REPORT
GEOTECHNICAL INVESTIGATION
PROPOSED NHCRWA CONTRACT NO. 28-B
2025 WATER DISTRIBUTION
AND TRANSMISSION SYSTEM
HARRIS COUNTY, TEXAS

PREPARED FOR:

Dannenbaum Engineering Corporation
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Houston, Texas 77098

PREPARED BY:

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HTS Project No. 16-S-299

December 30, 2016

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May 27, 2020

Dannenbaum Engineering Corporation
3100 West Alabama
Houston, Texas 77098

Attn: Mr. Carl D. McConnell, P.E. PMP
Ms. Kathy Bender

Re: Report
Geotechnical Investigation
Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

HTS Project No.: 16-S-299

Dear Mr. McConnell:

HTS, Inc. Consultants is pleased to submit our final geotechnical investigation report for the above referenced project. This report includes the results of field and laboratory testing as well as geotechnical recommendations pertaining to the proposed project.

We appreciate the opportunity to perform this geotechnical investigation and look forward to continued participation during the design and construction phases of this project. If you have any questions pertaining to this report, or if we may be of further service, please contact us at your convenience.

Respectfully submitted,
HTS, Inc. Consultants

Jubair Hossain, Ph.D., P.E.
Vice President

5-27-20

HTS, Inc. Consultants
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PROPOSED NHCRWA CONTRACT NO. 28-B
2025 WATER DISTRIBUTION AND TRANSMISSION SYSTEM
HARRIS COUNTY, TEXAS

1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

This report presents the results of a geotechnical investigation pertaining to the design and construction of the proposed 2025 water distribution and transmission system which includes approximately ±9,800 l.f. of 54-inch and 60-inch water line replacement along Grant Road starting from Lakewood Forest Drive, crossing Cypress Creek (HCFCD Unit No. K100-00-00), to Anderson Wood Drive, then crossing Anderson Ditch (HCFCD Unit No. K143-00-00), Jones Road, and Matzke Park, then along Copeland Drive to Mills Road in Harris County, Texas. The site location is shown in Figures 1 and 2A through 2D.

This geotechnical investigation was performed by HTS, Inc. Consultants (HTS) for North Harris County Regional Water Authority (NHCRWA) and Dannenbaum Engineering Corporation (DEC) in accordance with HTS Proposal No. DEC-3852 Revised dated February 6, 2015 and authorization by DEC through a contract for professional engineering services dated July 21, 2016.

The scope of work for this geotechnical investigation consisted of:

- **drilling and sampling a total of 13 geotechnical borings (Boring Nos.1 through 13) where 9 geotechnical borings (Boring Nos. 1, 4 through 7, and 10 through 13) were drilled to a depth of 20 feet along the proposed pipeline alignment, 2 geotechnical borings (Boring Nos. 2 and 3) were drilled to depths of 50 and 55 feet at the embankments of Cypress Creek, and 2 geotechnical borings (Boring Nos. 8 and 9) were drilled to depths of 50 and 55 feet at the embankments of Anderson Ditch, as shown in Figure 2A through 2D,**

- **performing field tests during drilling and recovering both disturbed and relatively undisturbed soil samples,**

- **measuring the depth to groundwater during drilling, approximately 10 minutes after the water is initially encountered, as applicable, and after the completion of drilling, as applicable,**

- **installing piezometers in Boring Nos. 2 and 9, and measuring the groundwater levels 2 weeks and 1 month after the installation of the piezometers,**

- **backfilling the borings with cement grout after the completion of the groundwater measurements,**

- **visually classifying samples obtained from the borings and conducting laboratory tests to determine the physical and mechanical properties of the soils,**

- **analyzing the field and laboratory test data,**

- **preparing gINT boring logs and soil profiles based on visual soil classifications and the results of laboratory tests,**

- **completing engineering analyses to develop recommendations pertaining to dewatering requirements for the water line excavations, water line trench shoring and bracing requirements, OSHA soil type classifications pertinent to trench shoring and bracing design, utility excavation/backfill requirements, and utility bedding requirements in accordance with the City of Houston or NHCRWA construction specifications/ design manuals,**

- **completing engineering analyses for the purpose of developing and providing recommendations for tunneling at the roadway/pipeline crossings, as applicable,**

- **developing/providing recommendations concerning lateral earth pressures that may be used for design of below ground structures,**

- **submitting a pdf file of the final report which presents the results of the geotechnical investigation, and**

- **submitting a final report of the geotechnical investigation.**

1.2 Description of Proposed Facilities

The proposed 2025 water distribution and transmission system includes approximately ±9,800 l.f. of 54-inch and 60-inch water line replacement along Grant Road starting from Lakewood Forest Drive to Anderson Wood Drive, then crossing Anderson Ditch, Jones Road, and Matzke Park, then along Copeland Drive to Mills Road in Harris County, Texas. Pipe installation at the roadways, Anderson Ditch (HCFCD Unit No. K143-00-00), and Cypress Creek (HCFCD Unit No. K100-00-00) crossings will include underground tunneling with steel casings. The water line material type, and invert depths were not available at the time of this geotechnical investigation.

1.3 Summary of Findings

The pertinent findings of this geotechnical investigation are provided below.

1.3.1 Subsurface Soil Strata

The subsurface soil strata at the locations of the 13 geotechnical borings are described by the soil properties provided in Tables 1 through 4B, Figures 4 through 13, on the Log of Borings provided in Appendix A, and the soil profiles shown in Figures 3A and 3B.

Data from the borings suggest that the upper 50 feet of overburden soils along the proposed water pipeline route consist of 5 soil layers. HTS has designated these 5 soil layers as Layers I through V as described below.

