Kenall Inc.
Geotechnical, Environmental & Material Engineers

January 12, 2016

HUITT-ZOLLARS, INC.
1500 S. Dairy Ashford, Suite 200
Houston, TX 77077

Attention: Mr. Greg Wine, P.E.

Subject: **Geotechnical Investigation**
Building Improvements for North East Water Purification Plant (NEWPP)
12121 North Sam Houston Parkway East
Humble, Texas
WBS No. S-000066-0029-3
Kenall Report No:1850-revised

Dear Mr. Wine:

Kenall Inc. (Kenall) is pleased to submit this report of findings, conclusions, and recommendations of a geotechnical investigation for the project specified above. This study was authorized by Huitt-Zollars, Inc.

This report briefly describes the methodology and testing procedures employed in our investigation. Laboratory test results are also presented, along with our conclusions and recommendations. This geotechnical investigation was conducted in general conformance with the scope and limitations of as modified in Chapter 11 of the current City of Houston's Public Works & Engineering Infrastructure Design Manual.

We appreciate the opportunity to work with you on this project. If you have any questions or require further information, please do not hesitate to contact our office.

Very Truly Yours,

Rajesh Tolikonda, E.I.T.
Staff Engineer

STATE OF TEXAS
KRISHNA D. PRASAD
91952
LICENSED
PROFESSIONAL ENGINEER

Kris D. Prasad, P.E.
Principal Engineer

Report Distribution: Client-(1) Copy and (1) email.

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EXECUTIVE SUMMARY

Kenall was retained by Huitt-Zollars to provide the geotechnical services for the proposed building improvements at the North East Water Purification Plant (NEWPP) in Humble, Texas. The project consists of construction of the new building at NEWPP. The area of the proposed building is 733 square feet and it will be utilized for storage purposes. The project area is located at 12121 North Sam Houston Parkway East in Humble, Texas.

The purpose of this study was to evaluate soil and groundwater conditions and to provide foundation design parameters and construction recommendations for proposed new building. This study was performed in general accordance with Chapter 11 of the latest City of Houston's Public Works & Engineering Infrastructure Design Manual.

Based on the subsurface conditions revealed by the soil borings, the findings and recommendations of this report are summarized below:

1. Subsurface soils at the site generally comprise of stiff to very stiff cohesive fat clays and sandy lean clays.

2. Groundwater was not encountered at the boring location.

3. Recommendations for foundation design should generally be in accordance with the latest City of Houston Standard Specification.

4. All excavation operations should be carried out in accordance with the latest City of Houston Standard Specifications.

Please note that this executive summary does not fully relate our findings and opinions, which are only presented through our full report.

1 INTRODUCTION

1.1 Project Description

Kenall was retained by Huitt-Zollars to provide the geotechnical services for the proposed building improvements at the NEWPP in Humble, Texas. The project consists of construction of the new building at NEWPP. The area of the proposed building is 733 square feet and it will be utilized for storage purposes. The project area is located at 12121 North Sam Houston Parkway East in Humble, Texas. A site vicinity map showing the approximate project location is presented in illustrations as Plate No.1 of this report.

The purpose of this study was to evaluate the soil and groundwater conditions and to provide design and construction recommendations for the proposed building foundation. This study was performed in general accordance with modified in Chapter 11 of the latest City of Houston's Public Works & Engineering Infrastructure Design Manual.

1.2 Geotechnical Investigation Program

The primary objectives of this study were to gather the information on the subsurface conditions at the site and to provide the recommendations for the proposed building. The objectives were accomplished by:

1. Drilling one (1) soil boring to a depth of 20 feet below the existing subgrade to determine soil stratigraphy and to obtain samples for laboratory testing;
2. Performing the laboratory tests in accordance with ASTM methods to determine physical and engineering characteristics of the soils;
3. Performing the engineering analyses in accordance with the latest City of Houston Design Manual, to develop design guidelines and recommendations; and
4. Providing a geotechnical report that includes all the field data, laboratory data, and geotechnical recommendations.

