Kenall Inc.

Geotechnical, Environmental & Materials Engineers

Proposed Weir and Lake Expansion
Lake Houston
Houston, Texas

Prepared For
The City of Houston
Houston, Texas

Project No.: 1615

Kenall Inc.

www.kenallinc.com

Kenall Inc.
Geotechnical, Environmental & Material Engineers

June 20, 2012

The City Of Houston
General Services Department
P.O.Box 1562
Houston, TX 77251-1562

Attention: Mr.Farooq Kirmani.P.G.

Subject: **Report of Geotechnical Investigation For Proposed Weir and Lake Expansion Lake Houston, Texas.**

Dear Mr. Kirmani:

Kenall Inc. is pleased to submit the report of geotechnical investigation for the above referenced project. This report has been prepared in accordance with our proposal/agreement dated May 08, 2012.

This report briefly describes the testing procedures employed in our investigation and presents the results of field exploration and laboratory testing. These results were used in engineering analyses to develop geotechnical design recommendations for typical foundation supporting system for the above referenced project as well as guidelines for earthwork during construction.

Soil samples will be held for a period of 30 days from the date of this report and then disposed of, unless an alternate disposition is requested.

We appreciate the opportunity to work with you on this phase of the project and we believe this report serves the referenced project needs. If you have any question or comments concerning this report or need any additional services during construction, please do not hesitate to contact the either of the undersigned.

Very Truly Yours,

Kris D. Prasad, P.E.
President
Kenall Inc.
(TBPE Registration # F-5366)

STATE OF TEXAS
KRISHNA D. PRASAD
91952
LICENSED
PROFESSIONAL ENGINEER

Rajesh Tolikonda, EIT
Staff Engineer

Copies Submitted: (2) Bound Copy & (1) Electronic Copy-Client

TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 PROJECT DESCRIPTION 1
3.0 PURPOSE AND SCOPE 1
4.0 FIELD EXPLORATION 2
5.0 LABORATORY TESTING 2
6.0 GENERAL SUBSURFACE CONDITIONS 3
6.1 Soil Conditions 3
6.2 Groundwater Conditions 3
7.0 FOUNDATION RECOMMENDATIONS FOR NEW WEIR 4
7.1 Lateral Earth Pressures 4
7.2 Retaining Wall Foundation System 5
7.3 Groundwater Control 6
8.0 GENERAL CONSTRUCTION RECOMMENDATIONS 6
8.1 Earthwork and Fill Compaction 7
8.2 Foundation Excavation and Construction 8
8.3 Vegetation Control 8
8.4 Design Review 9
9.0 LIMITATIONS 9
LIST OF ILLUSTRATIONS 10

1.0 INTRODUCTION

The proposed project consists of geotechnical investigation on constructing new Weir and Lake Expansion at Lake Houston, Texas.

2.0 PROJECT DESCRIPTION

Based on available information the proposed project consists of Geotechnical investigation on constructing new Weir and Lake Expansion at Lake Houston, Texas. A site plan showing the general location of the site is shown as Boring Location Plan, Plate № 1, attached to the end of this report.

3.0 PURPOSE AND SCOPE

The purpose of this geotechnical study is to explore soil and groundwater conditions at the subject site, as well as performing field and laboratory tests to aid in engineering analyses for developing geotechnical design recommendations for typical foundation supporting system for the referenced project.

The scope of services for this project include, but not necessarily limited to,

- Performing limited number of soil borings at selected locations on the subject site to evaluate the subsurface stratigraphy and groundwater conditions.

- Performing pertinent laboratory tests per prescribed ASTM standards and local practice to evaluate the physical and engineering properties of subsurface soils.

- Providing geotechnical design parameters for use in design of typical foundation supporting system for the project, as well as providing guidelines for earthwork (e.g. site preparation, grading and fill compaction) during construction.