LAYER	DEPTH BELOW GROUND SURFACE (FT)	SOIL DESCRIPTION
I	0 – 8	Light gray, dark gray, gray, tan, and light tan CLAYEY SAND, SILTY SAND, and SILTY CLAYEY SAND, loose to dense with ferrous nodules, clay pockets, concrete and brick pieces, and roots (not encountered in Boring No. 7).
IIa	1 – 18	Light gray, gray, light tan, and tan SANDY LEAN CLAY, LEAN CLAY, SANDY SILTY CLAY, and LEAN CLAY WITH SAND, stiff to hard with ferrous nodules, calcareous nodules, sand fissures, silt pockets, sand seams, and sand pockets. Note: A layer of fill material consisting of gray, light gray, and tan SANDY LEAN CLAY, stiff with roots was encountered in Boring No. 7 from the surface to a depth of 6 feet below the ground surface.
IIb	8 – 18	Light gray, reddish brown, and tan FAT CLAY, stiff to very stiff with sand fissures, sand pockets, sand seams, and silt seams (only encountered in Boring Nos. 1, 7, 11, and 12).
III	10 – 38	Light gray, reddish brown, tan, and light tan CLAYEY SAND, SILTY SAND, and POORLY GRADED SAND WITH SILT, very loose to very dense with ferrous nodules, calcareous nodules, clay seams, clay pockets, clay seams, and gravel.
IVa	28 – 48	Light gray, reddish tan, and tan FAT CLAY and FAT CLAY WITH SAND, stiff to hard with ferrous nodules, silt pockets, and slickensides (only encountered in Boring Nos. 2, 3, 8, and 9).
IVb	38 – 55	Gray, light gray, light tan, reddish brown, and tan LEAN CLAY and SANDY LEAN CLAY, stiff to hard with ferrous nodules, sand seams, sand pockets, and sand fissures (only encountered in Boring Nos. 2, 8, and 9).
V	43 – 55	Light tan and tan SILTY SAND, dense to very dense.

Laboratory testing was performed on samples of the subsurface materials obtained to classify the soils in accordance with ASTM D 2487 and to define the engineering properties of the soils. Portions of the test results indicating the high and low values of specific testing are provided in the table below:

LAYER	DEPTH (FT)	LIQUID LIMIT (%)		PLASTICITY INDEX (%)		MOISTURE CONTENT (%)		PASSING NO. 200 SIEVE (%)		UNCONFINED COMPRESSIVE STRENGTH (TSF)	
		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
I	0 – 8	21	NP	6	NP	16.8	3.2	42.9	16.8	0.5*	
IIa	1 – 18	47	24	30	9	22.1	9.5	74.0	51.3	10.1	1.3
IIb	8 – 18	63		42		24.4	18.8	95.8		3.8	2.4
III	10 – 38	37	NP	21	NP	19.6	3.9	43.8	11.2	4.3*	0.7*
IVa	28 – 48	85	76	61	53	35.3	15.4	90.1	80.6	1.9	1.1
IVb	38 – 55	45	22	26	8	25.8	13.2	91.2	63.3	3.7	2.2

NP - Non Plastic * Test was performed on clayey sand and silty clayey samples only.

Note: The sandy lean clay fill layer encountered in Boring No. 7 has a liquid limit of 28%, a plasticity index of 13%, a moisture content of 17.1%, and a percent soil passing the No. 200 sieve of 61.7%.

Consolidated Undrained (CU) Triaxial Soil Test Results

Given below is a table of the total and effective strength parameters of site soil samples based on the results of our laboratory testing. The results of the CU triaxial testing are provided in Figures 12 and 13 of this report.

BORING NO. (DEPTH)	TYPE OF MATERIAL	WET DENSITY (PCF.)	SAT. DENSITY (PCF.)	TOTAL STRENGTH PARAMETERS	EFFECTIVE STRENGTH PARAMETERS
B-9 (6' – 8')	LEAN CLAY WITH SAND	133.5	135.7	C =380.9 PSF Φ = 17.4°	C =289.3 PSF Φ= 22.5°
B-3 (16' – 18')	SANDY LEAN CLAY	124.9	131.7	C =406.5 PSF Φ = 19.6°	C =313.2 PSF Φ = 25.4°

Results of the Pinhole Testing

A pinhole dispersion testing was performed on selected soil samples obtained from the field investigation. The results of pinhole "dispersion" testing performed on the site soils for the current study are summarized below and are shown on the boring logs provided in Appendix A as well as in Tables 1 and 2.

BORING NO.	DEPTH (FT.)	SOIL LAYER NO.	TYPE OF MATERIAL	DISPERSION CHARACTERISTIC
3	10 – 12	IIA	SANDY LEAN CLAY (CL)	ND2 (SLIGHTLY DISPERSIVE)
9	4 – 6	IIA	SANDY LEAN CLAY (CL)	ND2 (SLIGHTLY DISPERSIVE)

The results of the pinhole dispersion testing on selected undisturbed soil samples obtained from the geotechnical borings revealed that the lean clay soils exhibited slightly dispersive characteristic (classified as ND2). The results of the pinhole testing are provided in Tables 3A and 3B of this report.

Results of the Crumb Testing on Clayey Soils

The results of the crumb testing on selected disturbed soil samples obtained from the geotechnical borings revealed that the sandy lean clay and lean clay with sand soils exhibited non-dispersive characteristics (classified as Grade 1). The results of the crumb testing are provided in Table 2 of this report.

Results of the Permeability Testing on Clayey Soils

Given below is a table of the permeability coefficients of site soil samples. The results of the permeability testing are provided in Tables 4A and 4B of this report.

BORING NO.	DEPTH (FT.)	SOIL LAYER NO.	TYPE OF MATERIAL	PERMEABILITY COEFFICIENT (K, CM/S)
3	18 – 20	III	CLAYEY SAND (SC)	1.46E-07
8	8 – 10	IIA	SANDY LEAN CLAY (CL)	6.33E-08

1.3.2 Groundwater

Groundwater measurements were obtained during drilling and after completion of drilling as applicable. Due to use of wet rotary, groundwater readings were obtained 10 minutes after water was initially encountered, as applicable, for Boring Nos. 2, 3, 8, and 9. The results of the groundwater measurements are presented in the table below:

BORING NO.	TOTAL DEPTH OF BORING (FT.)	DEPTH TO WATER DURING DRILLING (FT.)	DEPTH TO WATER APPROXIMATELY 10 MINUTES AFTER WATER WAS INITIALLY ENCOUNTERED (FT.)	DEPTH TO WATER AFTER COMPLETION OF DRILLING (FT.)	DEPTH TO OBSTRUCTION AFTER SECOND GROUNDWATER MEASUREMENT (FT.)
1	20	Dry	--	Dry	19.2
2	55	Dry to 20*	--	16.5**	24.9
3	50	24.3	23.7	14.5**	23.4
4	20	16.0	15.1	Dry	15.9
5	20	Dry	--	Dry	18.8
6	20	Dry	--	Dry	19.2
7	20	Dry	--	Dry	19.2
8	55	23.0	22.3	18.0**	21.8
9	50	23.0	23.5	16.9**	22.8
10	20	Dry	--	Dry	18.6
11	20	Dry	--	Dry	19.0
12	20	Dry	--	Dry	19.0
13	20	Dry	--	Dry	18.8

Note: Depths are referenced from the existing ground surface elevation at the time the borings were drilled.
* Prior to the use of the drilling fluid.
** Likely influenced by drilling fluid used to keep an open boring.
-- Not applicable.

