 > \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 0.7\ (\gamma HB_d - 1.4CH - \pi CB_d)$ in lbs/ linear foot

If $H_1 < \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 1.5H_1\ (\gamma H - \frac{1.4CH}{B_d} - \pi C)$ in lbs/ linear foot



STABILITY OF BOTTOM FOR BRACED CUT

APPENDIX A

LOG OF BORING NO. B-1

PROJECT : Odor Control Design at 11th Street Facility
WBS No. R-000020-0010-3
Houston, Texas

PROJECT NO. : 1140200501

LOCATION : N 13852327.09, E 3104193.69
See Plan of Borings (Figure 2)

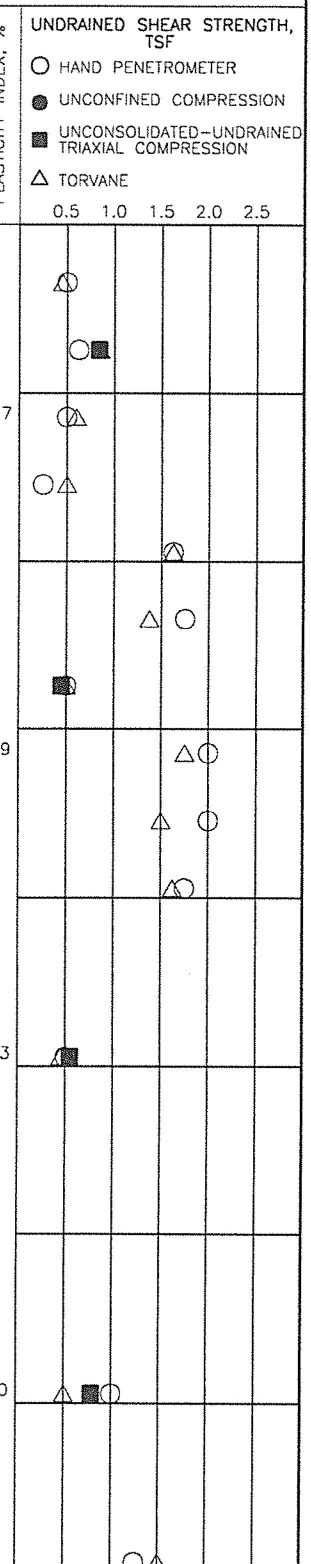
COMPLETION DEPTH : 40.0 FT.

SURFACE ELEVATION : 51.30 FT.

DATE : 02-28-14

SAMPLER : Shelby Tube/Split Spoon
DRY AUGER : 0.0 TO 40.0 FT.
WET ROTARY : -- TO -- FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
51.3	0	FILL: medium stiff to stiff brown lean clay w/grass and shell				18			
		-silty sand 10"-2'							
49.3		Stiff reddish brown LEAN CLAY (CL) w/sand			114	18			
	5	-medium stiff to stiff 6'-8'		80	99	20	36	19	17
		-very stiff yellowish brown and gray 8'-12'				20			
	10	-gray 10'-12' -w/ferrous stains 10'-14'				17			
		-medium stiff to stiff 12'-14'				14			
		-very stiff to hard 14'-18'			117	16			
	15	-gray 16'-18'		73		17	39	20	19
		-very stiff yellow and brown 18'-20'				15			
	20					14			
28.3		Medium stiff to stiff reddish brown LEAN CLAY (CL) w/silt seams							
	25			98	98	27	31	18	13
		-very stiff 28'-30'		97		27			
	30		30	99		23			
20.3		Dense reddish brown SILT (ML)	37	96		27			
18.3		Stiff to very stiff reddish brown and gray LEAN CLAY (CL) w/silt seams							
	35			98	102	26	32	22	10
		-very stiff 38'-40'							
11.3	40					29			



DEPTH TO WATER IN BORING :
∇: FREE WATER 1st ENCOUNTERED AT 40.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 31.0 FT.
HOLE OPEN TO 40.0 FT. AT END OF DRILLING.

Geotest Engineering, Inc.