Subsequent sections of this report contain descriptions of the field exploration, laboratory testing program, general subsurface conditions, design recommendations, and construction considerations.

2 FIELD INVESTIGATION

2.1 General

After obtaining clearance for the proposed boring in the field, one boring was drilled to the explored depth using a buggy rig. All drilling and sampling procedures were performed in accordance with the appropriate ASTM procedures.

2.2 Geotechnical Boring

The field exploration program undertaken at the project site was performed on August 21, 2014. Subsurface conditions were investigated by drilling one (1) soil boring (designated as B-1) to a depth of 20 feet below the existing grade. The approximate boring location is shown in illustrations as Plate No. 2. Each sample in the field was removed from the sampler, examined carefully, and then logged by an experienced soils technician. Portions of each sample were sealed, packaged, and transported to our Kenall facility. Borehole then backfilled with cement bentonite grout using tremie method in accordance with City guidelines.

Detailed descriptions of soils encountered in the boring is given in the boring log presented in illustrations as Plate No.3. Criteria for visual-manual classification of soil samples are presented in illustrations as Plate No.4.

2.3 Sampling Methods

Soil samples were continuously obtained to the termination depth of the boring. Cohesive soil samples were obtained with a three-inch thin-walled (Shelby) tube sampler in general accordance with the ASTM D1587 standard. Each sample was removed from the sampler in the field, carefully examined, and then classified. The shear strength of the cohesive soils was estimated by a hand penetrometer in the field. Suitable portions of each sample were sealed and packaged for transportation to our laboratory. Detailed descriptions of the soils encountered in the boring is given in the boring log presented in illustrations as Plate No. 3. A key to the soils classification and symbols used in the boring log is also shown in illustrations as Plate No. 4.

2.4 Survey Data

No survey data has been obtained for this investigation. The approximate X-Y coordinates and elevation[1] for the boring location as shown below.

Boring Number	Street Name(s)/ Location	Latitude	Longitude	Elevation (ft)	Proposed Boring Depth (ft)
B-1	1212 N Sam Houston Pkwy E, Humble, TX	29°56.01500' (42033922897.667ftUSE)	-095°11.86000' (9977128.944ftUSN)	55	26

[1] *Source*: "NWEPP site." 29°56.01500' -095°11.86000'. **Google Earth** January 11, 2016.

3 LABORATORY TESTING

Selected soil samples were tested in the laboratory to determine applicable physical and engineering properties. All tests except pocket penetrometer were performed according to the relevant ASTM Standards. These tests consisted of Moisture Content, Material Finer than No.200 Sieve, Liquid Limits and Plastic Limits, and Unconsolidated Undrained Triaxial Compression Test. The Atterberg Limits and percent passing number 200 sieve tests were used to verify field classification by the ASTM version of the Unified Soils Classification System, and the unconsolidated undrained compression tests were performed to obtain the undrained shear strength of the soil. The type and number of tests performed for this investigation are summarized below:

Table 1: Laboratory Tests Performed

Test Name	Test Method	Number of Tests
Hand Penetrometer	Not applicable	10
Moisture Content	ASTM D 2216	10
Liquid Limits and Plastic Limits	ASTM D 4318	2
Material Finer than No.200 Sieve	ASTM D 1140	2
Unconsolidated Undrained Triaxial Compression Test	ASTM D 2850	1

4 SUBSURFACE CONDITIONS

4.1 General Geology

The major surface geological formation that exists in the Humble, Texas area is Beaumont Formation. The project area lies in the Beaumont Formation.

The Beaumont Formation dips southeastward and extends beneath beach sand and waters of the Gulf of Mexico as far as the continental shelf. The courses of major streams and deltaic tributaries changed frequently during the period of deposition, generating a complex stratification of sand, silt, and clay deposits within the Beaumont clay. The Beaumont Formation was deposited on land near sea level in flat river deltas and in inter-delta regions. Soil deposition occurred in fresh water streams and in flood plains (as backwater marsh and natural levees). 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. The clays of this formation have moderate to high shear strength and relatively low compressibility. The sands of this formation are typically very fine and often silty.