The borings were backfilled with cement grout after the groundwater measurements were obtained.

Piezometers were installed at the locations of Boring Nos. 2 and 9 to define ground water level conditions in a longer period of time. The water levels were measured at 2 weeks and 1 month after installation and the results are as provided below and in Figures 14 and 15:

BORING NO. (PIEZOMETER NO.)	2-WEEKS AFTER INSTALLATION		1 MONTH AFTER INSTALLATION	
	DEPTH TO GROUNDWATER (FT.)	ELEVATION (FT.-MSL)	DEPTH TO GROUNDWATER (FT.)	ELEVATION (FT.-MSL)
2 (PZ-1)	27.7	+18.71	30.0	+16.41
9 (PZ-2)	23.7	+19.94	23.8	+19.84

1.4 Summary of Recommendations

The recommendations as summarized below are provided for use in the design and construction of the proposed water distribution and transmission system.

1.4.1 Water Line Design, Bedding, and Backfill Requirements

Water lines may be designed by using conventional conduit formulas and assuming a negative projection condition for the computation of loadings.

The total load on water lines will consist of the weight of the compacted backfill above the pipe, the weight of the pavement, and live loadings where applicable. The wet unit weight of compacted backfill is estimated to be 130 pounds per cubic foot (pcf) for clayey sand/lean clay backfill material.

Earthwork should conform to applicable provisions of Section 02317 titled "Excavation and Backfill for Utilities" and Section 02447 titled "Augering Pipe and Conduit" from the most recent version of City of Houston Department of Public Works and Engineering (COH-DPWE) "Standard Construction Specifications for Wastewater Collection Systems, Water Lines, Storm Drainage, Street Paving, and Traffic" (most recent COH-DPWE Standard Specifications).

Water line trenches should be excavated with trench widths that comply with the requirements of Subsection 3.05, Subparagraph C, page 02317-11 of Section 02317 of the above-referenced COH-DPWE Standard Specifications. Trench foundation for water lines should be prepared in accordance with Subsection 3.07 of Section 02317 of the above-referenced COH-DPWE Standard Specifications.

Bedding for the proposed water lines should be designed and installed as specified by Section 02317, Section 02447, Section 02511, Section 02512, and Drawing Nos. 02317-04 and 02447-01 of the above-referenced COH-DPWE Standard Specifications.

Backfill for water line excavations should consist of bank run sand or suitable earth fill as specified in Section 02320 of the above-referenced COH-DPWE Standard Specifications. Backfill should be placed in accordance with Section 02317 of the above-referenced COH-DPWE Standard Specifications.

1.4.2 Water Line Excavation Dewatering Requirements

Groundwater was encountered at depths ranging from 16.0 to 24.3 feet during drilling in only 4 of the 13 borings. Groundwater was encountered only in Boring Nos. 3, 4, 8, and 9 and the rest of the borings were dry, except in Boring No. 2 where the boring was dry to 20 feet and caved in before drilling fluid was used. Approximately 10 minutes after water was initially encountered, groundwater was measured at depths ranging from 15.1 to 23.7 feet beneath

the existing surface in the same 4 borings. Accordingly, it is not expected that groundwater will be present for excavations that are no deeper than about 14 feet beneath the surface. However, the Layer III sands may be part of a water bearing stratum that could hold water after prolonged wet periods or after heavy rainfall events. The use of sumps and pumps may be adequate for clayey soil above the groundwater levels previously provided. The use of well points, vacuum well points, or a comparable dewatering system may be required to dewater the excavations extending below the groundwater levels where the exposed soils consist of the site sands. Control of groundwater and surface water during the installation of the underground utilities should be performed in accordance with Section 01578 of the most recent version of COH-DPWE Standard Specifications.

1.4.3 Temporary Shoring and Bracing Requirements for Water Line Excavations

The contractor should ensure designing and constructing stable protection systems for excavations such as support systems, sloping and benching systems, shield systems, and other systems that provide protection.

Temporary special shoring, for use in the installation of structures or utilities that will require excavations deeper than 5 feet, should consist of vertical or sloped cuts, benches, shields, support systems, or other systems that will provide necessary protection in accordance with OSHA Standards and Interpretations, 29 CFR 1926, Subpart P, "Excavations".

If OSHA Standards and Interpretations, 29 CFR 1926, Subpart P, "Excavations" is used for the design of temporary excavation protection systems, the site Layers II and IV clays should be categorized as Type B soils while the Layers I and III sands should be categorized as Type C soils. The definitions of Type B and Type C soils are provided in Appendix A of the OSHA Standards and Interpretations, 29 CFR 1926, Subpart P, "Excavations" (www.osha.gov). In order to eliminate the potential for caving of trench excavations, trench safety shall be implemented for trench excavations that are deeper than 5 feet. The data, parameters, and recommendations provided in Appendix B titled "Trench Excavation Report" may be used.

1.4.4 Pipe Installation Under Roadway Right-of-Ways, Anderson Ditch, and Cypress Creek (Jacking, Boring, or Tunneling)

It is our understanding that the waterline installation at the roadways, existing pipelines, Anderson Ditch, and Cypress Creek crossings will be performed using underground tunneling with steel casing. Depending on tunneling depths and ground water fluctuations, groundwater could be expected within the tunneling path during the installation of the casing. It is recommended that the groundwater levels within the installation areas be monitored prior to the installation activities. Additionally, test pits on both ends of the installation

alignment may also be excavated prior to the construction activities in order to determine the actual groundwater levels. If the groundwater level is within the path of the tunneling operation, the water level must be lowered to at least 2 feet beneath the bottom of the proposed casing. Groundwater dewatering may be accomplished using well points, vacuum well points, or any other suitable dewatering system where sandy materials are encountered.

Tunneling operations for the installation of the proposed water line under the roadways, existing pipelines, Anderson Ditch, and Cypress Creek shall conform with applicable guidelines and regulations of the governing agency within the project area; and/or the guidelines and requirements of Item 431 titled "Jacking, Boring or Tunneling Pipe" and Item 432 titled "Tunnel Construction" of the most recent Harris County Engineering Department (HCED) Specifications titled "Specifications for the Construction of Roads and Bridges within Harris County, Texas" or subchapter F titled "Water Line Crossings" in Chapter 7 titled " Water Line Design Requirements" of City of Houston Infrastructure Design Manual dated July 01, 2016 and in accordance with the Section 02425 entitled "Tunnel Excavation and Primary Liner" of the 2016 COH-DPWE Standard Specifications.

