GEOTECHNICAL STUDY
23RD STREET RECONSTRUCTION
FROM BROADWAY AVENUE J TO SEAWALL BOULEVARD
GALVESTON COUNTY, TEXAS

PROJECT NO. 19-018E

TO

LJA ENGINEERING, INC.
HOUSTON, TEXAS

BY

GEOTECH ENGINEERING AND TESTING

SERVICING

TEXAS, LOUISIANA, NEW MEXICO, OKLAHOMA

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Project No. 19-018E
Report No. 1
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August 22, 2019

Attention: Mr. Wallace Trochesset, P.E.
Vice President

GEOTECHNICAL STUDY
23RD STREET RECONSTRUCTION
FROM BROADWAY AVENUE J TO SEAWALL BOULEVARD
GALVESTON COUNTY, TEXAS

Gentlemen:

Submitted here is Geotech Engineering and Testing (GET) geotechnical study of subsurface condition for the above referenced project. The planned paving improvements were discussed in detail with Mr. Wallace Trochesset, P.E. in order to plan a study that would provide the necessary design and construction recommendations. This study was conducted in general accordance with GET Proposal No. P19-008, Revision III, dated April 24, 2019 and authorized by Mr. Wallace Trochesset, P.E. on June 10, 2019.

This report presents the results of our geotechnical field exploration and laboratory testing together with recommendations for the design and construction of the proposed 23rd Street reconstruction project. Our recommendations are in general accordance with the City of Galveston Standard Construction Specifications.

We appreciate the opportunity to be of service. Should you have any questions or need additional assistance, please call.

Very truly yours,

GEOTECH ENGINEERING AND TESTING
TBPE Registration Number F-001183

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1.0 EXECUTIVE SUMMARY

It is planned to reconstruct approximately 4,000-ft linear feet of paving and 4,750-linear feet of drainage improvements with surface restored along 23rd Street area in Galveston County, Texas. Water, storm sewer and sanitary sewer lines will be constructed along 23rd Street from Broadway to Seawall Boulevard. Furthermore, storm sewer lines will be constructed along Avenue K Rear and Avenue N both from 21st Street to 23rd Street. A site vicinity map is presented on Plate 1. We understand that either concrete or asphalt pavement will be constructed along 23rd Street from Broadway to Seawall Boulevard, and Avenue K Rear and Avenue N, both from 21st Street to 23rd Street.

The subsoils and groundwater conditions were evaluated by conducting thirteen (13) soil test borings (B-1 through B-13) along the project alignment to a depth of 16-ft below the existing grade. Results of our field exploration and engineering analyses are summarized below:

1. In general, based on our field exploration and laboratory testing data, the soil stratigraphy along the project alignment generally appears to be relatively uniform. The soil stratigraphy along the project alignment is summarized as follows:

Stratum No.	Range of Depth, ft.	Soil Type
		ASPHALT PAVEMENT (3.0- to 5.5-inch in thickness)
		CONCRETE PAVEMENT (4.0- to 9.0-inch in thickness, except Borings B-10 and B-11)
I	0.3 – 2	FILL: SILTY SAND (SM), light brown, light gray, brown, brownish yellow, with root fibers to 2', gravels, shell
II	2 – 25	SILTY SAND (SM), loose to medium dense, gray to light gray, dark gray, greenish gray, brown to light brown, dark brown, brownish yellow, with root fibers to 16', shell, gravels

2. Depth to groundwater will be important for design and construction of the proposed storm sewers. Water level observations were made during and after about 0.5-hour of drilling. Our short-term field exploration indicates that groundwater was encountered at depths ranging between 6- to 12-ft during and after 0.5-hour drilling in Borings B-1 through B-13.

3. We understand that open cut excavation construction techniques will be used for the construction of storm sewers and water lines installations. Furthermore, auguring construction techniques will be used for sanitary sewer lines installations. The bedding and backfill recommendations for the construction of the proposed underground utilities are also presented in this report.

4. The bedding and backfill for the underground utilities should be conducted in accordance with the City of Galveston Standard Specifications, Section 02227 – Excavation and Backfill for Utilities and Section 02252 – Cement Stabilized Sand for backfill and bedding, respectively.

5. We understand that either concrete pavement or asphalt pavement will be used for this site. Our recommendations for pavement are presented in Section 8.0 of this report.

2.0 INTRODUCTION

It is planned to reconstruct approximately 4,000-ft linear feet of paving improvements and 4,750-linear feet of drainage improvements with surface restored along 23rd Street area in Galveston County, Texas. Water, storm sewer and sanitary sewer lines will be constructed along 23rd Street from Broadway to Seawall Boulevard. Furthermore, storm sewer lines will be constructed along Avenue K Rear and Avenue N both from 21st Street to 23rd Street. A site vicinity map is presented on Plate 1 and A-1 in Appendix A. We understand that either concrete or asphalt pavement will be constructed. The proposed alignments for paving improvements and underground utilities are presented on Plate 2. The specific project information is as follows:

Project	Remarks
Paving	New concrete or asphalt pavement will be constructed. We understand that the proposed roadway will be considered as an arterial. It will be designed per City of Galveston pavement details.
Storm Sewer Lines	The storm sewer lines will be up to 60-inches diameters. The invert depth of the storm sewer will be less than 10-ft. We understand the basic construction techniques for the sewer lines will be open cut.
Water Lines	The water lines will be about 6- to 8-inch in diameter. The water lines will be approximately 5 to 6-feet deep. The basic construction techniques for the sewer lines will be open cut.
Sanitary Sewer Lines	Sanitary sewer lines will be constructed along the proposed alignment. The sanitary sewer lines will be 6-inch to 30-inch in diameter. The invert depth of the sanitary lines is not available at the time of this study. The basic construction techniques for the sanitary sewer lines will be auguring.

The scope of our work consisted of conducting a geotechnical study for the project alignment and developing recommendations with respect to design and construction of the pavement and underground utilities. Furthermore, the proposed paving improvement and underground utilities will be constructed in accordance to The City of Galveston Specifications (Ref. 1).

This report briefly describes the field exploration and laboratory testing followed by our engineering analyses and recommendations.

3.0 FIELD EXPLORATION

3.1 Pavement Coring

The existing pavement was cored prior to drilling and sampling. The results of pavement coring show that the existing pavement consists of asphalt pavement in Borings B-10 and B-11 and asphalt pavement overlaid concrete pavement in Boings B-1 through B-9, B-12 and B-13. The existing pavement thicknesses are presented on Plate 3, and respective boring logs, Plates A-4 through A-16 in Appendix A. The pavement core locations were patched with Quickcrete.

3.2 Drilling and Sampling

The soil conditions were explored by conducting thirteen (13) borings along the project alignment. During sampling, locations of the borings were decided based on the discussion with Ms. Melissa DeLaRosa (City of Galveston representative) and presented in Plate A-2, in Appendix A. All pavement corings were conducted prior to drilling and sampling. Soil samples were obtained continuously at each boring location from the ground surface to 16-ft.

Cohesionless soils were generally sampled with a split-spoon sampler driven in general accordance with the Standard Penetration Test (SPT), ASTM D 1586. This test is conducted by recording the number of blows required for a 140-pound weight falling 30-inches to drive the sampler 12-inches into the soil. Driving resistance for the SPT, expressed as blows per foot of sampler resistance (N), is tabulated on the boring logs.

Soil samples were examined and classified in the field. This data, together with a classification of the soils encountered and strata limits, is presented on the soil stratigraphy profile, Plate A-3 in Appendix A. The logs of borings are presented on Plates A-4 through A-16 in Appendix A. A key to log terms and symbols is shown on Plate A-17 in Appendix A.

Depth to groundwater will be important for design and construction of the proposed underground utility lines. For this reason, borings were drilled dry and the depth at which groundwater was first encountered, then wet rotary was used to drill for borings B-1 through B-13. Water level observations made during and 0.5-hr after drilling in the borehole are indicated at the bottom portion of the individual logs. The boreholes were grouted with non-shrink grout using tremie method after the completion of the field work.

4.0 LABORATORY TESTS

4.1 General

Soil classifications and shear strengths were further evaluated by laboratory tests on representative samples of the major strata. The laboratory tests were performed in general accordance with ASTM Standards. Specifically, ASTM D 2487 is used for classification of soils for engineering purposes. Furthermore, summary of test results is presented in Plates A-18 through A-30 in Appendix A.

4.2 Classification Tests

As an aid to visual soil classifications, physical properties of the soils were evaluated by classification tests. The tests were conducted in general accordance with ASTM standards. These tests consisted of natural moisture content tests (ASTM D 4643), percent finer than the No. 200 sieve tests (ASTM D 1140). Similarity of these properties is indicative of uniform strength and compressibility characteristics for soils of essentially the same geological origin. Results of these tests are tabulated on the boring logs at respective sample depths.

4.3 Soil Sample Storage

Soil samples tested or not tested in the laboratory will be stored for a period of fourteen days subsequent to submittal of the final report. The samples will be discarded after this period, unless we are instructed otherwise.

5.0 SITE GEOLOGY

According to the soil survey of Galveston County, Texas (prepared by the U.S. Department of Agriculture Soil and Conservation Service (1976), geologically the project areas at the proposed project alignment lies on the soil of BBBX – Bb – Beaches (BBBX). This is in broad, nearly level to undulating, and nonsaline to extremely saline. It mainly consists of sandy marine deposits and varied amounts of shell fragments. It is reworked by both the tide and wind. It is barren. The lower areas are inundated daily by high tides. The higher areas are inundated regularly by spring tides. A high-water table is at or near the surface throughout the year.

The land area is immediately adjacent to the Gulf of Mexico from the mean tide to the back of the coastal dunes. The surface is plane in front of the dunes and is undulating within the dune area. The slopes range from as low as 0.2 percent in the area in front of the dunes to as high as about 15 percent on the side slopes of a few of the dunes. The mapped areas are long and narrow and range from 10 acres to about 100 acres.

6.0 GENERAL SOILS AND DESIGN CONDITIONS

6.1 Site Conditions

Currently, the project alignment along Avenue K Rear from 21st Street to 23rd Street is asphalt pavement, the rest of the project alignments are asphalt pavement overlaying concrete pavement. In general, the vicinity of the project alignment consists of residential and commercial facilities. Pictures of the project alignment were taken during our site visit. These pictures are presented on cover page and Appendix B.