Services with respect to surveying for line and grade, specific construction dewatering recommendations, environmental matters, temporary slopes, seepage analysis, storm water management, seepage analysis, erosion control, cost or quantity estimates, plans, specifications, and construction observation and testing were not included in the scope of services.

4.0 FIELD EXPLORATION

In order to evaluate subsurface conditions at the site, eight borings (1 thru 8) were drilled on May 05, 2012. Borings 1, 2, 3 and 8 were drilled to a depth of 20 feet and borings 4, 5, 6 and 7 were drilled to a depth of 15 feet. The approximate locations of borings are shown on the Boring Location Plan, Plate № 1, is attached to the end of this report.

Relatively undisturbed samples of the subsurface materials were obtained by means of a thin-walled Shelby tube sampler in general accordance with ASTM D 1587. The Shelby tube sampler was hydraulically pushed into the underlying soils at selected depths. The samples were extruded mechanically from the Shelby tubes in the field, visually classified, and a representative portion of each sample was wrapped in aluminum foil, and sealed in a plastic bag to prevent moisture losses and further disturbances. Pocket penetrometer tests were performed on cohesive soils in the field to measure the general consistency of soil. All the samples retained from field exploration were transported to our geotechnical laboratory for further examination, testing and analysis.

In addition, disturbed samples of subsurface soils were obtained by employing split spoon sampling procedure in general accordance with ASTM D 1586. The samples of subsurface materials were obtained by employing split spoon sampler with an outside diameter of 2 inches, inside diameter of 1.375 inches and a barrel of 21 inches as a part of standard penetration test (ASTM D 1586). The test is performed by driving the sampler into the soil by repeated blows on a 140-pound hammer falling 30 inches. The number of hammer blows required to advance the sampler twelve (12) inches (after seating) is recorded for each standard penetration test in the appropriate column in the field log and are shown on the Boring Logs, Plate Nos. 2 through 9 attached to the end of this soil report.

All the samples retained from field exploration were transported to our geotechnical laboratory for further examination, testing and analysis.

5.0 LABORATORY TESTING

The soil samples retained from the soil borings were examined and classified by a geotechnical engineer or a senior technician in our laboratory. Laboratory tests were then performed on selected soil samples as directed by the geotechnical engineer in accordance with prescribed ASTM standards. The tests results were used to evaluate the physical and engineering properties of the soils as a basis in providing recommendations for foundation design and earthwork construction. The details of laboratory test and respective ASTM Standard are provided in TABLE A below. Individual test results are shown on the Boring Logs, Plate №s. 2 through 9,

attached to the end of this report.

TABLE A: DETAILS OF LABORATORY TESTS PERFORMED

Test Name	Test Method
Hand Penetrometer	Not applicable
Moisture Content	ASTM D 2216
Atterberg Limits	ASTM D 4318
Dry Density	ASTM D 2937
Unconfined Compression	ASTM D 2166

6.0 GENERAL SUBSURFACE CONDITIONS

6.1 Soil Conditions

A comprehensive description of the encountered conditions can be obtained from the attached test boring logs, Plate Nos. 2 through 9 attached to the end of this report. The subsurface investigation indicated that the following generalized strata underlie the site to the depths investigated:

Stratum I: From ground level to a depth of 13.5 feet in the borings 1 thru 8 respectively. The soil of this stratum generally consists of dark gray, brown, gray, light gray and tan, firm to stiff to very stiff to hard FAT CLAY.

Stratum II: From underlying stratum I to the depth of 20 feet in borings 1 thru 8. The soil of this stratum generally consists of light gray, tan and brown, very loose to loose to medium dense SILTY SAND.

The soil symbols indicated in the stratum descriptions and on the boring logs represent the Unified Soil Classification (ASTM D-2488) group symbols and are based primarily on visual observation and limited laboratory testing of the specimens recovered. Criteria for visual-manual classification of soil samples are given in Plate № 10 attached to the end of this report.

6.2 Groundwater Conditions

No groundwater was encountered on drilling tools during drilling of all the borings.