4.2 Soil Stratigraphy

Our interpretation of soil and groundwater conditions at the project site is based on information obtained at the boring location only. This information has been used as the basis for our conclusions and recommendations. Significant variations at areas not explored by the project boring may require reevaluation of our findings and conclusions.

NEWPP Site:

Soil Description	Boring No.	Depth
Cohesive		
Light gray and tan, sandy lean clay and sand- FILL	B-1	0-4 ft (FILL)
Light gray and tan, very stiff sandy lean clay	B-1	4-6 ft (CL)
Gray, light gray and tan, stiff to very stiff fat clay.	B-1	6-20 ft (CH)

The fat clays are of high plasticity with a liquid limit of 66 and plasticity index of 48; the percent fines (percent passing No. 200 sieve) is 97 percent.

4.3 Groundwater Conditions

No groundwater was encountered in the boring drilled for this study. 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.

5 FOUNDATION DESIGN AND RECOMMENDATIONS

5.1 General

Kenall was retained by Huitt-Zollars to provide geotechnical services for the proposed building improvements at NEWPP in Humble, Texas. The project consists of construction of the new building at NEWPP. The project area is located at 12121 North Sam Houston Parkway East in Humble, Texas.

5.2 Foundation Recommendations

Based on soil conditions encountered in soil boring and our experience with the general area soils, we recommend supporting proposed building on drilled and underreamed piers.

A grading plan was not available during writing this report. For the purpose of writing this report we have assumed nominal cuts and fills are required to achieve the final grades. The following design recommendations were developed assuming the existing grade is within 2 ft of final grade.

5.2.1 Drilled and Underreamed Piers

Based on soil conditions encountered in the boring, the proposed building could be supported on drilled and underreamed piers bearing at a depth of at least ten (10) feet below existing grade or final grade, whichever is deep. Based on our experience with

general area soils, granular soils and groundwater seepage could be encountered during construction of underreamed piers. Kenall should observe the adjustments in pier depths in field.

Piers bearing at above depth may be sized for a net allowable bearing pressure of 2,000 psf for dead load plus sustained live load and 3,000 psf for total load conditions, whichever governs. These allowable bearing pressures contain factors of safety of about 3 and 2, respectively.

The minimum clear spacing between edges of adjacent piers of the new building should be at least one (1) underream diameter. The minimum clear spacing between edges of adjacent piers of the existing structures and the new piers should be at least one (1) underream diameter. Based on experience with the general area soils underreams can be successfully installed with a bell to shaft ratio of at least 2 and not exceeding 3. Piers designed using the recommended allowable bearing capacity will experience small settlements (less than 1 inch) that will be well within the tolerable limits for the proposed structure. Differential settlements should be on the order of one-half the total settlement.

The portion of the shaft in expansive soils within the depth of moisture change (approximately 8 ft below ground surface) could be subjected to uplift forces (soil-to-pier adhesion) caused by potential soil swell. In addition, the piers could be subjected to other uplift forces (tensile forces) due to the super structure. The pier shaft should be reinforced with sufficient tension steel over its entire length to resist these potential uplift forces (tensile forces) caused by swelling soils and superstructures. The uplift forces due to swelling soils should be resisted by the underreamed portion of the pier that acts as an anchor. Underreamed piers should be reinforced with sufficient tension steel over its entire length to resist potential uplift forces (tensile forces). Foundation reinforcement design will be the responsibility of Project Structural Engineer.

Caving of shaft may occur during construction of the drilled piers due to calcareous nodules and ferrous nodules and groundwater seepage that could be encountered at bearing depth during construction. In order to minimize the possibility of shaft caving during drilled pier construction, the construction contractor should be prepared to use cased piers or straight sided shaft foundations. We recommend that the drilling be performed under the supervision of a licensed Professional Engineer.

5.2.2 Floor Slab

As discussed in Section 4.2 of this report, the onsite soils consist of fill material. Grade-supported floor slabs placed on these soils will incur some degree of risk associated with distress.