6.2 Soil Stratigraphy

In general, based on our field exploration and laboratory testing data, the soil stratigraphy along the project alignment generally appears to be relatively uniform. Details of subsoil conditions at each boring location along the project alignment are presented on the respective boring logs. In general, the soils can be grouped into two (2) major strata with depth limits and characteristics as follows:

Stratum No.	Range of Depth, ft.	Soil Description
		ASPHALT PAVEMENT OVERLAY (3.0- to 5.5-inch in thickness)
		CONCRETE PAVEMENT (4.0- to 9.0-inch in thickness, except Borings B-10 and B-11)
I	0.3 – 2	FILL: SILTY SAND (SM), light brown, light gray, brown, brownish yellow, with root fibers to 2’, gravels, shell
II	2 – 16	SILTY SAND (SM), loose to medium dense, gray to light gray, dark gray, greenish gray, brown to light brown, dark brown, brownish yellow, with root fibers to 16’, shell, gravels

* Classification in general accordance with the modified Unified Soil Classification System (ASTM D 2487)

6.3 Soil Properties

Soil strength and how they relate to underground utilities and pavement design are summarized as follows:

Stratum No.	Soil Type	#200 Passing	SPT	Soil Expansivity	Remarks
I	Fill: Silty Sand (SM)	5 – 11	–	Non-Expansive	Moisture Sensitive
II	Silty Sand (SM)	6 – 24	7 – 28	Non-Expansive	Moisture Sensitive

Legend: SPT = Standard Penetration Test

6.4 Water-Level Measurements

The soil borings were first drilled dry to evaluate the presence of perched or free-water conditions. A wet rotary boring technique was used thereafter to the completion depth of the boring. The levels where free water was encountered in the open boreholes during and about 0.5-hour after drilling are shown on the boring logs. Our groundwater measurements are summarized below:

Boring Numbers (s)	Groundwater Depth, ft. at the time of Drilling	Groundwater Depth, ft. at 0.5 Hour Later
B-2. B-5 through B-7, and B-10 through B-13	6	6
B-3	7	7
B-1, B-4, and B-8	8	8
B-9	12	12

Fluctuations in groundwater generally occur as a function of seasonal moisture variation, temperature, groundwater withdrawal and future construction activities that may alter the surface drainage and subdrainage characteristics of this site.

An accurate evaluation of the hydrostatic water table in the relatively impermeable clays and low permeable silts/sands requires long term observation of monitoring wells and/or piezometers. It is not possible to accurately predict the pressure and/or level of groundwater that might occur based upon short-term site exploration.

We recommend that GET be immediately notified if a noticeable change in groundwater occurs from that mentioned in our report. We would be pleased to evaluate the effect of any groundwater changes on our design and construction sections of this report.

7.0 UNDERGROUND UTILITIES

7.1 General

We understand that underground utilities installation along the alignment will include storm sewers, sanitary sewers and waterlines. The storm sewer lines will be up to 60-inches diameters. The invert depth of the storm sewer will be less than 10-ft. The water lines will be about 6- to 8-inch in diameter. The water lines will be approximately 5 to 6-feet deep. We understand the basic construction techniques for the storm sewer lines and water lines will be open cut. The sanitary sewer lines will be 6-inch to 30-inch in diameter. The invert depth of the sanitary lines is not available at the time of this study. We understand the basic construction techniques for the sanitary sewer lines will be auguring. Furthermore, the proposed underground utilities will be constructed in accordance to The City of Galveston Specifications (Ref. 1).

7.2 Open Excavation Method

For open-trench construction, bedding and backfill for the proposed storm sewer lines and water lines should be constructed in accordance with the City of Galveston Specifications. Trenches for the proposed underground utilities must have a width below the top of the pipe of not less than the outside diameter of the pipe plus 24-inch and shall be wide enough to permit making up the joints but shall not be wider than the outside diameter of the pipe plus 36-inch.

In general, twelve-inch of bank sand should be placed above the utility lines. Twelve-inch lifts of bank sand should be placed below the utility lines for dry excavation bottom. In case of wet excavation bottom, geotextile fabrics should be placed at the excavation bottom and along the excavation sides to a height of at least 24-inch.

7.3 Augering and Augering Pits Method

We understand that augering method may be used for sanitary sewer lines installation. The augering should be conducted in accordance with the City of Galveston Standard Specifications, Section 027698 – Pipe Bursting/Crushing Sanitary Sewers. Augering should be started from approved pit locations. Excavation for pits and shoring installation should conform to the City of Galveston Standard Specifications, Section 02227 – Excavation and Backfill for Utilities. If the augering zone is within the cohesionless soils or caving soils, install casing as required by the City of Galveston Standard Specifications, Section 02315 – Pipe and Casing Augering for Sewers. The augering near existing structures or utility lines should be conducted in accordance with the City of Galveston Standard Specification. Diameter of auger hole should not exceed pipe bell diameter plus 2 inches. The receiving pit distance should conform to the City of Galveston Standard Specifications.

7.4 Storm and Sanitary Sewer Lines

Bedding and backfill for the storm and sanitary sewer lines should be in accordance with the City of Galveston Specifications, Section 02720 – Storm Sewers , Section 02730 – Gravity Sanitary Sewers and Section 02731 – Sanitary Sewer Force Main.

The results of our field exploration and laboratory testing indicate that unsatisfactory soils for excavation, such as silty sand (SM) soils exist in the borings. A summary of the unsatisfactory soils locations and depths are as follows:

Boring(s)	Depth, ft.
B-1 through B-13	0.3 to 16

If these conditions are encountered during the time of construction, suitable groundwater control measures should be implemented in accordance with the City of Galveston Specifications, Section 01563 – Control of Groundwater and Surface Water. Furthermore, the contractor may have to over excavate an additional 6 inches and remove unstable or unsuitable materials with approval by geotechnical engineer, and then place an equal depth of cement stabilized sand.

Due to potential variability of the on-site soils, unstable trench conditions may still exist in the areas where we did not conduct borings. If these conditions are encountered during the time of construction, a stable trench should be provided to allow proper bedding and installation.

Sand backfill used in the cement stabilized sand and sand backfill sections should be free of clay lumps, organic materials, or other deleterious substances, and should have a PI less than 4 for the cement-stabilized sand and less than 7 for the sand backfill section, and not more than 15% passing the No. 200 sieve. Cement stabilized sand should conform to the City of Galveston Specifications, Section 02252 – Cement Stabilized Sand.

Due to the presence of silty sands, relatively shallow groundwater table and corresponding hydrostatic pressure, the pipe should be restrained against movements by strapping over the pipe. The straps should be flat and strong enough to withstand the upward flow.

7.5 Waterlines

For open-trench construction, bedding and backfill for the proposed waterlines should be constructed in accordance with the City of Galveston Specifications, Section 02227 – Excavation and backfill for utilities. Trenches for the proposed waterlines must have a width below the top of the pipe of not less than the outside diameter of the pipe plus 24-inch and shall be wide enough to permit making up the joints but shall not be wider than the outside diameter of the pipe plus 36-inch.

In general, twelve-inches of bank sand should be placed above the waterlines. Twelve-inch lifts of bank sand should be placed below the waterlines for dry excavation bottom. In case of wet excavation bottom, geotextile fabrics should be placed at the excavation bottom and along the excavation sides to a height of at least 24-inch.

Due to the presence of silty sands, relatively shallow groundwater table and corresponding hydrostatic pressure, the pipe should be restrained against movements by strapping to helical piles over the pipe. The straps should be flat and strong enough to withstand the upward flow. Top straps should be connected to helical piles to resist uplift.

7.6 Groundwater Control

7.6.1 General

Our short-term field exploration indicates that groundwater was encountered at the time of drilling. Therefore, groundwater dewatering will be required. Fluctuations in groundwater can occur as a function of seasonal moisture variations. Groundwater control recommendations are presented in the following report sections.

7.6.2 Dewatering Technique

It is our opinion that groundwater should be lowered to a depth of at least three-ft below the deepest excavation grade in order to provide dry working conditions and firm bedding. Any minor water inflow in cohesive soil layers can probably be removed using a sump-pump or trench sump-pump. Wellpoint system can be used in the area where silty sand soils are present. The selection and proper implementation of an effective groundwater control system is the responsibility of the contractor. **Due to the presence of silty sand soils and the hydrostatic pressures, blow up may occur if an effective dewatering system is not in place at the time of construction.**

Design of a wellpoint system should consider the amount of groundwater to be lowered and the permeability of the affected soils. The selection and proper implementation of an effective groundwater control system is the responsibility of the contractor. The design of groundwater and surface water should be in accordance with The City of Galveston Specifications, Section 01563 – Control of Groundwater and Surface Water.

7.7 OSHA Soil Classifications

The subsoils can be classified in accordance with Occupational Safety and Health Administration (OSHA) Standards, dated October 31, 1989 of the Federal Register. OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. The description of four (4) types in classification system is summarized in the Appendix C

Based on our geotechnical exploration and laboratory test results, details of soil classifications at each boring are summarized in the OSHA Soil Classification and Trench Safety Recommendations, presented in Appendix C.

7.8 Excavations

An excavation or trench which is five-ft or deeper must be protected by sheeting/bracing shoring or sloped. Based on soil strength data and OSHA soil classifications, temporary (less than 24 hours) open-trenched, non-surcharged, and unsupported excavations should be made on slopes of about 1.5(h):1(v). Vertical cuts can be constructed, provided shoring and bracing are used for the excavation wall stability. Benched excavation can also be used with average slopes of about 1(h):1(v) and steps should not be higher than five-ft. In all cases, excavations should conform to OSHA guidelines. Flatter slopes may have to be used if large amounts of sand need to be excavated for deep installations. Specifications should require that no water be allowed to pond in the excavations. The surface slopes should be protected from deterioration and weathering if they are to be left open for more than 24 hours.

Excavations should be performed with equipment capable of providing a relatively clean bearing area. Excavation equipment should not disturb the soil beneath the design excavation bottom and should not leave large amounts of loose soil in the excavation.

7.9 Lateral Earth Pressures

In the event that open excavations are not used, the proposed underground utilities can be installed using trench sheeting. The sheeting can be constructed in the form of cantilever sheeting or with bracing. Lateral earth pressures for each method used are summarized on Plate 4. The trenching and shoring operations should follow OSHA Standards. We recommend a geotechnical engineer monitor all phases of trench excavation and bracing to assure trench safety. Furthermore, a letter for trench safety recommendation is provided separately.

7.10 Backfilling

7.10.1 Backfilling for Open-Excavation

Sand backfill used in the cement-stabilized sand and sand backfill section should be free of clay lumps, organic materials, or other deleterious material, and should have a PI less than 4 for cement-stabilized sand and less than 7 for the sand backfill, and not more than 15% passing the No. 200 sieve. Cement stabilized sand should conform to The City of Galveston Specifications, Section 02252 – Cement Stabilized Sand.

Random fill for zones above pipe bedding should be placed in loose lifts not exceeding eight-inch and compacted to 100% of the natural soil density. This value will be on the order of 95% of standard density (ASTM D 698) at a moisture content between optimum and +3% of optimum. These values should be verified by testing during construction.

7.10.2 Backfilling for Auger Pits and Auger Holes

Sand used in backfill sections should be free of clay lumps, organic materials, or other deleterious substances, and should have a PI less than 7, and not more than 15% passing the No. 200 sieve.

Backfill should be placed in accordance with The City of Galveston Specifications, Section 02227 – Excavation and Backfill for Utilities.

7.11 Loads Imposed on Buried Pipes

7.11.1 General

The loads on an underground pipe depend principally upon the weight of overburden soils, roadway and loads due to surcharges. For design of concrete pressure pipe, linear load due to overburden can be determined based on the design tables and charts presented in the "AWWA Manual of Water Supply Practices Concrete Pressure Pipe (AWWA M9)" developed by the American Concrete Pipe Association. Overburden pressure for the buried pipes at the project alignments are estimated by using the soil density (γ) and the height of the soil over the pipe (H).