FIGURE A-1

LOG OF BORING NO. B-2

PROJECT : Odor Control Design at 11th Street Facility
WBS No. R-000020-0010-3
Houston, Texas
PROJECT NO. : 1140200501

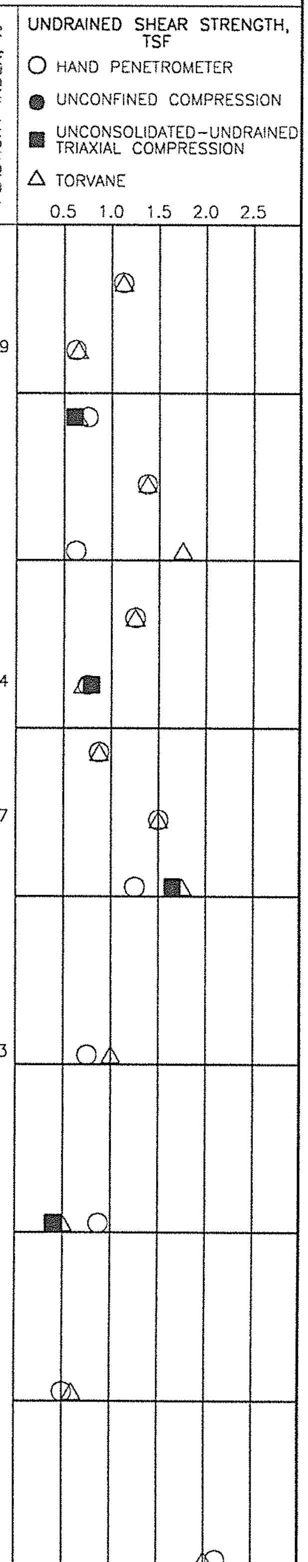
LOCATION : N 13852364.10, E 3104192.68
See Plan of Borings (Figure 2)
COMPLETION DEPTH : 40.0 FT.

SURFACE ELEVATION : 51.60 FT.
DATE : 02-28-14

SAMPLER : Shelby Tube/Split Spoon
DRY AUGER : 0.0 TO 40.0 FT.
WET ROTARY : -- TO -- FT.

ELEVATION, FEET	DEPTH, FEET	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
51.6	0	Very stiff gray LEAN CLAY (CL) w/sand -w/grass roots 0'-2' -stiff 2'-6' -yellow and gray 4'-12' -stiff to very stiff 8'-10'				16			
				75		17	35	16	19
	5				114	17			
						16			
	10					16			
						14			
39.6		Stiff yellowish brown and gray SANDY LEAN CLAY (CL) w/sand seams		65	116	15	31	17	14
	15					17			
35.6		Very stiff gray and brown FAT CLAY (CH)		99	84	39	88	31	57
					96	35			
31.6	20	Medium dense brown and gray SANDY SILT (ML)	12	58		14			
29.6		Stiff to very stiff reddish brown LEAN CLAY (CL)		100		23	32	19	13
	25	-medium stiff to stiff 28'-30'			99	25			
	30	-stiff 33'-35'				25			
	35	-hard 38'-40'				24			
11.6	40								

UNDRAINED SHEAR STRENGTH, TSF



DEPTH TO WATER IN BORING :
∇: FREE WATER 1st ENCOUNTERED AT 40.0 FT. DURING DRILLING; AFTER 20.0 MIN. AT 34.0 FT.
HOLE OPEN TO 40.0 FT. AT END OF DRILLING.

Geotest Engineering, Inc.

FIGURE A-2

LOG OF BORING NO. C-1

PROJECT : Odor Control Design at 11th Street Facility
WBS No. R-000020-0010-3
Houston, Texas

PROJECT NO. : 1140200501

LOCATION : See Plan of Borings (Figure 2)

COMPLETION DEPTH : 2.0 FT.

SURFACE ELEVATION : Existing Grade

DATE : 02-28-14

SAMPLER : Shelby Tube/Split Spoon
DRY AUGER : 0.0 TO 2.0 FT.
WET ROTARY : -- TO -- FT.

UNDRAINED SHEAR STRENGTH, TSF
○ HAND PENETROMETER
● UNCONFINED COMPRESSION
■ UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION
△ TORVANE
0.5 1.0 1.5 2.0 2.5

ELEVATION, FEET	DEPTH, FEET	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	STANDARD PENETRATION TEST, BLOWS PER FOOT	PERCENT PASSING NO. 200 SIEVE	DRY UNIT WEIGHT, PCF	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %
	0–2			12.5" Concrete							

DEPTH TO WATER IN BORING :
NO GROUNDWATER ENCOUNTERED DURING DRILLING.
HOLE OPEN TO 2.0 FT. AT END OF DRILLING.