Ground water level readings are considered to be a reliable indication of the water levels at the time indicated. Fluctuations of ground water levels, as well as perched water, may be expected with variations in precipitation,

evaporation, surface runoff, and related factors. The groundwater level at this site should be expected fluctuate with seasonal variation in the amount of rain fall (climatic changes) and subsurface drainage characteristics. More accurate groundwater levels can be obtained by installing and long-term monitoring of piezometers or monitoring wells. Long term monitoring of groundwater levels was beyond the scope of this study.

Since groundwater level variations are anticipated, design drawings and specifications should incorporate such possibilities and provide for dewatering, as required, during construction.

7.0 FOUNDATION RECOMMENDATIONS FOR NEW WEIR

The following design recommendations were developed on the basis of the previously described Project Characteristics (Section 2.0) and conditions encountered at the boring locations (Section 6.1). A grading plan was not available during writing this report.

If project criteria should change, including location of the retaining walls on the site or proposed grades, our office should conduct a review to determine if modifications to the recommendations are required. Further, it is recommended our office be provided with a copy of the final plans and specifications for review prior to construction.

7.1 Lateral Earth Pressures

The retaining wall should be designed to resist the lateral earth pressure exerted by soil. As requested, for the design of such retaining systems, the equivalent hydrostatic pressure values for both at rest and active earth pressure conditions are presented in table below.

LATERAL EARTH PRESSURE Horizontal ground surface extending backward from the top of the wall			
Material	**Condition**	**Equivalent Fluid Pressure, pcf**	
		Drained	**Undrained including Hydrostatic Pressure**
On-site Clayey Soil, Φ=11˚, γ_T =128 pcf	At-Rest, k_o=0.8	--	120
	Active, k_a=0.7	--	110
Free Draining Granular Soil Φ=31˚, γ_T =120 pcf	At-Rest, k_o=0.46	55	83
	Active, k_a=0.33	40	61

The use of active or at rest earth pressures depends on the amount of horizontal movement that can occur along the vertical wall height. The design active earth pressures assume that the top of the walls are not rigidly restrained and the walls can deflect at the top. If the walls are restrained, the at rest earth pressure values should be used. Furthermore, any additional lateral loads due to surcharge should be included in the design. Drainage systems should be provided near, or at the base of walls to collect and remove groundwater and prevent a buildup of hydrostatic pressure behind the walls. If provisions to prevent accumulation of water behind the walls are not provided, the walls should be designed to resist the full hydrostatic head in addition to the lateral earth pressure as outlined. The backfill soils should be compacted as discussed in Section 8.1 of this report.

7.2 Retaining Wall Foundation System

As discussed in Section 6.1 of this report clayey material was encountered at the surface of all the Borings and extended to a depth of about 13.5 ft below existing grade. Based on our visual observations during the drilling operations existing material appears to be fat clay. Fat clay could be susceptible to large and unpredictable settlements when loaded, and this material is not considered suitable for support of foundations. The magnitude of these settlements is difficult to predict due to inherent variable nature of clay. The most positive method to eliminate the risk of settlement due to compression of existing clay material is to remove the clay up to a depth of 3 feet from the foundation areas and replace it with engineered fill (Section 8.1 of this report).

After subgrade improvement performed as discussed above proposed retaining wall could be supported on shallow footings. The shallow footing foundation system can be designed using net allowable bearing pressures as provided in table below.

Bearing Material	Allowable Bearing Capacity, psf
Natural, Undisturbed Soil or control fill	2500

The above bearing pressures are applicable for footings bearing at a minimum depth of 3 ft below the lowest final adjacent site grade. In some cases, greater foundation depths are necessary for global stability of the planned wall. Global stability analysis is not included within the scope of this study. If desired, Kenall would be pleased to perform a global stability

analysis. The wall design engineer should review the recommended bearing depths to verify the walls are sufficiently designed to resist sliding, overturning, etc.