7.11.2 Loads Due to Overburden Pressure

Overburden or prism load for buried pipes is given by the following equation:

$$P = \gamma H$$

Where: P = Load due to weight of soils at depth, psf
γ = Total Unit weight of soil, 125 pcf
H = Height of the soil over the pipe, ft

Loadings per linear foot of pipe:

$$W_e = C_d \gamma (B_d)^2 \text{ (Marston Equation)}$$

$$C_d = \frac{1 - e^{-2ku'\left(\frac{H}{B_d}\right)}}{2ku'}$$

Where: W_e = Load, pounds per linear foot (lb/ft)
B_d = Trench width (ft)
C_d = Load Coefficient
k = Friction angle between backfill and soil
u' = Coefficient of friction between fill material and sides of trench
ku' = for sand = 0.165

7.11.3 Piping System Thrust Restraint

Fittings on underground pipes are subject to thrust forces inherited from the fluid pressure in the pipe and are directly proportional to the fluid pressure. Unbalance thrust forces will be developed in pressure pipelines due to changes in direction, cross-sectional areas, or when the pipe is terminated. These forces may cause joints to disengage if not adequately restrained. There will be a slight loss of head due to turbulence friction in bends of the pipes. This loss will cause a pressure change across the bend, but it is usually small enough to be neglected.

The thrust force may require more reaction than is available just from the pipe bearing against the backfill. In order to prevent intolerable movement and overstressing of the pipe, suitable buttressing should be provided. In general, thrust blocks, restrained joints and tie rods are common methods of providing reaction for the thrust restraint design. The thrust restraint design provisions described in this section are based on the American Water Works Association Manual M9 (1996)-Concrete Pressure Pipe.

The force diagram shown on Plate 5 illustrates the thrust force generated by flow at a bend in the pipe. The equations for computing this thrust force are also given on this plate. The values of thrust force for a surge pressure of 50 psi were computed for a bend angle of 90 degrees. Once the size of the thrust is determined, a thrust block size can be calculated based on the bearing capacity of the soil. The area of block required is equal to the thrust force (lb) divided by the safe bearing value of the soil (psf). In cohesive soils, the safe bearing value is equal to 2/3 of the average shear strength of the soil adjacent to the block which includes a factor of safety of 3. We believe that a factor of safety of 3 is appropriate in order to limit deflections required to mobilize the passive resistance within tolerable values.

For granular soil encountered at this site, a safe bearing value for thrust blocks can be taken as 90% of the effective overburden pressure at the mid height of the thrust block which includes a factor of safety of 3. The effective overburden pressure can be calculated based on the effective unit weight of the soil above the mid-height of the thrust block.

Geotechnical design parameters for designing the necessary buttressing are as follows:

γ : = Wet unit weight of soil − above water level : 125 pcf
Submerged unit weight of soil − below water level : 60 pcf
c : = Cohesion = 1000 psf (for clay)
ϕ : = Angle of internal friction = 30 degrees (for sand)

8.0 PAVEMENT SECTIONS

8.1 General

It is planned to reconstruct approximately 4,000-ft linear feet of paving improvements and 4,750-linear feet of drainage improvements with surface restored along 23rd Street area in Galveston County, Texas. We understand that either concrete or asphalt pavement will be constructed. The proposed concrete or asphalt roadway will be considered as a arterial.

The laboratory data indicates that the upper subsoils are classified as silty sand (SM) soils by the Unified Soil Classification System. These soils have subgrade moduli, k, ranging from 30 to 140 pci and CBR values ranging from 3 to 15.

Based on the subgrade soil properties, the recommended pavement thickness for rigid and flexible paving is given on Table I on the following page of this report. Our recommendations were developed on the City of Galveston Design Specifications, dated March 03, 1997 (Ref. 1).

Detailed traffic analysis was not conducted to evaluate the pavement sections in this report. We recommend that additional studies be conducted to evaluate the proposed pavement traffic loading. This information can be used to evaluate the required pavement sections. Adequate site drainage is essential to pavement performance in accordance with design criteria.

It should be noted that our recommendations on subgrade stabilization assume that final paving grade will be at the top of existing subgrade. Alternative subgrade stabilization recommendations will be required if the final subgrade is different from the one assumed in this report. Actual type and quantity of subgrade stabilization should be determined at the time of construction when the pavement subgrade has been exposed.

TABLE I

Rigid Pavement (Protected Corner)		Design Thickness for Arterial, in
Surface:	Concrete Pavement	7
Subgrade:	Lime-Fly Ash Stabilized Subgrade (See Notes 1 and 2, City of Galveston Design Specification Section 02242) Compact to 95% of Maximum Standard Proctor Density (ASTM D 698) at a moisture content within ±2% of optimum	6

Concrete flexural strength should be at least 570 psi at 28 days. This corresponds to a compressive strength of 3000 psi at 28 days. The paving should be reinforced with #4 bars at 18-inches on centers each. Suggested longitudinal and transverse joint spacing for concrete paving is 15-feet. The expansion joint spacing is approximately 80-feet. Steel used for reinforcements should be grade 60.

Flexible Pavement		Design Thickness for Arterial, in
Surface:	Hot-Mix Asphaltic Concrete (City of Galveston Design Specification Section 02510)	3
Base Course:	Crushed Stone (City of Galveston Design Specification Section 02231) and compacted to 95% of of Maximum Standard Proctor Density (ASTM D 698) at a moisture content between optimum and +3% of optimum.	10
Subgrade:	Lime-Fly Ash Stabilized Subgrade (See Notes 1 and 2, City of Galveston Design Specification Section 02242) Compact to 95% of Maximum Standard Proctor Density (ASTM D 698) at a moisture content within ±2% of optimum	8

NOTES:

1. Reference City of Galveston Design Specifications.

2. Use 2% lime and 8% fly-ash by dry weight to stabilize the upper soils. The application rates will be approximately 12 pounds of lime and 48 pounds of fly-ash per square yard for eight inches of compacted thickness.

8.2 Subgrade Stabilization

The type of subgrade stabilization for the concrete or asphalt pavement areas will depend on the final grade elevation. Subgrade preparation in pavement areas should specify compaction of the upper eight-inches to at least 95% of maximum standard Proctor density (ASTM D 698) at a moisture content with ±2% of optimum. Our field and laboratory tests indicate that the surficial soils consist of silty sand fill soils. Depending on the type of soils encountered, lime-fly ash stabilization of the surficial soils should most likely be performed. The upper eight-inches of the soils should be lime-fly ash stabilized, using 2% lime and 8% fly-ash by dry weight. The application rates corresponding to these additive amounts would be 12 pounds of lime and 48 pounds of fly-ash per square yard, for eight-inches of compacted thickness. City of Galveston Specification Section 02242 can be used as a procedural guide for placing, mixing and compacting lime-fly ash stabilizer and soils.

In the event lime-fly ash is not available, cement can be used to stabilize the subgrade soils. Subgrade preparation using cement stabilization in pavement areas should specify compaction of the upper eight-inches to at least 95% of maximum standard Proctor density (ASTM D 698) at a moisture content between ±2% of the optimum value. The ratio of cement to soil will be based on dry material weight and shall be established by the Geotechnical Engineer in the field to provide the desired stability. The ratio of cement to soil should be generally about 8% percent by dry weight. The application rate corresponding to this additive would be 45 pounds per square yard of six-inches of applications. City of Galveston Specification, Section 02252, can be used as a procedural guide for placing, mixing and compacting cement stabilized soils.

9.0 CONSTRUCTION CONSIDERATIONS

9.1 Site Preparation

The project site has the potential for construction problems related to the surficial layer of silty sand (SM) fill soils. The surficial silty sand (SM) fill soils could become extremely soft when wet, and must be stabilized, aerated, or replaced. In the event that the surficial silty sand (SM) fill soils become wet, they will experience rutting and pumping. Therefore, these soils should be improved. The depth of the improvement is generally to the bottom of the surficial granular layer. Our recommendations on subgrade improvements are presented in the earthwork section of this report. Site preparation for the proposed development should be conducted in accordance with The City of Galveston Specifications, Section 02105 – Site Preparations. In general, our recommendations for site preparations in the floor slab and pavement areas are summarized below:

1. In general, remove all vegetation, tree roots, organic topsoil, existing foundations, paved areas and any undesirable materials from the construction area. Tree trunks and tree roots under the floor slabs should be removed to a root size of less than 0.5-inch. We recommend that the stripping depth be evaluated at the time of construction by a soil technician.

2. Any on-site fill soils, encountered in the structure and pavement areas during construction, must have records of successful compaction tests signed by a licensed professional engineer that confirms the use of the fill and record of construction and earthwork testing. These tests must have been performed on all the lifts for the entire thickness of the fill. In the event that no compaction test results are available, the fill soils must be removed, processed and recompacted in accordance with our site preparation recommendations. Excavation should extend at least two-feet beyond the structure and pavement area. Alternatively, the existing fill soils should be tested comprehensively to evaluate the degree of compaction in the fill soils.

3. The subgrade areas should then be proofrolled with a loaded dump truck or similar pneumatic-tired equipment with loads not be less than 25-tons. The proofrolling serves to compact surficial soils and to detect any soft or loose zones. The proofrolling should be conducted in accordance with The City of Galveston Specifications. Any soils deflecting excessively under moving loads should be undercut to firm soils and recompacted. Any subgrade stabilization should be conducted after site proofrolling is completed and approved by the geotechnical engineer. The proofrolling operations should be observed by an experienced geotechnician.

4. The backfill soils in the trench/underground utility areas and tree root excavation areas should consist of selected structural fill, compacted per City of Galveston Specifications. In the event of compaction difficulties, the trenches should be backfilled with cement-stabilized sand or other materials approved by the geotechnical engineer. Due to high permeability of sands and potential surface water intrusion, bank sands should not be used as backfill material in the trench/underground utility areas and tree root excavation areas.

5. In cut areas, the soils should be excavated to grade and the surface soils proofrolled and scarified to a minimum depth of six-inch and recompacted to the previously mentioned density and moisture content.

6. Positive site drainage should be developed at the beginning of the project to limit construction difficulties with wet surface soils.

9.2 Suitability of On-Site Soils for Use as Fill

9.2.1 General

Fill requirements should be in accordance with The City of Galveston Specifications Section 02226 –Excavation and Backfill for Structures, Section 02227 – Excavation and Backfill for Utilities and Section 02229 – Utility Backfill Materials. The on-site soils can be used as fill materials as described in the following report sections.

9.2.2 Select Structural Fill

This is the type of fill that can be used for the underground utilities. These soils should consist of lean clays, free of root organics, with plasticity indices between 7 and 20 and amount of passing No. 200 sieve greater than 50 percent.

9.2.3 Structural Fill

This type does not meet the Atterberg limit requirements for select structural fill. This fill should consist of lean clays or fat clays. They can be used for the underground utilities backfill after treatment.

9.2.4 General Fill

This type of fill consists of sands and silts. These soils are moisture sensitive and are difficult to compact in a wet condition (they may pump). These soils can be used as structural fill with the understating that they can erode easily and if they get wet, they are difficult to compact (they may pump). These soils can result in a perched water table. The owner and the civil engineer must be aware of these potential issues.

9.2.5 On-Site Fill Soil Classification

Based on Borings B-1 and B-2, the on-site soils can be used as fill materials as described below:

Stratum No.[1]	Soil Type	Use as Fill: Select Structural Fill	Use as Fill: Structural Fill	Use as Fill: General Fill	Notes
I	Fill: Silty Sand (SM)	–	✓	✓	2, 3
II	Silty Sand (SM)	–	✓	✓	2, 3

Notes:
1. See soil stratigraphy and design conditions sections of this report for strata description.
2. All fill soils should be free of organics, roots, etc.
3. The on-site cohesionless soils are moisture sensitive and erode easily. These soils will pump when they get wet. Compaction difficulties will occur in these soils in a wet condition.

9.3 Surface Water Drainage

In order to minimize pounding of surface water, site drainage should be established early in project construction so that this condition will be controlled.