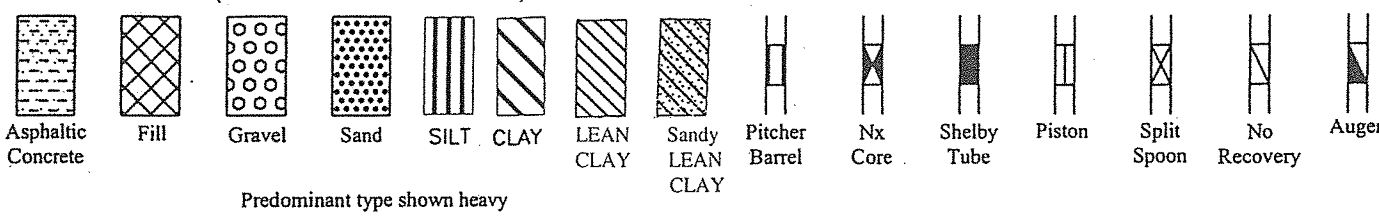
Geotest Engineering, Inc.

FIGURE A-3

SYMBOLS AND TERMS USED ON BORING LOGS

SOIL TYPES
(SHOWN IN SYMBOL COLUMN)

SAMPLER TYPES
(SHOWN IN SAMPLES COLUMN)



Predominant type shown heavy

TERMS DESCRIBING CONSISTENCY OR CONDITION

Basic Soil Type	Density or Consistency	Standard Penetration Resistance, (1) Blows/ft.	Unconfined Compressive Strength (q_u), (2) Tons/sq. ft.
Cohesionless	Very loose	Less than 4	Not applicable
	Loose	4 to <10	Not applicable
	Medium dense	10 to <30	Not applicable
	Dense	30 to <50	Not applicable
	Very dense	50 or greater	Not applicable
Cohesive	Very soft	Less than 2	Less than 0.25
	Soft	2 to <4	0.25 to <0.5
	Firm/Medium stiff	4 to <8	0.5 to <1.0
	Stiff	8 to <15	1.0 to <2.0
	Very stiff	15 to <30	2.0 to <4.0
	Hard	30 or greater	4 or greater

(1) Number of blows from 140-lb. weight falling 30-in. to drive 2-in. OD, 1-3/8-in. ID, split barrel sampler (ASTM D1586)

(2) q_u may also be approximated using a pocket penetrometer

TERMS CHARACTERIZING SOIL STRUCTURE

Parting: -paper thin in size | Seam: -1/8" to 3" thick | Layer: -greater than 3"

Slickensided	- having inclined planes of weakness that are slick and glossy in appearance.
Fissured	- containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated	- composed of thin layers of varying color and texture.
Interbedded	- composed of alternate layers of different soil types.
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	- predominantly 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.