In view of above discussion, we recommend to replace the existing fill material with at least 4 feet of select, non-expansive material (structural fill). The material should be installed below the bottom of floor slabs and top of surface of underlying soil. The select material (structural fill) should extend at least 4 feet beyond the exterior walls (wall facing

parking lot) of the proposed building. Requirements for select, non-expansive material (structural fill) are discussed in Section 6.1 of this report

5.2.3 Grade Beams and Void Boxes

The excavations for the grade beams should be clean and free of any loose materials prior to concrete placement. A void space of four (4) inches should be provided beneath the bottom of grade beams. This void space allows for movement of the expansive soils below the grade beams without distressing the structural system. Structural cardboard void forms are often used to provide this void space.

Void Boxes are typically placed under the grade beams to provide the void space, and act as a barrier separating the grade beams from the underlying soils. The void boxes collapse when the underlying soils swell, thus minimizing the uplift loads caused by the expansive soils on grade beams. However, in some cases these voids may act as a channel for water to travel under a foundation system with poor area drainage. If this condition exists, it may result in higher seasonal movements than predicted in this report and may cause distress to floor slab. Close attention should be exercised during construction of these voids.

It is our opinion that the determination whether or not to provide voids under the grade beams be made after both the positive and negative aspects are evaluated. Kenall from our experience with these voids, as well as the experiences of other experts, brings us to the conclusion that even though they may be effective in reducing swell pressures on the grade beams, they may provide free water which would be available for absorption by slab support soils.

5.2.4 Groundwater Control

No groundwater was encountered on drilling tools during drilling operations. 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.

It is recommended that the actual groundwater conditions be verified by the contractor at the time of construction and that groundwater control be performed in general accordance with the latest City of Houston Standard Specifications.

6 CONSTRUCTION CONSIDERATIONS

6.1 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 ±2 percentage points of the material's optimum.

Any select, non-expansive fill (structural fill) used at the site should have a Liquid Limit less than 40 and a Plasticity Index between 8 and 20. The select fill material should be placed in maximum of eight (8) inch loose lifts and compacted to a minimum of 98 percent of the maximum dry density as per ASTM D-698 in loading areas (grade beam) and 95 percent of the maximum dry density as per ASTM D-698 in other areas. The fill should be compacted at moisture content within three percent above optimum to reduce swelling potential of compacted fill.

6.2 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.

The Contractor should be responsible for monitoring existing structures nearby and taking necessary action to mitigate impact to adjacent structures. Existing structures located close to the proposed construction excavations should be surveyed prior to construction and pre-existing conditions of such structures and their vicinity be adequately recorded.

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.

Based on experience with the general area soils underreams can be successfully installed with a bell to shaft ratio of at least 2 and not exceeding 3. If the underreams are unstable or marginally stable with 3:1 bell to shaft ratio, the bell to shaft ration can be changed by increasing the shaft diameter. If the soil conditions warrant the changing of the shaft diameter, the Structural Engineer of record should be informed about any changes because they may require a change in reinforcing steel or bell diameter.

6.1 Site Drainage

It is recommended that site drainage be well developed. Drainage is important from the standpoint of soil stability. Surface water should be directed away from the foundation soils (use a minimum slope of 5% within 10 feet of foundation). No ponding of surface water should be allowed near the structure. Good drainage should be provided not only under the structure, but the general area should be well drained.

6.2 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.

6.3 Design Review

Review of the design and construction plans as well as the specifications should be performed by Kenall 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 to perform a design review, additional fees would be applicable.

7 LIMITATIONS

This report was prepared for the exclusive use of the Huitt-Zollars, Inc. and City of Houston, for specific application to the construction of the referenced project at the aforementioned location in Humble, 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.