The excavations for footings should be carefully monitored during construction to locate any pockets or seams of loose unsuitable material. Any unsuitable material encountered during footing excavation should be removed and replaced with engineered fill as recommended in Section 8.1 of this report. Reinforcing steel should be preferably placed and the footing should be poured the same day of excavation to prevent the bearing surface from any disturbances. Sides of the foundation excavation may slough to some extent with time. Sloughed soils and other debris in the bottom of the excavation should be removed prior to steel placement. If for some reason the footing cannot be poured the same day of excavation, a seal slab should be placed to protect the exposed foundation soils. If the foundation is formed, the edges should be backfilled with lean concrete or compacted cement-stabilized sand (two sacks of cement per cubic yard of sand). The excavation should be sloped sufficiently to create internal sumps for runoff collection and removal. All forming material should be removed prior to back-filling.

Resistance to wind-induced and other lateral forces can be developed by friction acting along the base of the footing and the passive earth pressure acting against the sides of footing. We recommend an allowable uniform passive earth pressure of 750 psf acting along the sides of the footing. The passive pressure should be neglected along top 2 ft of the soil in contact with the footing. The frictional resistance along the base of the footing may be calculated using an allowable friction coefficient of 0.30.

7.3 Groundwater Control

No groundwater was encountered on drilling tools during drilling of all the borings. Based on our experience seasonal groundwater seepage could be encountered during excavation for foundations and utility conduits. In cohesive soils groundwater may be collected in the excavated bottom sumps for pump disposal. In semi cohesion less soils or granular soils dewatering will be required. In such cases groundwater typically controlled by installation of vacuum well points for excavation generally shallower than 15 feet or deep wells with submersible pumps for excavation deeper than 15 feet. The groundwater level in these soils should be lowered and maintained at least 5 feet below the level of excavation.

8.0 GENERAL CONSTRUCTION RECOMMENDATIONS

The recommendations in this report are based on the subsoil conditions encountered in the field exploration and laboratory testing. Due to the geological deposition of the Pleistocene soils in the Gulf Coastal area, variations could occur in the subsurface conditions within the site. If significant variation is noticed during construction our office should be contacted to review and verify the conclusions presented in this report.

8.1 Earthwork and Fill Compaction

The site should be stripped to suitable depths to remove any top soil and miscellaneous fill material. The exposed subgrade should then be proof-rolled with a 20-ton pneumatic roller or loaded dump truck to locate weak and soft areas. Any soft or loose material exposed should be removed and replaced with well-compacted material. The proof-rolling should be performed under the supervision of a licensed Professional Geotechnical Engineer.

Samples of the subgrade soil should be obtained prior to compaction operations for laboratory moisture/density testing (Proctor Tests). The tests will provide a basis for evaluating the in-place density requirements during compaction operations. A qualified soil technician should perform sufficient in-place density tests during the filling operations to verify that proper levels of compaction are being attained.

Prior to placing any new fill the natural subgrade should be scarified to a minimum depth of six (6) inches. The scarified soils should then be recompacted to a minimum of 95 percent of the standard Proctor maximum dry density (ASTM D-698) and within the range of 1 percentage point below to 3 percentage points above the material's optimum.

Any select, non-expansive fill (structural fill) used at the site should have a Liquid Limit less than 35 and a Plasticity Index between 10 and 20. The select fill material should be placed in maximum of eight (8) inch loose lifts and compacted to a minimum of 95 percent of the maximum dry density as per ASTM D-698. The moisture content should be within 1 percentage point below to 3 percentage points above material's optimum.

Clay soils with plasticity index greater than or equal to 25 used as fill should be compacted to a dry density between 95 to 98 percent of standard Proctor maximum dry density (ASTM D-698) and within the range of 2 to 6 percentage points above the material's optimum.