9.4 Earthwork

9.4.1 General

Difficult access and workability problems will most likely occur in the surficial silty sand fill soils due to poor site drainage, wet season, or site geohydrology. Considering the soils stratigraphy, the construction of this project should be conducted during the dry season to avoid major earthwork problems. The subgrade soils should be improved if they become wet and experience pumping problems. This condition can be improved by (a) opening up to dry up, (b) mixing cohesionless soils with cohesive soils, (c) improving drainage, (d) removing and replacing with dry cohesive soils or (e) chemically modifying or stabilizing the soils. These alternatives are discussed in the following report sections.

9.4.2. Improving Drainage

The project site drainage in the pumping soils can be accomplished by placing several shallow bleeder ditches (about 18-inches ±) in the surficial cohesionless soils. These bleeder ditches should be directed to a low area, such as a hole (detention pond) or another ditch in the lowest elevation area of the site. This will allow the surficial soils to drain the water and make the drying process faster. The hole/low area should not be under the building areas. The excess water can be pumped out of the hole and moved off-site.

9.4.3. Subgrade Drying

The on-site wet soils can be opened up so that it would dry up. However, opening up the surficial cohesionless soils for drying purposes may not be practical, due to cyclic rainfall in the Gulf-Coast area.

9.4.4. Soil Mixing

The on-site cohesionless (sands Strata I and II) soils can be mixed with cohesive soils to reduce subgrade pumping. The soils can come from imported in. GET can do a mix design to come up with soil mix percentages, if this option is considered.

9.4.5. Removal and Replacement

The surficial cohesionless soils can be removed and replaced with select structural fill. The actual depth of removal and replacement should be evaluated in the field, but it can be whole thickness of surficial cohesionless soils. This procedure will include removal of the surficial cohesionless soils, proofrolling and compacting the subgrade cohesive soils to a minimum of 95 percent standard Proctor density (ASTM D 698). The site can then be backfilled with select structural fill, compacted to a minimum of 95 percent of standard Proctor density. The proofrolling should be in accordance with the site preparation section of this report. All of the fill soils should be placed and tested in accordance with the site preparation section of this report.

9.4.6. Modification/Stabilization

We recommend that the on-site cohesionless soils be modified (to dry up), using 5 to 10 percent fly ash by dry weight. The fly ash stabilization should be in accordance to City of Galveston Standard Specification, 02242 – Lime/Fly Ash Stabilized Subgrade. The estimated amounts of fly ash per depth of modification are as follows:

Modification	Fly Ash Weight Range, lbs. per Square Yard	
Depth, in.	5%	10%
6	23	45
12	46	90
18	69	135
24	92	180

We recommend that five percent fly ash be used if the surficial soils are relatively moist at the time of application. Higher levels (10 percent) of fly ash should be used if wet and soggy subgrade soils are encountered.

The subgrade soils should be removed to a depth of 24-inch (or more) below existing grade. These soils should be stockpiled. The soils below a depth of 24-inch should be modified to a depth of 12-inch. These soils should be compacted to a minimum of 95 percent of standard Proctor density (ASTM D 698). The stockpiled soils should then be modified and replaced in six-inch lifts and compacted to 95 percent of maximum dry density as determined by ASTM D 698 at moisture contents within ±2 percent of optimum.

Due to poor drainage and the depth of the cohesionless soils, the depth of stabilization may be as deep as depth of cohesionless soils. A test section can be implemented for this purpose. The subgrade soils should be modified in six-inch lifts and compacted within four hours of mixing and placement. All of the subgrade soils should be compacted to a minimum of 95 percent of the standard Proctor density at the moisture content with optimum. The degree of compaction for the lifts, below a depth of 24-inch can be relaxed to 90 percent of maximum dry density to ease the construction procedures.

The subcontractor who will be doing the subgrade modification or stabilization should be experienced with stabilization procedures and methods. Furthermore, all of the earthwork at this project should be monitored by our geotechnician to assure compliance with the project specifications.

Once the subgrade is constructed, the soils at the top of subgrade should be slicked and the subgrade needs to be crowned such that the all surface water would drain away. No low areas should be left within the subgrade areas, since these areas would hold water and destroy the subgrade structure.

9.5 Construction Surveillance

Construction surveillance and quality control tests should be planned to verify materials and placement in accordance with the specifications. The recommendations presented in this report were based on a discrete number of soil test borings. Soil type and properties may vary across the site. As a part of quality control, if this condition is noted during the construction, we can then evaluate and revise the design and construction to minimize construction delays and cost overruns. We recommend the following quality control procedures be followed by a qualified engineer or technician during the construction of the facilities:

- Monitor all phases of trench safety (if trench is used).
- Observe the site stripping and proofrolling.
- Verify the type, depth and amount of stabilizer.
- Verify the compaction of subgrade soils and backfill soils.
- Evaluate the quality of fill and monitor the fill compaction for all lifts.
- Monitor and test the excavations for strength, cleanness, depth, size, etc.
- Observe all excavation operations.

10.0 RECOMMENDED ADDITIONAL STUDIES

This report has been based on assumed conditions/characteristics of the proposed development where specific information was not available. It is recommended that civil engineer along with any other design professionals involved in this project carefully review these assumptions to ensure they are consistent with the actual planned development. When discrepancies exist, they should be brought to our attention to ensure they do not affect the conclusions and recommendations provided herein. We recommend that GET be retained to review the plans and specifications to ensure that the geotechnical related conclusions and recommendations provided herein have been correctly interpreted as intended.

11.0 STANDARD OF CARE

The recommendations described herein were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical engineering profession practicing contemporaneously under similar conditions in the locality of the project. No other warranty or guarantee, expressed or implied, is made other than the work was performed in a proper and workmanlike manner.

12.0 REPORT DISTRIBUTION

This report was prepared for the sole and exclusive use by our client and owner, based on specific and limited objectives. All reports, boring logs, field data, laboratory test results, maps and other documents prepared by GET as instruments of service shall remain the property of GET. GET assumes no responsibility or obligation for the unauthorized use of this report by other parties and for purposes beyond the stated project objectives and work limitations.

13.0 REFERENCE

1. "City of Galveston Specifications", City of Galveston.

SITE VICINITY MAP

PROJECT: Geotechnical Study 23rd Street Reconstruction from Broadway Avenue J to Seawall Boulevard
Galveston County, Texas

SCALE: NOT TO SCALE	DATE: AUGUST 2019	PROJECT NO.: 19-018E

NORTH

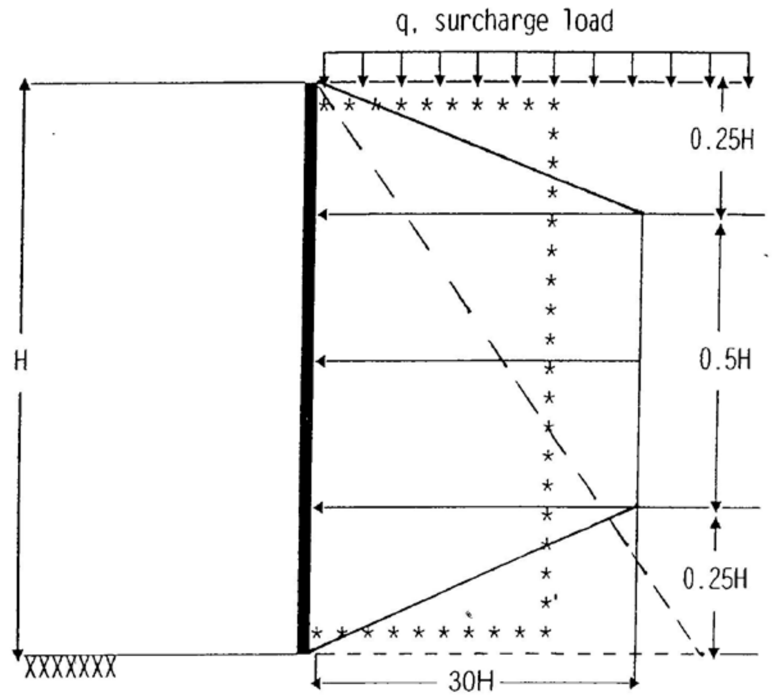
PROPOSED ALIGNMENTS AND BORING NUMBERS FOR 23RD STREET RECONSTRUCTION
FROM BROADWAY AVENUE J TO SEAWALL BOULEVARD
GALVESTON COUNTY, TEXAS

Alignment	Boring No.	From	To
23rd Street	B-1 through B-9	Broadway Avenue J	Seawall Boulevard
Avenue K Rear	B-10 and B-11	23rd Street	21st Street
Avenue N	B-12 and B-13	23rd Street	21st Street

EXISTING PAVEMENT THICKNESS

Boring Locations	Pavement Thickness, inches	
	Asphalt	Concrete
B-1	6	4
B-2	3	4
B-3	3	4
B-4	3	4
B-5	3	4
B-6	4	6
B-7	5.5	9
B-8	5	4
B-9	5.5	4
B-10	4	–
B-11	4	–
B-12	3	5.5
B-13	3	4.5

LATERAL EARTH PRESSURE DIAGRAM



Legend:

——————————— Braced Excavation (stiff clays)
* * * * * * * * * * * * * Braced Excavation (sands)
- - - - - - - - - - - - - - - Cantilivered sheeting

Active Pressure:

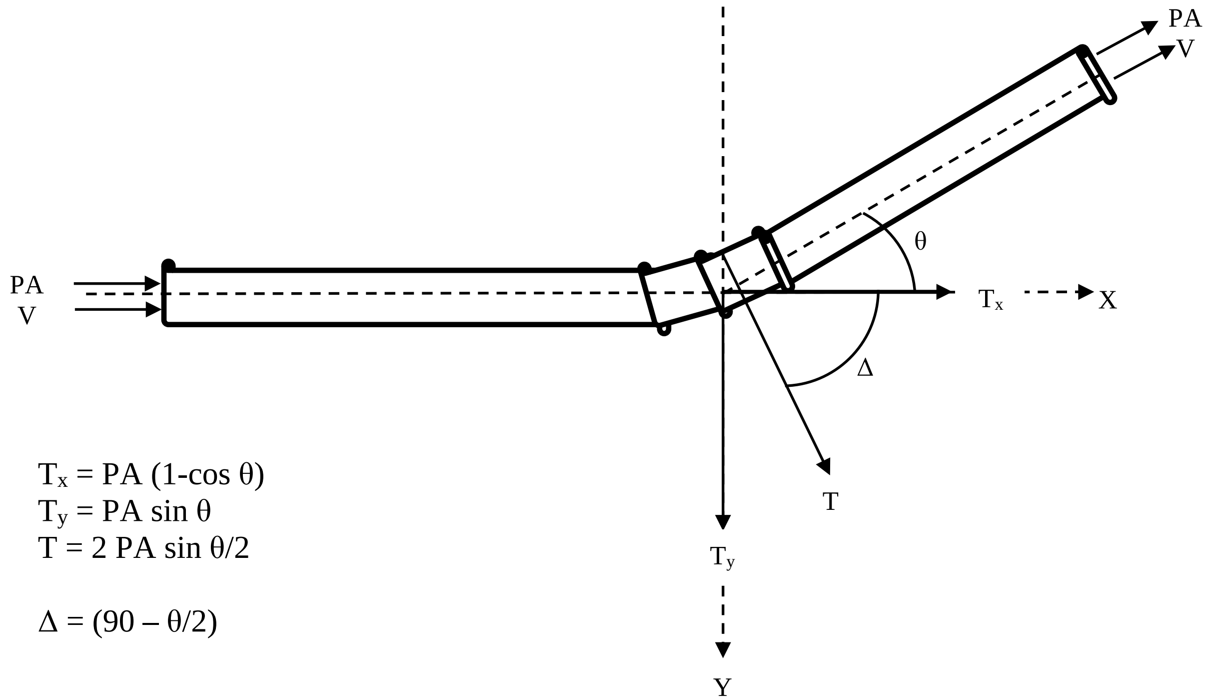
(a) Braced Excavation (stiff clays) = 0.5q + 30H + 62.4H
(b) Braced Excavation (sands) = 0.4q + 18H + 62.4H
(c) Cantilivered sheeting = 0.7q + 42H + 62.4H

where: q = surcharge load, psf
H = wall height, ft.