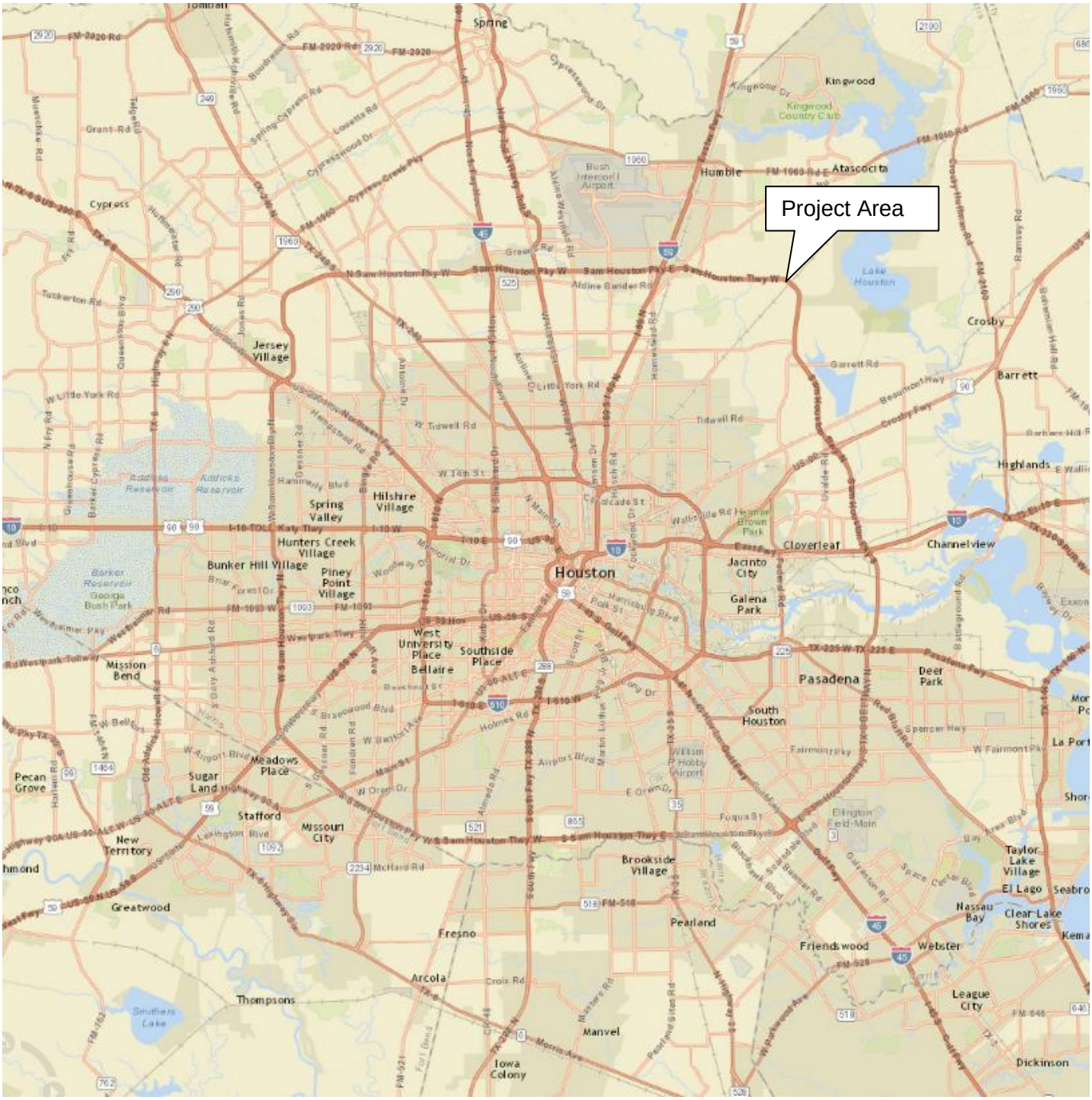
The analyses and recommendations contained in this report are based on the data obtained from the referenced subsurface exploration. The boring indicates subsurface conditions only at the specific locations and times, and only to the depths penetrated. The boring does not necessarily reflect strata variations 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. Kenall is not responsible for any claims, damages, or liability associated with interpretation of subsurface data, reuse of the subsurface data, or engineering analyses without expressed written authorization of Kenall.