APPENDIX B

Report No. 1140200501

Project: Odor Control Design at 11th Street Facility

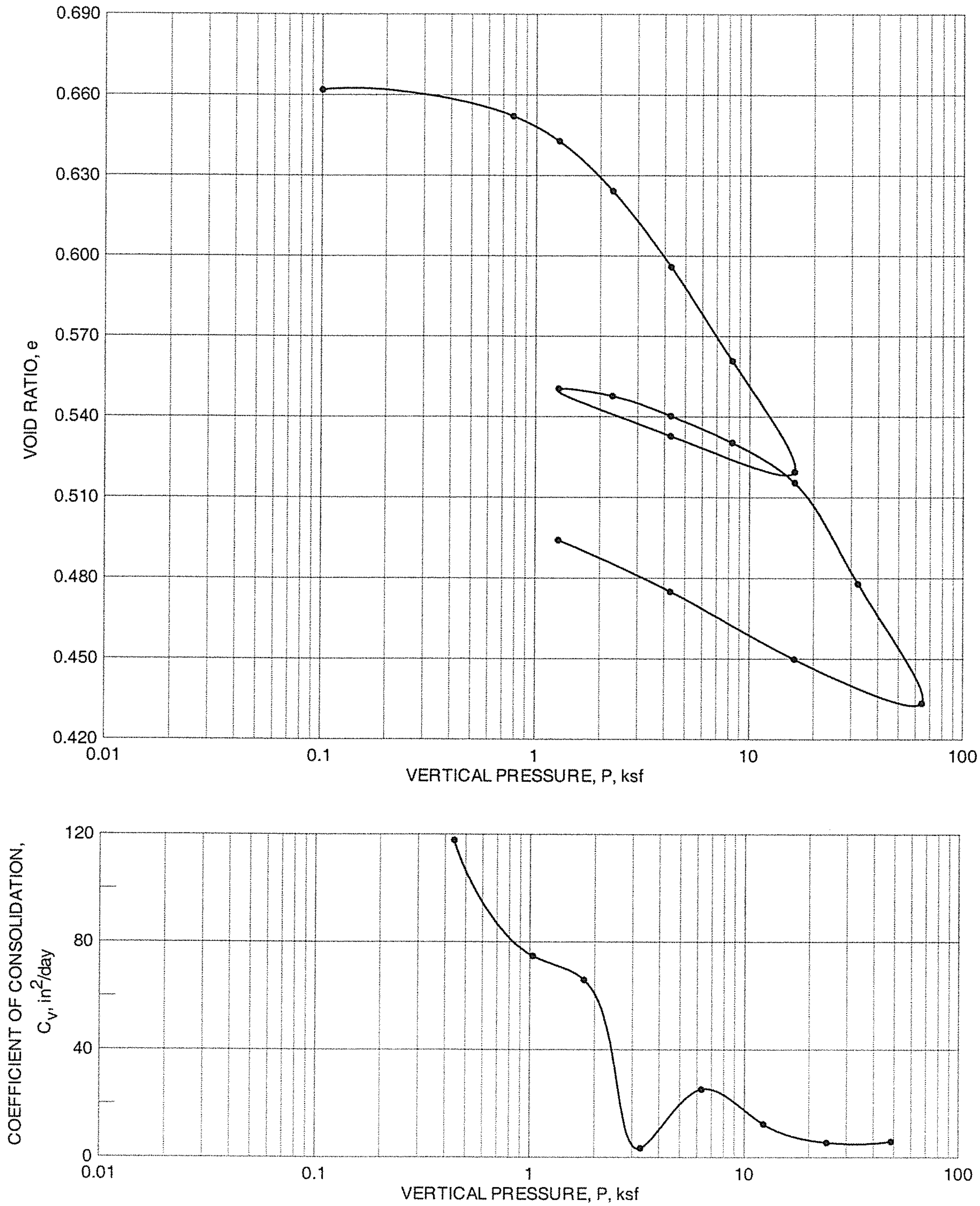
Boring No.: B-1 Sample No. 3 Depth (ft): 4-6

Description: Brown and gray Lean Clay

Moisture Content: 18 Liquid Limit: 36 Specific Gravity: 2.64

Dry Unit Weight (pcf): 99 Plasticity Index: 17

e_o = 0.667
C_c = 0.148
C_r = 0.034
P_c = 1.8 ksf



CONSOLIDATION TEST RESULTS

Geotest Engineering, Inc.

FIGURE B-1

Report No. 1140200501

Project: Odor Control Design at 11th Street Facility;