Notes:

1. The above Active Pressure Equations account for the groundwater at the surface.
2. The final lateral pressures should be reviewed prior to construction.
3. Trench excavation and construction should be observed by a geotechnical engineer.
4. The means and methods for a safe excavation is the responsibility of the contractor.

THRUST FORCES ACTING ON BEND



T_x = PA (1-cos θ)
T_y = PA sin θ
T = 2 PA sin θ/2

Δ = (90 – θ/2)

Where:

T = Resultant Thrust Force on the Bend
T_x = Component of Thrust Force in X-Direction
T_y = Component of Thrust Force in Y-Direction
P = Maximum Sustained Pressure
A = Pipe Cross Sectional Area
θ = Bend Deflection Angle
V = Fluid Velocity

Δ = Angle between T and X-axis
D = Inside Diameter of the Pipe

Sample Calculation:

Given P = 50 psi, D = 12-inch
$A = \pi d^2/4 = 113.1 \text{ in}^2$

For θ = 90°
T = 2 PA sin θ/2 = 2 * 50 * 113.1 * sin (90/2) = 7997.4 lb = 7.99 kips
Tx = PA (1 - cos θ) = 50 * 113.1 * (1 – cos 90°) = 5.66 kips
Ty = PA sin θ = 50 * 113.1 * sin 90° = 5.66 kips

APPENDIX A

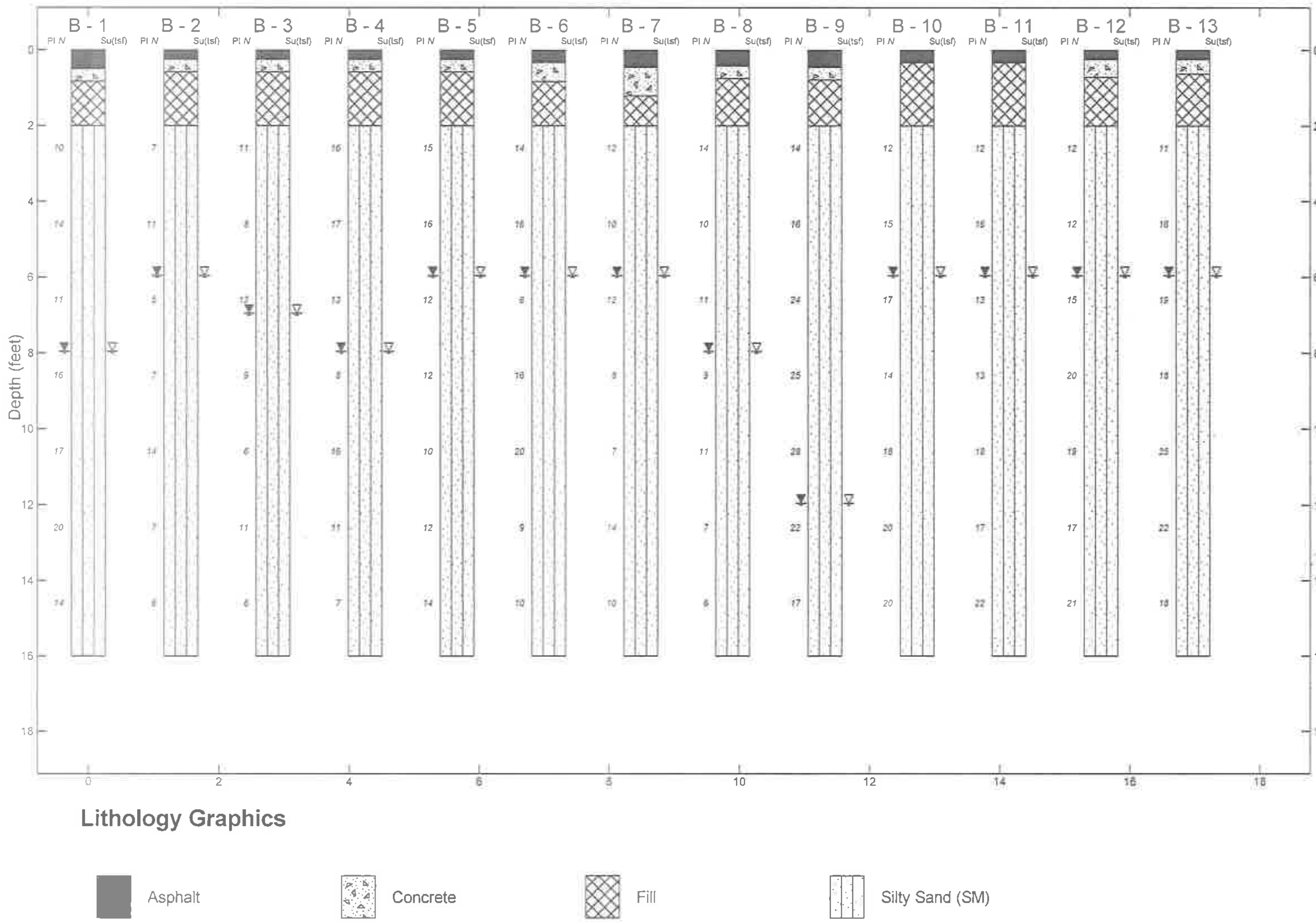
SITE VICINITY MAP

PROJECT: Geotechnical Study 23rd Street Reconstruction from Broadway Avenue J to Seawall Boulevard
Galveston County, Texas

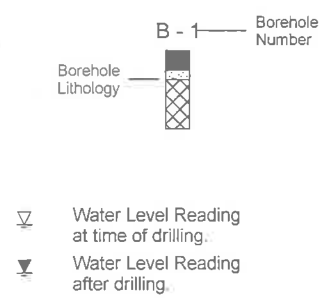
NORTH

SCALE: NOT TO SCALE	DATE: AUGUST 2019	PROJECT NO.: 19-018E

PLAN OF BORINGS (boring dimensions and locations are approximate)			NORTH
PROJECT: Geotechnical Study 23rd Street Reconstruction from Broadway Avenue J to Seawall Boulevard Galveston County, Texas			
SCALE: NOT TO SCALE	DATE: AUGUST 2019	PROJECT NO.: 19-018E	



Explanation



Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396

G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard

Galveston County, TX

JOB NUMBER	PLATE NUMBER
19-018E	Plate A-3

LOG OF BORING NO. B - 1

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DESCRIPTION:
- ASPHALT PAVEMENT (6" in thickness)
- CONCRETE PAVEMENT (4" in thickness)
- FILL: SILTY SAND (SM), light gray, light brown, with root fibers to 2'
- SILTY SAND (SM), loose, light brown, gray, with root fibers to 4'
  - medium dense, brown 4' to 16'
  - with gravels 6' to 8'

SPT N-VALUE blows per foot	OVM, ppm	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
		11				8				
10		15								
14		22								
11		17								
16		26				13				
17		24								
20		26								
14		28								

UNDRAINED SHEAR STRENGTH, tsf
▲ HAND PENETROMETER
▮ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL
0.5 1.0 1.5 2.0 2.5

Depth scale (ft): 0, 5, 10, 15, 20

WATER OBSERVATIONS:
∇ : WATER ENCOUNTERED AT 8.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 8.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 8 ft.
WET ROTARY: 8 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 2

GET GEOTECH ENGINEERING & TESTING
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

Columns: DEPTH, ft | SPT N-VALUE blows per foot | OVM, ppm | SYMBOL | SAMPLES | DESCRIPTION | NATURAL MOISTURE CONTENT, % | LIQUID LIMIT, % | PLASTIC LIMIT, % | PLASTICITY INDEX, % | PERCENT PASSING NO. 200 SIEVE | SUCTION (pF) | DRY UNIT WEIGHT, pcf | PERCENT COMPACTION | PASSING/FAILING (P/F)

UNDRAINED SHEAR STRENGTH, tsf
- ▲ HAND PENETROMETER
- ▮ TORVANE
- ● UNCONFINED COMPRESSION
- ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL

0.5 1.0 1.5 2.0 2.5

DESCRIPTION

ELEVATION: Existing Grade

- ASPHALT PAVEMENT (3" in thickness)
- CONCRETE PAVEMENT (4" in thickness)
- FILL: SILTY SAND (SM), light gray, light brown
- SILTY SAND (SM), loose, brown, light gray
  - medium dense 4' to 6', gray 4' to 16'
  - medium dense 10' to 12'

Depth scale: 0, 5, 10, 15, 20

SPT N-VALUE blows per foot	NATURAL MOISTURE CONTENT, %	PERCENT PASSING NO. 200 SIEVE
	8	
7	19	12
11	10	
5	26	
7	25	
14	21	
7	25	6
6	27	

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 3

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

UNDRAINED SHEAR STRENGTH, tsf: ▲ HAND PENETROMETER; ▮ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL (scale 0.5, 1.0, 1.5, 2.0, 2.5)

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			ASPHALT PAVEMENT (3" in thickness)									
			CONCRETE PAVEMENT (4" in thickness)									
			FILL: SILTY SAND (SM), brown, light brown, with root fibers to 2'	8								
			SILTY SAND (SM), medium dense, brown, light brown, with root fibers to 6'									
	11			18								
			- loose, light gray 4' to 6', dark gray 4' to 16'									
5	8			11				19				
	12			23								
			- loose 8' to 12', gray 6' to 16'									
	9			28								
10			- with shell 10' to 12'									
	6			26				16				
	11			28								
			- loose 14' to 16'									
15	6			26								
20												

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 7.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 7.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 7 ft.
WET ROTARY: 7 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 4

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)	UNDRAINED SHEAR STRENGTH, tsf
0			ASPHALT PAVEMENT (3" in thickness)										
			CONCRETE PAVEMENT (4" in thickness)										
			FILL: SILTY SAND (SM), brown, dark brown, with shell	20									
	16		SILTY SAND (SM), medium dense, brown, dark brown, gray, with root fibers to 12', shell	23									
			- dark gray 4' to 16', brownish yellow 4' to 8'										
5	17			24									
	13			24				20					
			- loose 8' to 10'										
	8			22									
10	16			21									
	11			24									
			- loose 14' to 16'										
15	7			24				14					
20													

UNDRAINED SHEAR STRENGTH legend: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL. Scale: 0.5, 1.0, 1.5, 2.0, 2.5

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 8.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 8.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 8 ft.
WET ROTARY: 8 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 5

GET GEOTECH ENGINEERING & TESTING

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard

LOCATION: Galveston County, TX

PROJECT NO.: 19-018E STATION NO.:

DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

UNDRAINED SHEAR STRENGTH, tsf: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL (scale 0.5, 1.0, 1.5, 2.0, 2.5)