Sandy clay soils with a plasticity index less than 25 used a fill should be compacted to at least 95 percent of standard Proctor maximum dry density

(ASTM D-698) and within the range of 1 percentage point below to 3 percentage points above the material's optimum.

8.2 Foundation Excavation and Construction

The foundation excavations should be inspected under the supervision of a licensed Professional Geotechnical Engineer to confirm that the bearing soils are similar to those encountered in our field exploration and that the foundation areas have been properly prepared. The geotechnical engineer should be immediately notified should any subsoil conditions be uncovered that will alter the conclusions and recommendations contained in this report. Further investigation and supplemental recommendations may be required if such a condition is encountered.

For drilled piers, the concrete should be placed in a timely manner after drilling to minimize the potential for caving of the foundation soils. Piers should not be poured without the prior approval of a licensed Professional Geotechnical Engineer. Prior to placement of concrete, the foundations excavations should be inspected to verify that:

1. The foundations bear in the proper bearing strata.

2. The drilled shaft is to the proper dimensions and reinforcing steel is placed as shown on the structural drawings.

3. The shaft has been drilled plumb within specified tolerances.

4. Excessive cutting, build up of cutting, and any other soft compressible materials have been removed from the bottom of the excavations.

5. Any groundwater seepage observed in the pier excavations and sloughing of soils has been handled properly.

8.3 Vegetation Control

We recommend trees not to be closer than half the canopy diameter of mature trees from the structure, typically a minimum of 20 feet. This will minimize possible foundation settlement caused by the tree root systems.

8.4 Design Review

Review of the design and construction plans as well as the specifications should be performed by **Kenall Inc.** before release. The review is aimed at determining if the geotechnical design recommendations and construction criteria presented in this report have been properly interpreted. Design review is not within the scope of work authorized in this study. Should you elect to retain **Kenall Inc.** to perform a design review, additional fees would be applicable.

9.0 LIMITATIONS

This report was prepared for exclusive use of **The City of Houston** and the design team for specific application to the construction of the referenced project at the aforementioned location Houston, Texas. Our report was prepared in accordance with generally accepted geotechnical engineering practice common to the local area. No other warranty, express or implied, is made.