In trenchless excavation for the portion of the water line under the existing roadway, tunnel shafts will be required. These shafts need to be shored because the side walls are normally cut vertical because of space limitation and/or to conserve space. Tunnel shafts should be designed as braced excavations in accordance with the applicable previous sections for open cut excavations. Tunnel shafts should be constructed in accordance with Section 02400 entitled "Tunnel Shafts" of the 2016 COH-DPWE Standard Specifications.

1.4.5 Earth Pressure Design Parameters for Long Term Conditions

Earth pressure coefficients may be used to define the lateral loads exerted by the overburden soils on underground structures. Earth pressure coefficients, as provided in this report, were computed by using Rankines' methods. Earth pressure design parameters provided in this report for use in designing below ground structures, are based on effective stress, shear strength parameters. Long term, effective stress, shear strength parameters should be used for the design of permanent underground structures. Below ground structures at the proposed site may be designed by using the following design parameters:

ON SITE SOILS	WEIGHT OF EQUIVALENT FLUID FOR ACTIVE CASE (PCF)	WEIGHT OF EQUIVALENT FLUID FOR PASSIVE CASE (PCF)	ACTIVE EARTH PRESSURE COEFFICIENT (K_A)	PASSIVE EARTH PRESSURE COEFFICIENT (K_P)	EFFECTIVE STRESS ANGLE OF INTERNAL FRICTION (°)*	EFFECTIVE STRESS COHESION (PSF)*	WET UNIT WEIGHT (PCF)
Sands	86	276	0.33	3.00	30	0	134
Lean Clays	95	271	0.45	2.88	22.5**	290**	135
Fat Clays	98	218	0.53	2.32	18	200	129

* Estimated Value.
** Values obtained from CU triaxial testing.

The weights of equivalent fluid shown above, include hydrostatic forces but do not include surcharge forces imposed by construction equipment or vehicular loadings. Surcharge forces must be considered in order to compute maximum stresses for use in the design of below ground structures.

The weights of equivalent fluid for the passive case and the passive earth pressure coefficients shown above do not include a safety factor. It is recommended that for design purposes, a factor of safety of 2 be applied to the effective stress angle of internal friction to calculate for the passive case and the passive earth pressure coefficients. With the use of a safety factor of 2, the weights of equivalent fluid for the passive case will be 166, 189, and 183 pcf for the site fat clays, lean clays, and sands, respectively. The passive earth pressure coefficients will be 1.55, 1.75, and 1.70 pcf for the site fat clays, lean clays, and sands, respectively.

2.0 FIELD INVESTIGATION

A total of 13 geotechnical borings were drilled for this current geotechnical investigation on October 3, 7, 10, 11, 13, 28, and 29, 2016. The boring locations, as shown in Figures 2A through 2D, were selected by DEC and located/staked in the field by HTS. Drilling, sampling, and testing were performed in accordance with applicable ASTM procedures by using a truck-mounted drill rig and conventional auger and wet rotary methods. Van and Sons Drilling Company performed drilling under contract to HTS and under the supervision of an HTS engineering technician.

Soil sampling during the drilling of the geotechnical borings consisted of continuous sampling to between 12 and 20 feet, depending on the purpose of the boring, and intermittent sampling thereafter, with both disturbed and relatively undisturbed samples being obtained.

Disturbed soil samples were taken from the auger of the sampler or in conjunction with standard penetration test procedures. The standard penetration test (SPT) blow count is defined as the number of SPT hammer blows that are required to advance a split spoon sampler 1 foot into the soil. One SPT hammer blow consists of a 140-pound hammer free

falling for a distance of 30 inches. The results of the standard penetration test provide a basis for estimating the relative strength and compressibility of the soil profile components. The samples recovered were removed from the auger of the sampler or the split spoon sampler and placed into airtight plastic bags.

Relatively undisturbed samples were obtained by hydraulically forcing sections of 3-inch O.D. tubing (Shelby tube) into the subsoils. The tube samples were extruded in the field, sealed with foil, and placed into airtight plastic bags. Estimates of the unconfined compressive strengths and undrained shear strengths of the cohesive soils were obtained with pocket penetrometer readings being taken on the tube samples.

The soils samples were visually classified in accordance with ASTM D 2488 standards and methods. All samples were transported to HTS' laboratory for purposes of performing laboratory tests on selected samples.

3.0 LABORATORY TESTING

A laboratory testing program was conducted to obtain engineering properties for use in performing engineering analyses and to adjust field soil classifications. The following laboratory tests were performed:

LABORATORY TEST	TEST STANDARD
Moisture Content of Soils	ASTM D 2216
Dry Density of Soils	ASTM D 2937
Percent Soil Particles Passing a No. 200 Sieve	ASTM D 1140
Liquid Limit, Plastic Limit, and Plasticity Index	ASTM D 4318
Unconfined Compressive Strength of Cohesive Soils	ASTM D 2166
Unconsolidated Undrained Triaxial Compression Test	ASTM D 2850
Consolidated Undrained Triaxial Compression Test (with pore pressure measurements – 3 stages)	ASTM D 4767
Crumb Testing	ASTM D 6572
Pinhole Testing	ASTM D 4647
Permeability Testing (Falling Head Method)	ASTM D 5084

The number of tests and the test results are presented in the attached Tables 1 through 4B and Figures 4 through 13. All tests were performed in accordance with applicable ASTM standards and methods and soil classifications were completed in accordance with the guidelines and requirements of ASTM D 2487 and ASTM D 2488.

4.0 SUBSURFACE CONDITIONS

4.1 Subsoils

The subsurface soil conditions as determined from the drilling of the geotechnical borings are provided in:

- **Section 1.3.1 of this report,**
- **the Log of Borings in Appendix A, and**
- **Figures 3A and 3B.**

The boring logs were prepared by using both field visual classifications and the results of laboratory testing. The stratification lines shown on the boring logs represent the approximate boundaries between soil types and the transitions between soil types may be gradual.

4.2 Groundwater

Groundwater conditions are described in Section 1.3.2 of this report and in the boring logs provided in Appendix A of this report. The depth to groundwater was obtained by:

- **observing the drilling operations and the free moisture contained in the samples recovered during drilling, measuring water level depths during drilling and approximately 10 minutes after water was initially encountered, and after completion of drilling, as applicable, and**

- **obtaining water level measurements in the piezometers in about 2 weeks and 1 month after the installations of the piezometers.**

It is possible that seasonal variations will cause fluctuations in the water levels measured at the time of our field investigation. We recommend that the contractor determine the actual groundwater level at the site at the time of the construction activities in order to assess the impact, if any, of the groundwater to the construction activities. It should be noted that recommendations contained in this report are based on groundwater depths at the time of this geotechnical investigation and that an accurate determination of the true groundwater level may require several days or even months of observations.