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			ASPHALT PAVEMENT (3" in thickness)									
			CONCRETE PAVEMENT (4" in thickness)									
			FILL: SILTY SAND (SM), brown, light brown, with shell	23				11				
	15		SILTY SAND (SM), medium dense, brown, gray, with root fibers to 12', gravels, shell	23								
5	16			24								
			- light gray 6' to 16'									
	12			24								
	12			22				7				
10			- loose 10' to 12'									
	10			21								
	12			24								
15	14			24								
20												

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 6

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)	UNDRAINED SHEAR STRENGTH, tsf
0			ASPHALT PAVEMENT (4" in thickness)										
			CONCRETE PAVEMENT (6" in thickness)										
			FILL: SILTY SAND (SM), brown, light brown, with shell	23									
			SILTY SAND (SM), medium dense, brown, gray, with shell										
	14			24				8					
5	16			25									
			- loose 6' to 8'										
	6			26									
			- light gray 8' to 10'										
	16			29									
10	20			28				6					
			- loose 12' to 16'										
	9			32									
15	10			32									
20													

Legend (Undrained Shear Strength, tsf; scale 0.5, 1.0, 1.5, 2.0, 2.5):
- ▲ HAND PENETROMETER
- ■ TORVANE
- ● UNCONFINED COMPRESSION
- ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 7

GET GEOTECH ENGINEERING & TESTING
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			ASPHALT PAVEMENT (5.5" in thickness)									
			CONCRETE PAVEMENT (9" in thickness)									
			FILL: SILTY SAND (SM), light gray, light brown, with root fibers to 2'									
			SILTY SAND (SM), medium dense, light brown, gray, with root fibers to 16'	19								
	12			20								
			- loose 4' to 6'									
5	10			22				10				
	12			23								
			- loose 8' to 12'									
	8			21								
10												
	7			21								
	14			23				13				
			- loose 14' to 16'									
15	10			21								
20												

UNDRAINED SHEAR STRENGTH, tsf: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL (scale 0.5, 1.0, 1.5, 2.0, 2.5)

WATER OBSERVATIONS:
∇ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 8

Sheet 1 of 1

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)	UNDRAINED SHEAR STRENGTH, tsf
0			ASPHALT PAVEMENT (5" in thickness)										
			CONCRETE PAVEMENT (4" in thickness)										
			FILL: SILTY SAND (SM), light gray, brownish yellow	24									
	14		SILTY SAND (SM), medium dense, light gray, brownish yellow, with root fibers to 12'	21									
			- loose 4' to 6', gray, light brown 4' to 8'										
5	10			22									
	11			23				10					
			- loose, dark gray, with gravels 8' to 10'										
	9			21									
10			- gray, light brown 10' to 16'										
	11			20									
			- loose 12' to 16'										
	7			22									
15	6			20				12					
20													

UNDRAINED SHEAR STRENGTH, tsf legend: ▲ HAND PENETROMETER; ▮ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL. Scale: 0.5, 1.0, 1.5, 2.0, 2.5

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 8.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 8.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 8 ft.
WET ROTARY: 8 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 9

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

UNDRAINED SHEAR STRENGTH, tsf: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL (scale 0.5, 1.0, 1.5, 2.0, 2.5)

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)	UNDRAINED SHEAR STRENGTH, tsf
0			ASPHALT PAVEMENT (5.5" in thickness)										
			CONCRETE PAVEMENT (4" in thickness)										
			FILL: SILTY SAND (SM), light brown	14				5					
			SILTY SAND (SM), medium dense, light brown										
	14			15									
			- light gray 4' to 6'										
5	16			14									
			- gray 6' to 8'										
	24			17									
			- brown, with gravels 8' to 10'										
	25			13				34					
10			- gray 10' to 12'										
	28			15									
			- greenish gray 12' to 16'										
	22			24									
15	17			22									
20													

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 12.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 12.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 12 ft.
WET ROTARY: 12 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 10

GEOTECH ENGINEERING & TESTING
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)	UNDRAINED SHEAR STRENGTH, tsf
0			ASPHALT PAVEMENT (4" in thickness)										
			FILL: SILTY SAND (SM), brown, with gravels	16									
			SILTY SAND (SM), medium dense, brown, greenish gray, with gravels										
	12			26				10					
5	15			27									
	17			45									
			- gray, light brown 8' to 10'										
	14			23									
10			- dark gray 10' to 12'										
	18			25				12					
			- gray 12' to 16'										
	20			25									
15	20			25									
20													

Legend: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL
Shear strength scale: 0.5 1.0 1.5 2.0 2.5

WATER OBSERVATIONS:
∇ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

LOG OF BORING NO. B - 11

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)	UNDRAINED SHEAR STRENGTH, tsf
0			ASPHALT PAVEMENT (4" in thickness)										
			FILL: SILTY SAND (SM), brown, gray, with shell	16									
			SILTY SAND (SM), medium dense, gray, brown, with shell										
	12			24									
5	16			27				13					
	13			30									
	13			25									
10	18			31				6					
			- light gray 12' to 16'										
	17			24									
15	22			25									
20													

UNDRAINED SHEAR STRENGTH, tsf legend: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL. Scale: 0.5, 1.0, 1.5, 2.0, 2.5

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 12

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

UNDRAINED SHEAR STRENGTH, tsf: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL (scale 0.5, 1.0, 1.5, 2.0, 2.5)

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			ASPHALT PAVEMENT (3" in thickness)									
			CONCRETE PAVEMENT (5.5" in thickness)									
			FILL: SILTY SAND (SM), brown, light brown, with shell	21								
			SILTY SAND (SM), medium dense, gray, light brown, with shell									
	12			21								
5	12			21								
			- dark gray 6' to 12'									
	15			20				11				
	20			23								
10												
	19			22								
			- light gray 12' to 16'									
	17			25								
15	21			24				6				
20												

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

LOG OF BORING NO. B - 13

GET GEOTECH ENGINEERING & TESTING
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: G/S for 23rd Street Reconstruction From Broadway to Seawall Boulevard
LOCATION: Galveston County, TX
PROJECT NO.: 19-018E STATION NO.:
DATE: 6-15-19 COMPLETION DEPTH: 16.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)	UNDRAINED SHEAR STRENGTH, tsf
0			ASPHALT PAVEMENT (3" in thickness)										
			CONCRETE PAVEMENT (4.5" in thickness)										
			FILL: SILTY SAND (SM), brown, light brown, with gravels, shell	22				9					
			SILTY SAND (SM), medium dense, gray, light gray, with shell										
	11			24									
5	16			22									
	19			23									
			- dark gray 8' to 12'										
	18			22				25					
10			- dark brown 10' to 12'										
	25			21									
	22			22									
15	18			22									
20													

UNDRAINED SHEAR STRENGTH legend: ▲ HAND PENETROMETER; ■ TORVANE; ● UNCONFINED COMPRESSION; ○ UNCONSOLIDATED-UNDRAINED TRIAXIAL. Scale: 0.5, 1.0, 1.5, 2.0, 2.5

WATER OBSERVATIONS:
∇ : WATER ENCOUNTERED AT 6.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 6.0 ft. AFTER 0.5-HOUR

DRY AUGER: 0 TO 6 ft.
WET ROTARY: 6 TO 16 ft.

DRILLED BY: GET (T)
LOGGED BY: Victor

OVM2 19-018E.GPJ OVM.GDT 8/8/19

KEY TO LOG TERMS AND SYMBOLS

UNIFIED SOIL CLASSIFICATIONS

Symbol	Material Descriptions
GW	WELL GRADED-GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM	SILTY GRAVELS, GRAVEL-SAND SILT MIXTURES
GC	CLAY GRAVELS, GRAVEL-SAND CLAY MIXTURES
SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP	POORLY GRADED SANDS, OR GRAVELLY SANDS, LITTLE OR NO FINES
SM	SILTY SANDS, SAND-SILT MIXTURES a
SC	CLAYEY SANDS, SAND-SILT MIXTURES b
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, LEAN CLAYS
OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENT
	FILL SOILS

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	-	Having incline planes of weakness that are slick and glossy in appearance.
Fissured	-	Containing shrinkage cracks frequently filled with fine sand or silt: usually vertical.
Laminated	-	Composed of thin layers of varying colors and soil sample 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 sizes missing.
Pocket	-	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	-	Inclusion less than ⅛-inch thick extending through the sample.
Seam	-	Inclusion ⅛- to 3-inch thick extending through the sample.
Layer	-	Inclusion greater than 3-inch thick extending through the sample.
Interlayered	-	Soils sample composed of alternating layers of different soil types.
Intermixed	-	Soil samples composed of pockets of different soil type and layered or laminated structure is not evident.

COARSE GRAINED SOILS (major portion retained on No. 200 Sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Conditions rated according to standard penetration test (SPT)* as performed in the field.

Descriptive Terms	Blows Per Foot*
Very Loose	0 – 4
Loose	5 – 10
Medium Dense	11 – 30
Dense	31 – 50
Very Dense	over 50

* 140 pound weight having a free fall of 30-inch

SOIL SAMPLERS

- SHELBY TUBE SAMPLER
- STANDARD PENETRATION TEST
- AUGER SAMPLING

FINE GRAINED SOILS (major portion passing No. 200 Sieve): Include (1) inorganic or organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by hand penetrometer readings or by unconfined compression tests.

Descriptive Term	Undrained Shear Strength Ton/Sq. Ft.
Very Soft	Less than 0.13
Soft	0.13 to 0.25
Firm	0.25 to 0.50
Stiff	0.50 to 1.00
Very Stiff	1.00 to 2.00
Hard	2.00 or higher

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above because of weakness or cracks in the soil. The consistency ratings of such soils are based on hand penetrometer readings.

TERMS CHARACTERIZING ROCK PROPERTIES

VERY SOFT OR PLASTIC	Can be remolded in hand: corresponds in consistency up to very stiff in soils.
SOFT	Can be scratched with fingernail.
MODERATELY HARD	Can be scratched easily with knife; cannot be scratched with fingernail. Difficult to scratch with knife.
VERY HARD	Cannot be scratched with knife.
POORLY CEMENTED OR FRIABLE	Easily crumbled.
CEMENTED	Bounded Together by chemically precipitated materials.
UNWEATHERED	Rock in its natural state before being exposed to atmospheric agents.
SLIGHTLY WEATHERED	Noted predominantly by color change with no disintegrated zones.
WEATHERED	Complete color change with zones of slightly decomposed rock.
EXTREMELY WEATHERED	Complete color change with consistency, texture, and general appearance or soil.