ILLUSTRATIONS

Description:	Plate No.
Site Vicinity Plan	1
Plan of Boring	2
Boring Log	3
Symbols and Terminology used in Boring Log	4



N

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

PROJECT AREA LOCATION MAP
12121 N Sam Houston Pkwy E, Humble, TX
(http://www.gims.houstontx.gov/PortalWS/R.aspx?M.aspx&app=GIMS)

WBS No.: S-001000-0039-4	Project No.: 1850	Plate No. 1

Google earth

feet 100
meters 40

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

BORING LOCATION PLAN

Boring Location Map
EWPP, 12121 N Sam Houston Pkwy E

Project No. 1850	Plate No. 2

LOG OF BORING

PROJECT: Building Improvements for NEWPP
12121 N Sam Houston Pkwy E
Humble, Texas

CLIENT: Huitt-Zollars, Inc.
Houston, TX

BORING NO. 1
PROJECT NO. 1850
DATE 8-21-14
SURFACE ELEVATION N/A

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

GROUNDWATER INFORMATION:
No groundwater 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- UU Test (TSF)	DESCRIPTION OF STRATUM
				14							Light gray, gray and tan, sandy lean clay-FIll with sand from 0-2 feet
2											
			P=1.75	16		28	14	14	56		
4											4.0
			P=2.5	16							Light gray and tan, very stiff SANDY LEAN CLAY
6											6.0
			P=1.5	31							Dark gray, light gray and tan, stiff to very stiff FAT CLAY with ferrous nodules
8											
			P=1.0	31							
10											
			P=1.25	34							
12											
			P=2.25	31	91	66	18	48	97	0.69	
14											
			P=2.25	33							
16											
			P=2.5	31							
18											
			P=2.5	31							
											20.0

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

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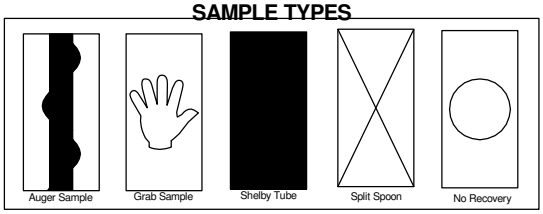
UNIFIED SOIL CLASSIFICATION CHART-ASTM 2487

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

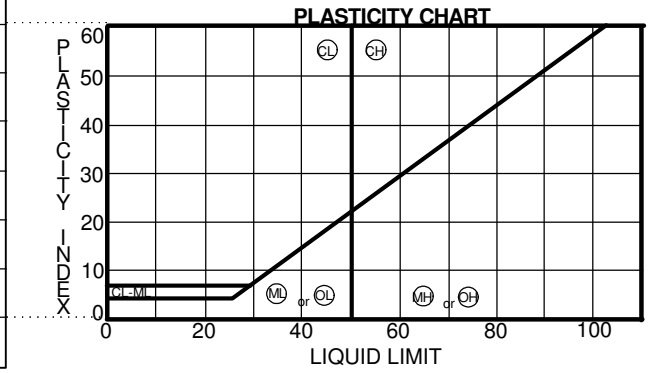
SAMPLE TYPES



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)

Boulders	Cobbles	Gravel		Sand			Silt or Clay	Clay
		Coarse	Fine	Coarse	Medium	Fine		

Sieve sizes: 6", 3", 3/4", 4, 10, 40, 200

Grain size in mm: 152, 76.2, 19.1, 4.76, 2.0, 0.42, 0.074, 0.002

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

ABBREVATIONS USED FOR CONSISTENCY

COHESIVE SOILS	COHESIONLESS SOILS
V/So: Very Soft	V/Lo: Very Loose
So: Soft	Lo: Loose
Fm: Firm	M/De: Medium Dense
St: Stiff	De: Dense
V/St: Very Stiff	V/De: Very Dense
Hd: Hard	

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Geotechnical, Environmental & Material Engineers

Approved By: KP | Prepared By: IG

KEY TO SOIL CLASSIFICATION AND SYMBOLS

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