5.0 ENGINEERING ANALYSES

Engineering analyses were performed in order to determine design parameters that can be used for the construction of the proposed water transmission and distribution system for the NHCRWA in the Harris County, Texas. Analyses performed included:

- **analyses of subsurface soil grain size and plasticity characteristics and site groundwater levels as necessary to identify potential dewatering requirements,**

- **analyses of subsurface soil grain size, plasticity, and shear strength properties as necessary to categorize the site subsurface soil and groundwater conditions with regard to OSHA requirements for trench shoring/bracing, and**

- **analyses to determine lateral earth pressure design parameters which can be used in the design of permanent below ground structures and temporary below ground structures such as trench shoring/bracing.**

5.1 Potential Dewatering Requirements

Potential dewatering requirements were developed based upon measured groundwater level depths, the types of subsurface soils encountered, and the grain size characteristics of the subsurface soils. A dewatering system will most likely be required for sandy soils that occur below the groundwater table. The use of well points, vacuum well points, or a comparable dewatering system should provide for the effective dewatering of sandy soils which occur below the groundwater table and are found to contain less than 15 to 20% soil particles passing a No. 200 sieve. Sumps and sump pumps may be used to effectively dewater soils that occur below the groundwater table and contain more than 20% soil particles passing a No. 200 sieve.

5.2 OSHA Guidelines for Trench Shoring/Bracing

The site soils were categorized as Type B and C soils in accordance with OSHA requirements as referenced in Section 1.4.3 of this report. The site soils were categorized based upon the site groundwater conditions, the results of laboratory tests (moisture content determinations, Atterberg Limits, percent soil particles passing a No. 200 sieve, and unconfined compression tests) and pocket penetrometer values measured during drilling.

5.3 Earth Pressure Analyses for Design of Below Ground Structures

Earth pressure coefficients may be used to define the lateral loads exerted by the overburden soils on underground structures. The earth pressure coefficients for the soils, as provided in this report, were computed by using Rankine's methods. The recommended lateral earth pressure coefficients and equivalent fluid weight values, provided in this report, are based on soil properties as summarized in Section 1.4.5 of this report. Earth pressure design parameters provided in this report for use in designing permanent below ground structures are based on effective stress and shear strength parameters.

6.0 CONSTRUCTION CONSIDERATIONS

The following recommendations should be followed with regard to construction of the proposed water transmission and distribution system:

- **Construction dewatering should be performed in order to result in the lowering of the groundwater table to a depth of at least 3 feet below the bottoms of excavations.**

- **Utility backfill criteria should comply with the recommendations provided in Section 1.4.1 of this report.**

- **Construction operations should be monitored by a representative of the geotechnical engineer.**

- **Materials testing should be performed to assure that acceptable materials and construction methods are provided by the contractor.**

7.0 CLOSING REMARKS

HTS has performed a geotechnical investigation and provided recommendations pertaining to the design and construction of the proposed water transmission and distribution system for the NHCRWA in Harris County, Texas. This report has been prepared for the exclusive use of DEC and the NHCRWA in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.

In the event that changes are made in the nature, design, or location of the proposed facilities, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and the findings/recommendations of this report are modified or verified in writing. The analyses and recommendations presented in this report are based upon data obtained from 13 geotechnical borings drilled October 3, 7, 10, 11, 13, 28, and 29, 2016. The nature and extent of variations within the subsurface materials may not become evident until after construction is initiated. If significant variations in the subsurface materials are encountered during construction, it may be necessary to re-evaluate the recommendations provided in this report.

TABLES

TABLE 1

LABORATORY TEST SUMMARY

PROJECT: Proposed NHCRWA Contract No. 28-B
20252 Water Distribution and Transmission System
HTS PROJECT NO.: 16-S-299

LOCATION: Harris County, Texas

CLIENT: Dannenbaum Engineering Corporation

Boring No.	Sample Depth (feet)	Type of Material	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (%)			-200 Sieve (%)	Deviator Stress (tsf)	Strain (%)	Lateral Pressure (psi)	Remarks
					LL	PL	PI					
1	4-6	Sandy Lean Clay (CL)	16.8	114.4	31	15	16	61.6	1.3 (1)	9.6	0	(1) Sample bulged at failure.
	10-12	Sandy Lean Clay (CL)	17.3	115.0	24	15	9	63.5	1.7 (1)	8.3	0	(2) Sample failed along slickensides.
												(3) Sample failed along sand fissures.
2	2.5-4	Silty Sand (SM)	3.2		Non Plastic			16.8				
	13.5-15	Silty Sand (SM)	11.2		Non Plastic			23.3				
	33-35	Fat Clay (CH)	28.4	92.0	85	24	61	88.8	1.8 (2)	11.6	34	33'-35': UU Triaxial Test
	38-40	Sandy Lean Clay (CL)	20.3	107.7	45	19	26	63.3	2.2 (1)	15.0	0	
3	4-6	Silty Clayey Sand (SC-SM)	16.8	110.2	20	14	6	38.8	0.5 (3)	1.8	0	
	10-12	Sandy Lean Clay (CL)	15.7		32	15	17	56.5				10'-12': Pinhole Test
	16-18	Sandy Lean Clay (CL)	22.1		47	17	30	59.7				16'-18': Crumb Testing-Grade 1 (ND)
	18-20	Clayey Sand (SC)	16.7		37	16	21	37.1				16'-18': CU Triaxial Test
	23-25	Clayey Sand (SC)	15.7	116.7	28	15	13	22.8	4.3 (1)	15.0	24	18'-20': Permeability Test- K=1.46E-07 cm/s
	38-40	Fat Clay (CH)	28.2	96.6					1.1 (2)	2.6	0	23'-25': UU Triaxial Test
	43-45	Fat Clay (CH)	35.3	87.1	76	23	53	90.1	1.9 (2)	15.0	44	43'-45': UU Triaxial Test
4	2-4	Sandy Lean Clay (CL)	10.0	119.8	32	14	18	60.6	3.1 (1)	3.7	0	
	14.5-16	Silty Sand (SM)	19.6		Non Plastic			22.7				
5	6-8	Sandy Lean Clay (CL)	10.7	124.0	37	15	22	65.8	6.9 (3)	3.2	0	
6	4-6	Sandy Lean Clay (CL)	11.3	129.0	42	17	25	63.4	10.1 (3)	6.0	0	
	10-12	Sandy Lean Clay (CL)	9.7	117.8	34	16	18	51.3	6.6 (1)	5.9	11	10'-12': UU Triaxial Test