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: G/S for 23rd Street Reconstruction from Broadway Avenue J to Seawall Boulevard

Galveston County, Texas

CONSULTANT PROJECT NUMBER: 19-018E

BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-1	1	0	0.5													Asphast Pavement (6-inch in thickness)
	2	0.5	0.83													Concrete Pavement (4-inch in thickness)
	3	0.83	2	AG		11					8					FILL: Silty Sand (SM)
	4	2	4	SS	10	15										Silty Sand (SM)
	5	4	6	SS	14	22										Silty Sand (SM)
	6	6	8	SS	11	17										Silty Sand (SM)
	7	8	10	SS	16	26					13					Silty Sand (SM)
	8	10	12	SS	17	24										Silty Sand (SM)
	9	12	14	SS	20	26										Silty Sand (SM)
	10	14	16	SS	14	28										Silty Sand (SM)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: G/S for 23rd Street Reconstruction from Broadway Avenue J to Seawall Boulevard

Galveston County, Texas

CONSULTANT PROJECT NUMBER: 19-018E

BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-2	1	0	0.25													Asphast Pavement (3-inch in thickness)
	2	0.25	0.58													Concrete Pavement (4-inch in thickness)
	3	0.58	2	AG		8										FILL: Silty Sand (SM)
	4	2	4	SS	7	19					12					Silty Sand (SM)
	5	4	6	SS	11	10										Silty Sand (SM)
	6	6	8	SS	5	26										Silty Sand (SM)
	7	8	10	SS	7	25										Silty Sand (SM)
	8	10	12	SS	14	21					6					Silty Sand (SM)
	9	12	14	SS	7	25										Silty Sand (SM)
	10	14	16	SS	6	27										Silty Sand (SM)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: G/S for 23rd Street Reconstruction from Broadway Avenue J to Seawall Boulevard

Galveston County, Texas

CONSULTANT PROJECT NUMBER: 19-018E

BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-3	1	0	0.25													Asphast Pavement (3-inch in thickness)
	2	0.25	0.58													Concrete Pavement (4-inch in thickness)
	3	0.58	2	AG		8										FILL: Silty Sand (SM)
	4	2	4	SS	11	18										Silty Sand (SM)
	5	4	6	SS	8	11					19					Silty Sand (SM)
	6	6	8	SS	12	23										Silty Sand (SM)
	7	8	10	SS	9	28					16					Silty Sand (SM)
	8	10	12	SS	6	26										Silty Sand (SM)
	9	12	14	SS	11	28										Silty Sand (SM)
	10	14	16	SS	6	26										Silty Sand (SM)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

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Galveston County, Texas

CONSULTANT PROJECT NUMBER: 19-018E

	SAMPLE							ATTERBERG LIMITS				SHEAR STRENGTH (TSF)				
		DEPTH (FT)														
BORING NO.	NO.	Top	Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pct)	LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-4	1	0	0.25													Asphast Pavement (3-inch in thickness)
	2	0.25	0.58													Concrete Pavement (4-inch in thickness)
	3	0.58	2	AG		20										FILL: Silty Sand (SM)
	4	2	4	SS	16	23										Silty Sand (SM)
	5	4	6	SS	17	24										Silty Sand (SM)
	6	6	8	SS	13	24					20					Silty Sand (SM)
	7	8	10	SS	8	22										Silty Sand (SM)
	8	10	12	SS	16	21										Silty Sand (SM)
	9	12	14	SS	11	24										Silty Sand (SM)
	10	14	16	SS	7	24					14					Silty Sand (SM)

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B-5	1	0	0.25													Asphast Pavement (3-inch in thickness)
	2	0.25	0.58													Concrete Pavement (4-inch in thickness)
	3	0.58	2	AG		23					11					FILL: Silty Sand (SM)
	4	2	4	SS	15	23										Silty Sand (SM)
	5	4	6	SS	16	24										Silty Sand (SM)
	6	6	8	SS	12	24										Silty Sand (SM)
	7	8	10	SS	12	22					7					Silty Sand (SM)
	8	10	12	SS	10	21										Silty Sand (SM)
	9	12	14	SS	12	24										Silty Sand (SM)
	10	14	16	SS	14	24										Silty Sand (SM)

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B-6	1	0	0.33													Asphast Pavement (4-inch in thickness)
	2	0.33	0.83													Concrete Pavement (6-inch in thickness)
	3	0.83	2	AG		23										FILL: Silty Sand (SM)
	4	2	4	SS	14	24					8					Silty Sand (SM)
	5	4	6	SS	16	25										Silty Sand (SM)
	6	6	8	SS	6	26										Silty Sand (SM)
	7	8	10	SS	16	29										Silty Sand (SM)
	8	10	12	SS	20	28					6					Silty Sand (SM)
	9	12	14	SS	9	32										Silty Sand (SM)
	10	14	16	SS	10	32										Silty Sand (SM)

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B-7	1	0	0.46													Asphast Pavement (5.5-inch in thickness)
	2	0.46	1.21													Concrete Pavement (9-inch in thickness)
	3	1.21	2	AG		19										FILL: Silty Sand (SM)
	4	2	4	SS	12	20										Silty Sand (SM)
	5	4	6	SS	10	22					10					Silty Sand (SM)
	6	6	8	SS	12	23										Silty Sand (SM)
	7	8	10	SS	8	21										Silty Sand (SM)
	8	10	12	SS	7	21										Silty Sand (SM)
	9	12	14	SS	14	23					13					Silty Sand (SM)
	10	14	16	SS	10	21										Silty Sand (SM)

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BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-8	1	0	0.42													Asphast Pavement (5-inch in thickness)
	2	0.42	0.75													Concrete Pavement (4-inch in thickness)
	3	0.75	2	AG		24										FILL: Silty Sand (SM)
	4	2	4	SS	14	21										Silty Sand (SM)
	5	4	6	SS	10	22										Silty Sand (SM)
	6	6	8	SS	11	23					10					Silty Sand (SM)
	7	8	10	SS	9	21										Silty Sand (SM)
	8	10	12	SS	11	20										Silty Sand (SM)
	9	12	14	SS	7	22										Silty Sand (SM)
	10	14	16	SS	6	20					12					Silty Sand (SM)

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Galveston County, Texas

Geotechnical Consultant's Name: Geotech Engineering and Testing

CONSULTANT PROJECT NUMBER: 19-018E

BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-9	1	0	0.46													Asphast Pavement (5.5-inch in thickness)
	2	0.46	0.79													Concrete Pavement (4-inch in thickness)
	3	0.79	2	AG		14					5					FILL: Silty Sand (SM)
	4	2	4	SS	14	15										Silty Sand (SM)
	5	4	6	SS	16	14										Silty Sand (SM)
	6	6	8	SS	24	17										Silty Sand (SM)
	7	8	10	SS	25	13					34					Silty Sand (SM)
	8	10	12	SS	28	15										Silty Sand (SM)
	9	12	14	SS	22	24										Silty Sand (SM)
	10	14	16	SS	17	22										Silty Sand (SM)

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BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-10	1	0	0.33													Asphast Pavement (4-inch in thickness)
	2	0.33	2	AG		16										FILL: Silty Sand (SM)
	3	2	4	SS	12	26					10					Silty Sand (SM)
	4	4	6	SS	15	27										Silty Sand (SM)
	5	6	8	SS	17	45										Silty Sand (SM)
	6	8	10	SS	14	23										Silty Sand (SM)
	7	10	12	SS	18	25					12					Silty Sand (SM)
	8	12	14	SS	20	25										Silty Sand (SM)
	9	14	16	SS	20	25										Silty Sand (SM)

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BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-11	1	0	0.33													Asphast Pavement (4-inch in thickness)
	2	0.33	2	AG		16										FILL: Silty Sand (SM)
	3	2	4	SS	12	24										Silty Sand (SM)
	4	4	6	SS	16	27					13					Silty Sand (SM)
	5	6	8	SS	13	30										Silty Sand (SM)
	6	8	10	SS	13	25										Silty Sand (SM)
	7	10	12	SS	18	31					6					Silty Sand (SM)
	8	12	14	SS	17	24										Silty Sand (SM)
	9	14	16	SS	22	25										Silty Sand (SM)

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BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-12	1	0	0.25													Asphast Pavement (3-inch in thickness)
	2	0.25	0.71													Concrete Pavement (5.5-inch in thickness)
	3	0.71	2	AG		21										FILL: Silty Sand (SM)
	4	2	4	SS	12	21										Silty Sand (SM)
	5	4	6	SS	12	21										Silty Sand (SM)
	6	6	8	SS	15	20					11					Silty Sand (SM)
	7	8	10	SS	20	23										Silty Sand (SM)
	8	10	12	SS	19	22										Silty Sand (SM)
	9	12	14	SS	17	25										Silty Sand (SM)
	10	14	16	SS	21	24					6					Silty Sand (SM)

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BORING NO.	SAMPLE				SPT	WATER CONTENT(%)	DRY DENSITY (pct)	ATTERBERG LIMITS			PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE				LL (%)	PL (%)	PI (%)		UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	
B-13	1	0	0.25													Asphast Pavement (3-inch in thickness)
	2	0.25	0.63													Concrete Pavement (4.5-inch in thickness)
	3	0.63	2	AG		22										FILL: Silty Sand (SM)
	4	2	4	SS	11	24										Silty Sand (SM)
	5	4	6	SS	16	22										Silty Sand (SM)
	6	6	8	SS	19	23										Silty Sand (SM)
	7	8	10	SS	18	22										Silty Sand (SM)
	8	10	12	SS	25	21										Silty Sand (SM)
	9	12	14	SS	22	22										Silty Sand (SM)
	10	14	16	SS	18	22										Silty Sand (SM)

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APPENDIX B

Project Alignments Pictures

PROJECT PICTURES

Project No. 19-018E

P-1 (A Picture of Coring Operation along 23rd Street)

P-2 (A View of Project Alignment along 23rd Street)

PROJECT PICTURES

Project No. 19-018E

P-3 (A Picture of Drilling Operation along 23rd Street)

P-4 (A Picture of Drilling Operation along Avenue N)

APPENDIX C

OSHA Soil Classification and Trench Safety Recommendations

OSHA SOIL CLASSIFICATION AND TRENCH SAFETY RECOMMENDATIONS

General

Occupational Safety and Health Administration (OSHA) requires a trench protective system for trenches deeper than five-ft. Trenches that are deeper than five-ft, should be shored, sheeted, braced or laid back to a stable slope, or some other appropriate means of protection should be provided where workers might be exposed to moving ground or caving. OSHA developed a soil classification system to be used as a guideline in determining protective requirements for trench excavations.

OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. These classifications are summarized in the following report sections.

Stable Rock

means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A Soil

means cohesive soils with an unconfined compressive strength of 1.5-ton per square foot (tsf) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam, silty clay loam, sandy clay loam, caliche and hardpan. No soil is Type A if:

- The soil is fissured; or
- The soil is subject to vibration from heavy traffic, pile driving or similar effects; or
- The soil has been previously disturbed; or
- The soil is part of a slope, layered system where the layers dip into the excavation on a slope of 4(h): 1(v) or greater; or
- The material is subject to other factors that would require it to be classified as a less stable material.

Type B Soil

- Cohesive soil with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf; or
- Granular cohesionless soils including: angular gravel, silt, silt loam, sandy loam, and in some case, silty clay loam and sandy clay loam; or
- Previously disturbed soils except those which would otherwise be classified as Type C soil; or
- Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

- o Dry rock that is not stable; or
- o Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than 4(h): 1(v), but only if the material would otherwise be classified as Type B.

Type C Soil

- o Cohesive soil with an unconfined compressive strength of 0.5 tsf or less; or
- o Granular soils including gravel, sand, and loamy sand; or
- o Submerged soil or soil from which water is freely seeping; or
- o Submerged rock that is not stable; or
- o Materials in a sloped, layered system where the layers dip into the excavation on a slope 4 (h) : 1(v) or steeper.

Under the assumption that appropriate groundwater control measures are carried out, and the groundwater table, if present, is lowered and maintained at least 3-ft below the excavation depths, the stable cohesive soils (CL) and (CH), with unconfined compressive strength greater than 0.5 tsf, are classified as OSHA soil Type "B". The granular soils, which are less stable, are classified as OSHA soil Type "C".