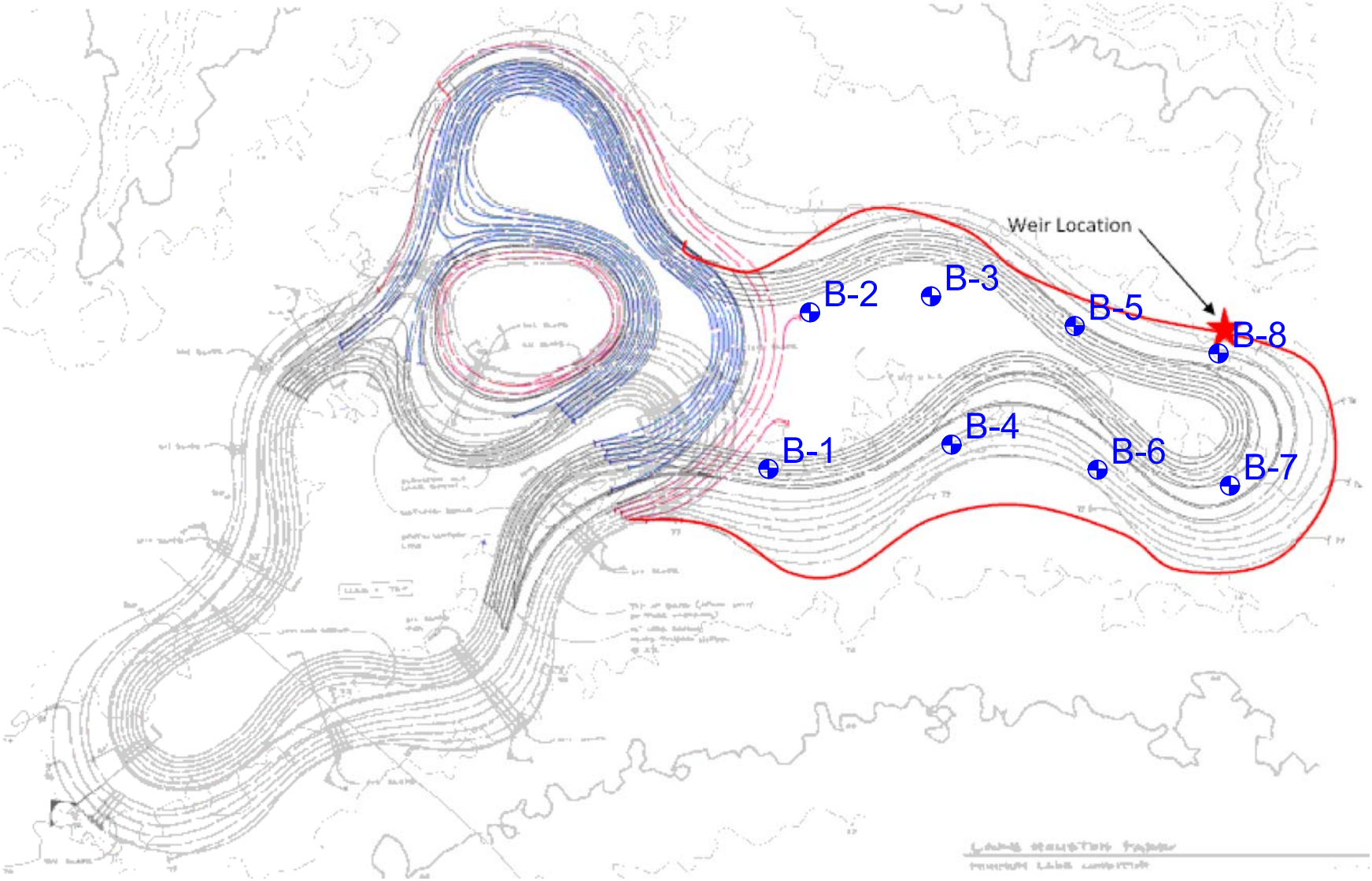
The analyses and recommendations contained in this report are based on the data obtained from the referenced subsurface exploration. The boring results indicate subsurface conditions only at the specific locations and time, and only to the depths penetrated. The boring does not necessarily reflect strata variations that may exist in subsurface conditions within the site. The validity of the recommendations is based in part on assumptions about the stratigraphy made by the Geotechnical Engineer. Such assumptions may be confirmed only during earthwork and construction. If subsurface conditions different from those described are noted during construction, recommendations in this report must be reevaluated.

If any changes in the nature, design, or location of the project are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report are modified or verified in writing by **Kenall Inc**. **Kenall Inc.** is not responsible for any claims, damages, or liability associated with interpretation of subsurface data, or reuse of the subsurface data or engineering analyses without expressed written authorization of **Kenall Inc**.

LIST OF ILLUSTRATIONS

The following illustrations are included for this report.

	Plate No.
Boring Location Plan	1
Boring Logs	2 through 9
Symbols and Terms used on Boring Logs	10



Kenall Inc.
Geotechnical, Environmental & Material Engineers

Scale: Not to Scale	Approved By: KP	Prepared By: RT

BORING LOCATION PLAN
Proposed Weir and Lake Expansion
Lake Houston
Houston, Texas

Project No. 1615	Plate No. 1

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 1
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Light to dark gray, brown, gray and tan, firm to stiff to very stiff to hard FAT CLAY
			P=1.25	20		51	17	34			
2											
			P=0.75	21							
4											
			P=1.75	21		61	14	47			
6											
			P=3.75	23							
8											
			P=4.50	18		60	17	43	75		
10											
12											
											13.5
											Light Gray,Tan, medium dense SILTY SAND
14			N=23	9							
16											
18											
			N=24	5							
											20.0