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TABLE 1

LABORATORY TEST SUMMARY

PROJECT: Proposed NHCRWA Contract No. 28-B
20252 Water Distribution and Transmission System
HTS PROJECT NO.: 16-S-299

LOCATION: Harris County, Texas

CLIENT: Dannenbaum Engineering Corporation

Boring No.	Sample Depth (feet)	Type of Material	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (%)			-200 Sieve (%)	Deviator Stress (tsf)	Strain (%)	Lateral Pressure (psi)	Remarks
					LL	PL	PI					
7	0-2	Sandy Lean Clay (FILL)	17.1		28	15	13	61.7				
	8-10	Lean Clay With Sand (CL)	16.2	116.8	46	18	28	74.0	3.3 (1)	7.8	0	
8	6-8	Sandy Lean Clay (CL)	9.5		40	17	23	63.3				6'-8': Crumb Testing- Grade 1 (ND)
	8-10	Sandy Lean Clay (CL)	10.8		42	18	24	68.1				8'-10': Permeability Test- K= 6.33E-08 cm/s
	10-12	Sandy Lean Clay (CL)	10.8		39	17	22	62.1				
	16.5-18	Clayey Sand (SC)	6.3		25	16	9	43.8				
	33.5-35	Fat Clay With Sand (CH)	17.3					80.6				
	38-40	Lean Clay (CL)	17.6	112.9	43	18	25	91.2	3.7 (1)	14.8	39	38'-40': UU Triaxial Test
	43-45	Sandy Lean Clay (CL)	13.2	122.0	24	15	9		2.4 (3)	11.3	0	
	53-55	Lean Clay (CL)	25.8	105.0					3.0 (2)	14.9	54	53'-55': UU Triaxial Test
9	4-6	Lean Clay With Sand (CL)	11.3		33	17	16	70.1				4'-6': Pinhole Test
	6-8	Lean Clay With Sand (CL)	12.4		43	19	24	73.1				6'-8': CU Triaxial Test
	10-12	Lean Clay With Sand (CL)	13.2	117.3	43	19	24	72.5	5.9 (1)	14.8	11	10'-12': UU Triaxial Test
	18.5-20	Clayey Sand (SC)	3.9		37	17	20	21.7				18'-20': Crumb Testing- Grade 1 (ND)
	28.5-30	Silty Sand (SM)	19.4		Non Plastic			18.9				
	43-45	Lean Clay (CL)	13.7		22	14	8					
	48-50	Lean Clay (CL)	15.4	115.6					1.2 (1)	6.0	0	
10	2-4	Lean Clay With Sand (CL)	11.4	122.4	29	16	13	72.4	4.7 (3)	4.2	0	
	8-10	Sandy Lean Clay (CL)	15.0	119.1	42	17	25	69.7	5.9 (3)	4.9	0	
	16.5-18	Poorly Graded Sand With Silt (SP-SM)	6.0		Non Plastic			11.2				

TABLE 1

LABORATORY TEST SUMMARY

PROJECT: Proposed NHCRWA Contract No. 28-B
20252 Water Distribution and Transmission System
HTS PROJECT NO.: 16-S-299
LOCATION: Harris County, Texas

CLIENT: Dannenbaum Engineering Corporation

Boring No.	Sample Depth (feet)	Type of Material	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (%)			-200 Sieve (%)	Deviator Stress (tsf)	Strain (%)	Lateral Pressure (psi)	Remarks
					LL	PL	PI					
11	2-4	Sandy Lean Clay (CL)	12.8	120.6					2.1 (3)	8.1	0	
	6-8	Lean Clay With Sand (CL)	14.8	108.9	39	18	21	71.6	4.3 (3)	5.9	0	
	13-15	Fat Clay (CH)	24.4	110.2	63	21	42	95.8	2.4 (1)	7.2	0	
12	0-2	Silty Clayey Sand (SC-SM)	4.2		21	17	4	42.9				
	4-6	Sandy Lean Clay (CL)	15.5	118.6	46	20	26	62.3	1.8 (3)	7.9	0	
	8-10	Fat Clay (CH)	18.8	116.2					3.8 (1)	9.2	0	
13	4-6	Lean Clay With Sand (CL)	15.1	116.9	42	19	23	70.7	3.5 (1)	14.3	5	4'-6': UU Triaxial Test
	6-8	Lean Clay With Sand (CL)	12.8	124.6					4.6 (1)	12.0	0	
	10-12	Clayey Sand (SC)	17.0	112.9	28	15	13	39.8	0.7 (3)	5.7	0	

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TABLE 2

CRUMB TEST FOR DETERMINATION OF DISPERSIBILITY OF CLAYEY SOILS (ASTM D 6572, METHOD A)

PROJECT: Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
LOCATION: Harris County, Texas

HTS PROJECT NO.: 16-S-299
DATE: November 7, 2016

CLIENT: Dannenbaum Engineering Corporation

Specimen Data:

☑ Disturbed ☐ Undisturbed

Specimen type: ☑ Natural irregularly shaped crumb ☐ Remolded crumb cube

Moisture content: ☑ Natural moisture ☐ Air-dried ☐ Distilled water added to remold specimen

Curing time _____ min. Water used: ☑ Distilled ☐ Distilled and demineralized

Initial water temperature 23.4 °C

Time at beginning of test 9:22 ☑ am ☐ pm

Tested by: E.R. Date tested: 11/07/16

Checked by: _____ Date: _____

TEST CONDITIONS:

Boring Number	Depth (feet)	2-Minute		1-Hour		6-Hour	
		Grade*	°C	Grade*	°C	Grade*	°C
3	16 - 18	1	23.3	1	22.8	1	22.6
8	6 - 8	1	23.4	1	22.8	1	22.5
9	10 - 12	1	23.3	1	22.9	1	22.6

* Grade 1 - Non Dispersive
Grade 2 - Intermediate
Grade 3 - Dispersive
Grade 4 - Highly Dispersive

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TABLE 3A
PINHOLE DISPERSION TEST
METHOD A
(ASTM D 4647)

PROJECT: Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
HTS PROJECT NO.: 16-S-299