Based on our geotechnical exploration and laboratory test results, details of soil classifications at the boring locations are summarized below:

Boring No.	Depth Range [(1)], ft	Soil Type	OSHA Soil Classification
B-1 through B-13	0.3 – 2	Fill: Silty Sand (SM)	C
	2 – 16	Silty Sand (SM)	C

Note: 1. Refer to each boring log of soils stratigraphy

Stockpiling of excavated materials may not be allowed near the banks of excavated areas. Generally, a distance of one-half the excavation depth on both sides of the trench should be kept clear of any excavated material.

Underground utility trenches should be provided with proper trench support system. The trench should be provided with a temporary shoring system on excavations deeper than five-ft. The trenches can be made using shored, sheeted and braced, laid back stable slope or other means of appropriate protection system should be provided where workers are exposed to moving ground or caving. The slopes may be constructed in accordance with Table B-1 and shoring may be constructed in accordance with Table C-1.1, Table C-1.2 and Table C-1.3 of 29 CFR Part 1926 of OSHA.

In the event that trench sheeting is used, the sheeting can be constructed in the form of cantilever sheeting or with bracing. Lateral earth pressures for each method used are summarized on Plate D-1. The trenching and shoring operations should follow OSHA Standards. We recommend that a geotechnical engineer monitor all phases of trench excavation and bracing to assure trench safety.

Timber shoring as outlined in 29 CFR Part 1926 of OSHA recommendation may be used in the construction of trench supporting system.

For trench excavation, it is necessary to maintain the stability of the sides and base and not to disturb the soil below the excavation grade. In braced cuts, if the 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 the differential hydrostatic head. For cuts in cohesive soils (such as fat clay and lean clay), stability of the bottom can be evaluated in accordance with the procedure outlined on Plate C-2. However, due to presence of cohesionless subsoils (i.e., silty sand) encountered at the site, dewatering may be required to prevent bottom blowup if the groundwater is encountered during construction. Design soil parameters presented on Plates C-3 through C-3.3 can be used for design.

Groundwater Control

We understand that the depths of underground utilities will be less than 15-ft deep. Our short-term field exploration indicates that groundwater was encountered at depths ranging from 6- to 12-ft during drilling and 0.5-hour of after drilling. Therefore, groundwater dewatering may be required. Fluctuations in groundwater can occur as a function of seasonal moisture variation. Groundwater control recommendations are presented in the following report sections.

It is our opinion that groundwater should be lowered to a depth of at least three-ft below the deepest excavation grade in order to provide dry working conditions and firm bedding. Any minor water inflow in cohesive soil layers can probably be removed using a sump-pump or trench sump-pump. Wellpoint system can be used in the area where cohesionless (i.e. silty sand) soils are present. **Due to the presence of silty sand and the hydrostatic pressures, blow up may occur if an effective dewatering system is not in place at the time of construction.**

Piezometers should be installed near the excavation area to further evaluate groundwater levels in the area prior to construction. The piezometers should be left in place during construction to monitor groundwater levels and effectiveness of the dewatering system.

Design of a wellpoint system should consider the amount of groundwater to be lowered and the permeability of the affected soils. The selection and proper implementation of an effective groundwater control system is the responsibility of the contractor. The design of groundwater and surface water should be in accordance with the City of Galveston Specifications, Section 01563 – Control of Groundwater and Surface Water.

The results of our field exploration and laboratory testing indicate that unsatisfactory soils for excavation, such as silty sand soils exist in the borings. A summary of the unsatisfactory soils locations and depths are as follows:

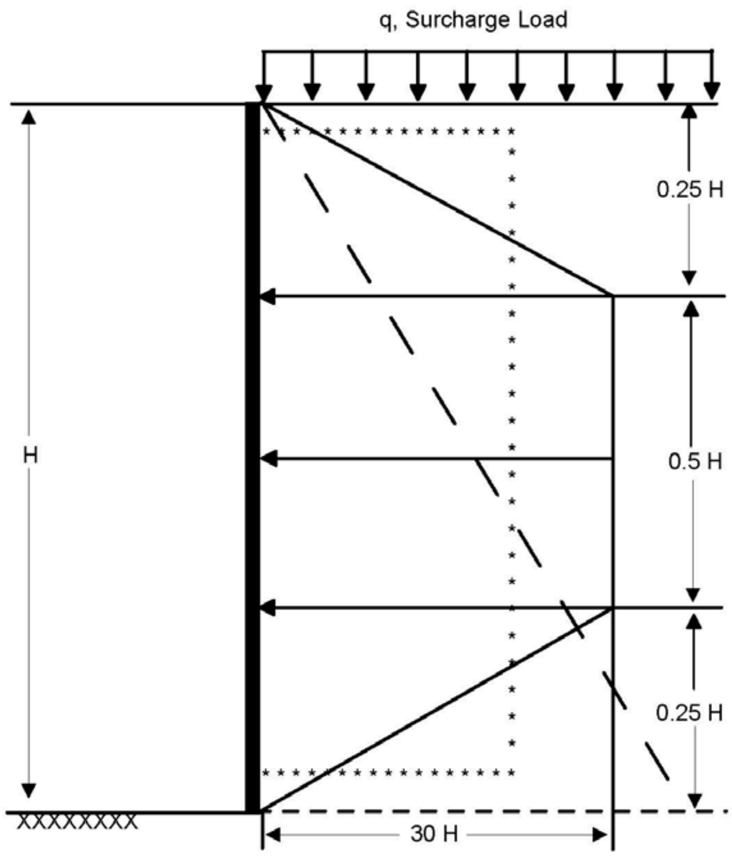
Boring(s)	Depth, ft.
B-1 through B-13	0.3 to 16

If these conditions are encountered during the time of construction, suitable groundwater control measures should be implemented in accordance with The City of Galveston Specifications, Section 01563 – Control of Groundwater and Surface Water. Furthermore, the contractor may have to over excavate an additional 6 inches and remove unstable or unsuitable materials with approval by geotechnical engineer, then place an equal depth of cement stabilized sand.

Due to potential variability of the on-site soils, unstable trench conditions may still exist in the areas where we did not conduct borings. If these conditions are encountered during the time of construction, a stable trench should be provided to allow proper bedding and installation.

Our recommendation on trench safety at the project site does not address the effects of excavations on existing buildings/facilities at the project site. This study was outside the scope of our work.

LATERAL EARTH PRESSURE DIAGRAM



Legend:

———————— Braced Excavation (stiff clays)
* * * * * * * * * * * * * Braced Excavation (sands)
- - - - - - - - - - - - - - - Cantilevered sheeting

Active Pressure:

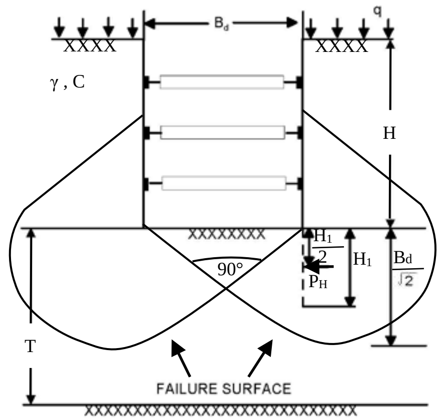
(a) Braced Excavation (stiff clays) = 0.5q + 30H + 62.4H
(b) Braced Excavation (sands) = 0.4q + 18H + 62.4H
(c) Cantilevered sheeting = 0.7q + 42H + 62.4H

where: q = surcharge load, psf: A value of 250 psf can be assumed.
H = wall height, ft.

Notes:

1. The above Active Pressure Equations account for the groundwater at the surface.
2. The final lateral pressures should be reviewed prior to construction.
3. Trench excavation and construction should be observed by a geotechnical engineer.
4. The means and methods for a safe excavation is the responsibility of the contractor.
5. In case of layered soils, active pressure should be calculated based on the dominant or more critical soil conditions.

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:

Safety Factor, $F_s = \dfrac{N_c c}{\gamma H + q}$

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

q = Surcharge (assumed q = 250psf)

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)

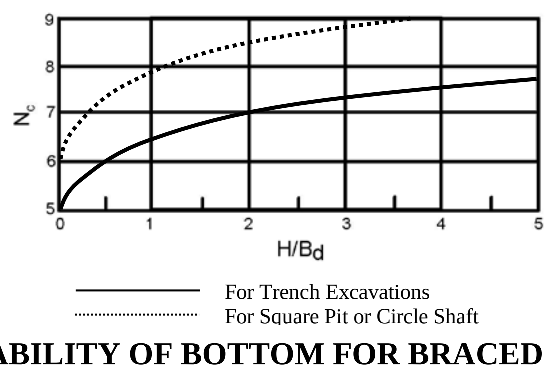
H_1 = Buried length = $\dfrac{B_d}{2} \geq 5$ feet

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 $H_1 > \dfrac{2}{3}\dfrac{B_d}{\sqrt{2}}$, $P_H = 0.7\,(\gamma H B_d - 1.4CH - \pi c B_d)$ in lbs/linear foot

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



STABILITY OF BOTTOM FOR BRACED CUT

SOIL DESIGN PARAMETERS

(BASED ON BORINGS B-1)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 4	125	28
SILTY SAND (SM)	4 – 16	125	30

(BASED ON BORING B-2)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 4	125	28
SILTY SAND (SM)	4 – 6	125	30
SILTY SAND (SM)	6 – 10	125	28
SILTY SAND (SM)	10 – 12	125	30
SILTY SAND (SM)	12 – 16	125	28

(BASED ON BORING B-3)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 4	125	30
SILTY SAND (SM)	4 – 6	125	28
SILTY SAND (SM)	6 – 8	125	30
SILTY SAND (SM)	8 – 12	125	28
SILTY SAND (SM)	12 – 14	125	30
SILTY SAND (SM)	14 – 16	125	28

SOIL DESIGN PARAMETERS

(BASED ON BORINGS B-4)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 8	125	30
SILTY SAND (SM)	8 – 10	125	28
SILTY SAND (SM)	10 – 14	125	30
SILTY SAND (SM)	14 – 16	125	28

(BASED ON BORING B-5)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 10	125	30
SILTY SAND (SM)	10 – 12	125	28
SILTY SAND (SM)	12 – 16	125	30

(BASED ON BORING B-6)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 6	125	30
SILTY SAND (SM)	6 – 8	125	28
SILTY SAND (SM)	8 – 12	125	30
SILTY SAND (SM)	12 – 16	125	28

SOIL DESIGN PARAMETERS

(BASED ON BORINGS B-7)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 4	125	30
SILTY SAND (SM)	4 – 6	125	28
SILTY SAND (SM)	6 – 8	125	30
SILTY SAND (SM)	8 – 12	125	28
SILTY SAND (SM)	12 – 14	125	30
SILTY SAND (SM)	14 – 16	125	28

(BASED ON BORINGS B-8)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 4	125	30
SILTY SAND (SM)	4 – 6	125	28
SILTY SAND (SM)	6 – 8	125	30
SILTY SAND (SM)	8 – 10	125	28
SILTY SAND (SM)	10 – 12	125	30
SILTY SAND (SM)	12 – 16	125	28

(BASED ON BORING B-9)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 16	125	30

(BASED ON BORING B-10)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 16	125	30

SOIL DESIGN PARAMETERS

(BASED ON BORING B-11)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 16	125	30

(BASED ON BORING B-12)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 16	125	30

(BASED ON BORINGS B-13)

Soil Type	Depth Range, ft.	γ, pcf	ϕ
FILL: SILTY SAND (SM)	0 – 2	125	28
SILTY SAND (SM)	2 – 16	125	30