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

Kenall Inc.
Geotechnical, Environmental & Material Engineers

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 2
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Light gray to dark gray, brown, gray and tan, stiff to very stiff to hard FAT CLAY
			P=1.25	19					83		
2											
			P=1.25	17		64	15	49			
4											
			P=2.75	20	112					1.29	
6											
			P=4.0	23		77	21	56			
8											
			P=4.50	15		54	16	38			
10											
12											
											13.5
											Tan, medium dense SILTY SAND
14			N=17	4							
16											
18											
			N=21	3					20		
											20.0

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

Kenall Inc.
Geotechnical, Environmental & Material Engineers

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 3
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Light gray, gray and brown, very stiff FAT CLAY
			P=2.25	19		55	16	39			
2											
			P=2.75	20							
4											
			P=2.25	22		67	18	49			
6											
			P=3.50	18							
8											
			P=3.75	20		67	20	47	91		
10											
12											
											13.5
											Brown, medium dense SILTY SAND
14			N=17	15							
16											
18											
			N=19	12							
											20.0

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

Kenall Inc.
Geotechnical, Environmental & Material Engineers

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 4
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Gray and tan, stiff to very stiff to hard FAT CLAY
			P=4.5	10							
2											
			P=4.5	12		60	14	46			
4											
			P=3.25	18							
6											
			P=3.75	22		81	20	61			
8											
			P=3.5	21		72	21	51			
10											
12											
											13.5
14			N=16	4					14		Light Gray,Tan, medium dense SILTY SAND
											15.0
16											
18											

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

Kenall Inc.
Geotechnical, Environmental & Material Engineers

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 5
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Light and tan, stiff to very stiff to hard FAT CLAY
			P=4.0	14		65	15	50	86		
2											
			P=1.75	18							
4											
			P=4.25	15		60	14	46			
6											
			P=3.75	18							
8											
			P=4.0	18							
10											
12											13.5
14			N=17	9							Light Gray, medium dense SILTY SAND 15.0
16											
18											

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

Kenall Inc.
Geotechnical, Environmental & Material Engineers

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 6
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Light Gray,tan, Very stiff to hard FAT CLAY
			P=4.5	16							
2											
			P=4.25	15		59	13	46			
4											
			P=3.75	15							
6											
			P=2.75	18		68	18	50			
8											
			P=4.25	22					92		
10											
12											
13.5											Light Gray and tan, medium dense SILTYSAND
14			N=29	10							
15.0											
16											
18											

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

Kenall Inc.
Geotechnical, Environmental & Material Engineers

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 7
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Light gray, very stiff to hard FAT CLAY
			P=2.75	18		64	19	45			
2											
			P=2.75	18							
4											
			P=4.5	15		67	14	53			
6											
			P=4.5	16							
8											
			P=4.5	9					86		
10											
12											
											13.5
14			N=28	7							Light Gray, medium dense SILTY SAND
											15.0
16											
18											

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

Kenall Inc.
Geotechnical, Environmental & Material Engineers

LOG OF BORING

PROJECT: Weir and Lake Expansion Project
Lake Houston
Houston, Texas

CLIENT: City of Houston
Houston, TX

BORING NO. 8
PROJECT NO. 1615
DATE 5-15-12
SURFACE ELEVATION N/A

DRILLING METHOD(S):
Continuous Flight Auger (CFA)

GROUNDWATER INFORMATION:
No water Encountered

FIELD DATA				LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	SAMPLES	N: BLOWS/FT T: TONS/SQ FT P: TONS/SQ FT R: PERCENT RQD: PERCENT	MOISTURE CONTENT (%)	DRY DENSITY POUNDS/CU.FT	ATTERBERG LIMITS (%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	MINUS NO. 200 SIEVE (%)	SHEAR STRENGTH (TONS/SQ FT)	DESCRIPTION OF STRATUM
											Light to Dark gray, gray and tan, very stiff to hard FAT CLAY
			P=4.5	16		63	17	46	85		
2											
			P=3.75	15							
4											
			P=2.5	16		50	15	35			
6											
			P=4.5	14							
8											
			P=4.5	17	110	55	16	39		3.57	
10											
12											
											13.5
											Light Gray, medium dense SILTY SAND
14			N=26	8							
16											
18											
			N=29	5							
											20.0