LOCATION: Harris County, Texas
DATE OF TEST: November 11, 2016

CLIENT: Dannenbaum Engineering Corporation

BORING NO: 3
DEPTH: 10' - 12'
TYPE OF MATERIAL: Sandy Lean Clay (CL)
CLASSIFICATION: ND-2

SPECIMEN DATA:

Specimen Curing Time	Water Content (%)	Unit Dry Weight (pcf)	Liquid Limit	Plastic Limit	Plasticity Index	-200 Sieve (%)
None	15.7	116.5	32	15	17	56.5

TEST CONDITIONS:

Hydraulic Head (mm)	Rate of Flow (ml/sec)	Cloudiness of Flow		Length of Test (min)	Needle Punch Hole (mm)	Effluent
		Side	Top			
1020	1.74	Slightly Cloudy	Slightly Cloudy	25	1.74	Distilled Water

TABLE 3B
PINHOLE DISPERSION TEST
METHOD A
(ASTM D 4647)

PROJECT: Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
HTS PROJECT NO.: 16-S-299

LOCATION: Harris County, Texas
DATE OF TEST: November 11, 2016

CLIENT: Dannenbaum Engineering Corporation

BORING NO: 9
DEPTH: 4' - 6'
TYPE OF MATERIAL: Sandy Lean Clay (CL)
CLASSIFICATION: ND-2

SPECIMEN DATA:

Specimen Curing Time	Water Content (%)	Unit Dry Weight (pcf)	Liquid Limit	Plastic Limit	Plasticity Index	-200 Sieve (%)
None	11.3	127.5	33	17	17	70.1

TEST CONDITIONS:

Hydraulic Head (mm)	Rate of Flow (ml/sec)	Cloudiness of Flow		Length of Test (min)	Needle Punch Hole (mm)	Effluent
		Side	Top			
1020	3.1	Completely Clear	Completely Clear	25	1.06	Distilled Water

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TABLE 4A: FALLING HEAD / RISING TAIL HYDRAULIC CONDUCTIVITY TEST

(ASTM D-5084-03)

Project No:	16-S-299	Sample Identification:	B-3 (18'-20')
Technician:	M. Coronado	Sample Description:	Clayey Sand (SC)
			LL = 37, PL = 21, PI = 37.1

Project : Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission

INITIAL CONDITIONS				FINAL CONDITIONS			
WATER CONTENT		SPECIMEN DATA		WATER CONTENT		SPECIMEN DATA	
Tare No.:	K-7	Length, in:	2.195	Tare No.:	51	Length (L), in:	2.197
Wet+Tare, gms:	591.45	Diameter, in:	2.762	Wet+Tare, gms:	162.01	Diameter, in:	2.764
Dry+Tare, gms:	569.67	Wet mass, gms:	458.09	Dry+Tare, gms:	142.08	Wet mass, gms:	461.09
Tare Weight, gms:	438.86	Area, cm^2:	38.66	Tare Weight, gms:	30.50	Area (A), cm^2:	38.71
Moisture, %	16.7	Volume, cc:	215.5	Moisture, %	17.9	Volume, cc:	216.0
		Unit wet wt, pcf:	132.6			Unit wet wt, pcf:	133.2
Specific Gravity:	2.70	Unit dry wt, pcf:	113.7	Specific Gravity:	2.70	Unit dry wt, pcf:	113.0
Saturation, %:	93.3	Void Ratio:	0.482	Saturation, %:	98.2	Void Ratio:	0.491
Perm. Cell No.:	3	Burret diam, cm:	1.06	Burret area (a), cm^2.:	0.882	Burret factor,cm/cc:	1.009
Cell Pressure, psi:	5	Head Pressure, psi:	3.0	Tail Pressure, psi:	2.0	Hydraulic Gradient:	15.9

PERMEABILITY MEASUREMENTS

Date	Time	Elapsed Time (Δt) (sec)	Temp (C)	Pressure Diff. (psi)	Head Rdg (cc)	Tail Rdg (cc)	Head Change (cm)	Tail Change (cm)	Total Head (h_1, h_2) (cm)	Permeability Kt (cm/sec)	Permeability K_{20} (cm/sec)
11/4/2016	08:45 AM	0	22.9	1.0	2.0	20.0	0.000	0.000	88.46	0.00E+00	0.00E+00
11/4/2016	09:15 AM	1800	22.9	1.0	2.2	19.8	0.202	0.202	88.06	1.62E-07	1.51E-07
11/4/2016	09:45 AM	1800	22.9	1.0	2.3	19.7	0.101	0.101	87.86	8.10E-08	7.56E-08
11/4/2016	10:15 AM	1800	22.9	1.0	2.5	19.3	0.202	0.404	87.25	2.44E-07	2.28E-07
11/4/2016	10:45 AM	1800	22.9	1.0	2.6	19.1	0.101	0.202	86.95	1.23E-07	1.15E-07
11/4/2016	11:15 AM	1800	22.9	1.0	2.7	18.9	0.101	0.202	86.65	1.23E-07	1.15E-07
11/4/2016	11:45 AM	1800	22.9	1.0	2.9	18.6	0.202	0.303	86.14	2.06E-07	1.93E-07
11/4/2016	12:15 PM	1800	22.9	1.0	3.1	18.3	0.202	0.303	85.64	2.07E-07	1.94E-07

Coefficient of Permeability, k = **1.46E-07** cm/sec

Computed By: GEV Date: 6/6/2016 Checked By: GEV Date: 06/06/16

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TABLE 4B: FALLING HEAD / RISING TAIL HYDRAULIC CONDUCTIVITY TEST

(ASTM D-5084-03)

Project No:	16-S-299	Sample Identification:	B-8 (8'-10')
Technician:	M. Coronado	Sample Description:	Sandy Lean Clay (CL)
			LL = 42, PL = 22, PI = 68.1