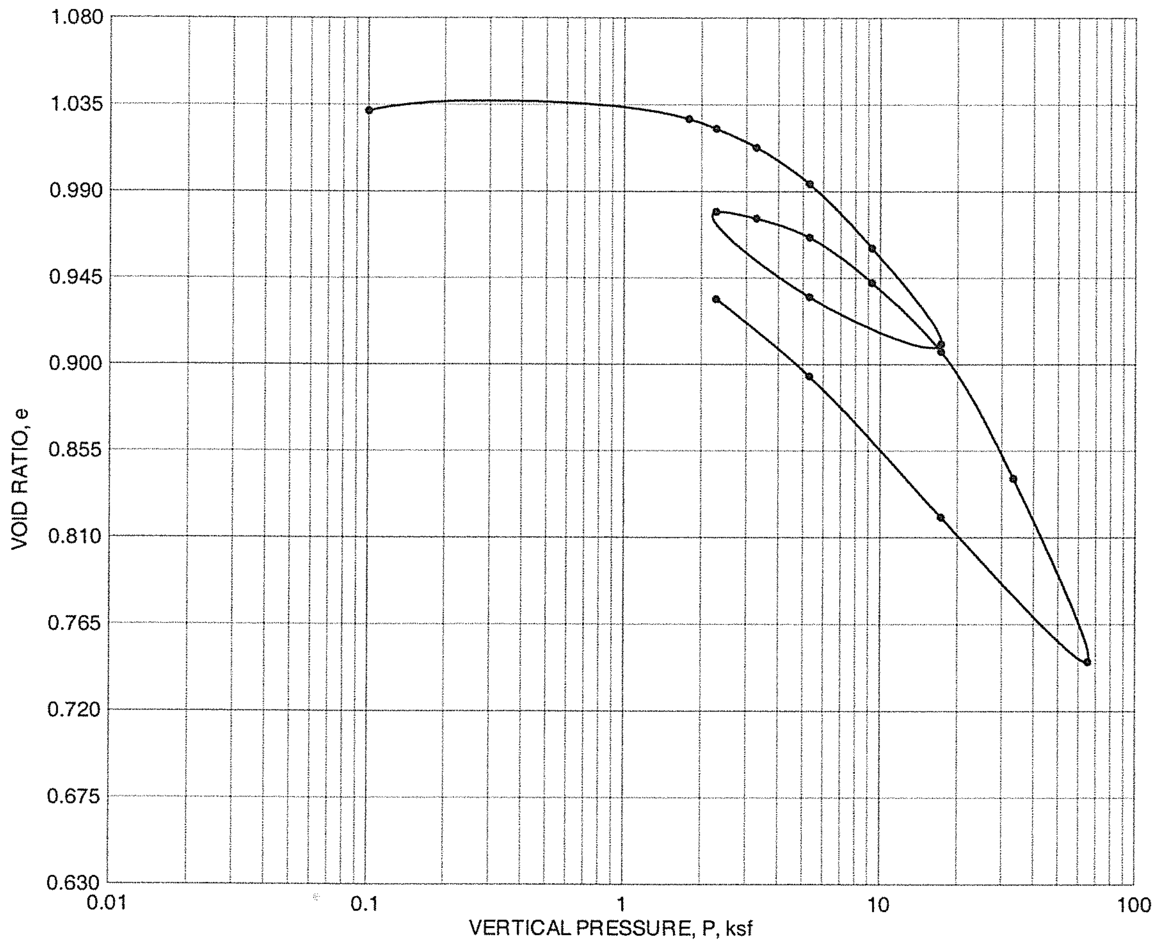
Boring No.: B-2 Sample No. 9 Depth (ft): 16-18

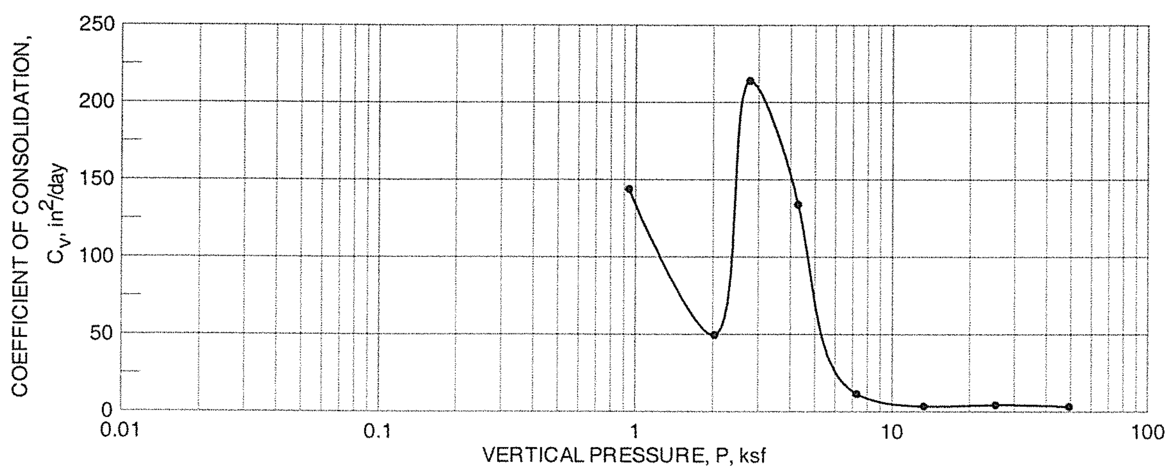
Description: Brown and gray Fat Clay

e_o = 1.036
C_c = 0.324
C_r = 0.062
P_c = 9.5 ksf

Moisture Content: 38 Liquid Limit: 88 Specific Gravity: 2.76

Dry Unit Weight (pcf): 84 Plasticity Index: 57





CONSOLIDATION TEST RESULTS

Geotest Engineering, Inc.

FIGURE B-2