N - STANDARD PENETRATION TEST RESISTANCE
T - TORVANE
P - POCKET PENETROMETER RESISTANCE
R - PERCENTAGE OF ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

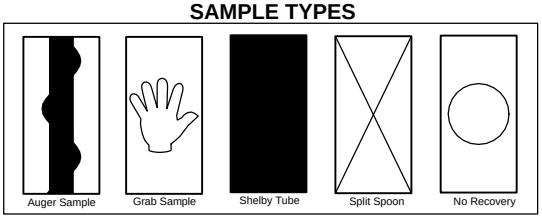
Kenall Inc.
Geotechnical, Environmental & Material Engineers

UNIFIED SOIL CLASSIFICATION CHART-ASTM 2487

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

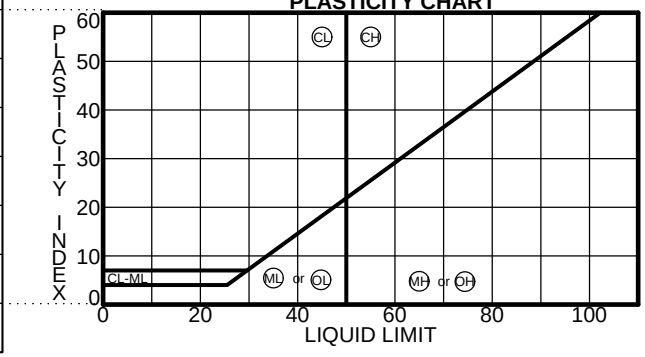
SAMPLE TYPES



GROUNDWATER

- Water level encountered during drilling operations
- Water level after drilling operations
- Water level after 24 hours

PLASTICITY CHART



CONSISTENCY OF COHESIVE SOILS

Description	Unconfined Compressive Strength-TSF	Blows Per Foot
Very Soft	Less than 0.25	0-2
Soft	0.25 to 0.50	2-4
Firm	0.50 to 1.00	4-8
Stiff	1.00 to 2.00	8-15
Very Stiff	2.00 to 4.00	15-30
Hard	4.00 & Higher	>30

RELATIVE DENSITY-GRANULAR SOILS

Description	Penetration Resistance Blow per Foot	Relative Density-%
Very Loose	0-4	0-15
Loose	4-10	15-35
Medium Dense	10-30	35-65
Dense	30-50	65-85
Very Dense	>50	85-100

CLASSIFICATION OF GRANULAR SOILS

U.S. Standard Sieve Size (s)

	6"	3"	3/4"	4	10	40	200
Boulders	Cobbles	Gravel: Coarse	Gravel: Fine	Sand: Coarse	Sand: Medium	Sand: Fine	Silt or Clay / Clay
	152	76.2	19.1	4.76	2.0	0.42	0.074 / 0.002

Grain Size in mm

TERMS CHARACTERIZING SOIL STRUCTURE

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 colors and texture
Interbedded	- composed of alternate layers of different soil types
Calcareous Nodules	- containing appreciable quantities of calcium carbonate
Ferrous Nodules	- containing appreciable quantities of ferrous materials
Well Graded	- having wide range in grain sizes and substantial amounts of all intermediate particle size
Poorly Graded	- predominantly of one grain size, or having a range of sizes with some intermediate size missing

Kenall Inc.
Geotechnical, Environmental & Material Engineers

Approved By: KP	Prepared By: RT

KEY TO SOIL CLASSIFICATION AND SYMBOLS

Project No. 1615	Plate No. 10