Project : Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission

INITIAL CONDITIONS				FINAL CONDITIONS			
WATER CONTENT		SPECIMEN DATA		WATER CONTENT		SPECIMEN DATA	
Tare No.:	P2	Length, in:	2.195	Tare No.:	58	Length (L), in:	2.201
Wet+Tare, gms:	574.39	Diameter, in:	2.816	Wet+Tare, gms:	159.36	Diameter, in:	2.867
Dry+Tare, gms:	556.72	Wet mass, gms:	485.34	Dry+Tare, gms:	142.09	Wet mass, gms:	507.98
Tare Weight, gms:	392.87	Area, cm^2:	40.18	Tare Weight, gms:	30.80	Area (A), cm^2:	41.65
Moisture, %	10.8	Volume, cc:	224.0	Moisture, %	15.5	Volume, cc:	232.8
		Unit wet wt, pcf:	135.2			Unit wet wt, pcf:	136.1
Specific Gravity:	2.70	Unit dry wt, pcf:	122.0	Specific Gravity:	2.70	Unit dry wt, pcf:	117.8
Saturation, %:	76.5	Void Ratio:	0.381	Saturation, %:	97.5	Void Ratio:	0.430
Perm. Cell No.:	7	Burret diam, cm:	1.06	Burret area (a), cm^2.:	0.882	Burret factor,cm/cc:	1.009
Cell Pressure, psi:	5	Head Pressure, psi:	3.0	Tail Pressure, psi:	2.0	Hydraulic Gradient:	15.9

PERMEABILITY MEASUREMENTS

Date	Time	Elapsed Time (Δt) (sec)	Temp (C)	Pressure Diff. (psi)	Head Rdg (cc)	Tail Rdg (cc)	Head Change (cm)	Tail Change (cm)	Total Head (h_1, h_2) (cm)	Permeability Kt (cm/sec)	Permeability K_{20} (cm/sec)
11/4/2016	08:50 AM	0	22.9	1.0	2.0	20.0	0.000	0.000	88.46	0.00E+00	0.00E+00
11/4/2016	09:15 AM	1500	22.9	1.0	2.1	19.9	0.101	0.101	88.26	9.01E-08	8.41E-08
11/4/2016	09:45 AM	1800	22.9	1.0	2.2	19.7	0.101	0.202	87.96	1.13E-07	1.05E-07
11/4/2016	10:15 AM	1800	22.9	1.0	2.3	19.5	0.101	0.202	87.65	1.13E-07	1.06E-07
11/4/2016	11:15 AM	3600	22.9	1.0	2.4	19.4	0.101	0.101	87.45	3.79E-08	3.54E-08
11/4/2016	01:55 PM	9600	22.9	1.0	2.5	19.3	0.101	0.101	87.25	1.42E-08	1.33E-08
11/4/2016	02:55 PM	3600	22.9	1.0	2.6	19.2	0.101	0.101	87.05	3.81E-08	3.55E-08

Coefficient of Permeability, k = **6.33E-08** cm/sec

Computed By: GEV Date: 6/6/2016 Checked By: GEV Date: 06/06/16

FIGURES

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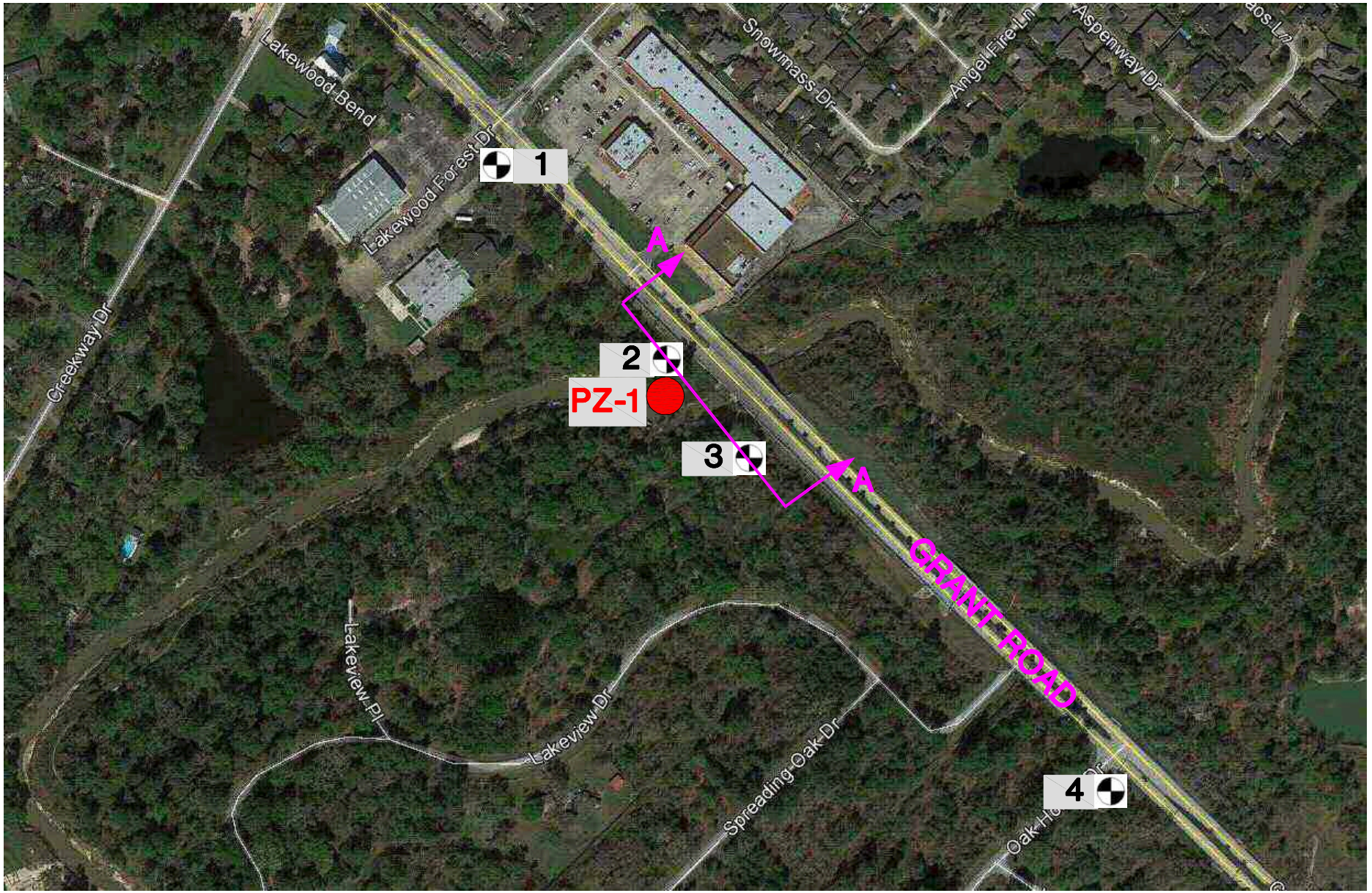
Proposed NHCRWA Contract No. 28-B
2025 Water Distribution
and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11-21-16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11-21-16	
HTS PROJECT NO.:	16-S-299			FIGURE: 1

VICINITY MAP



Legend

- Geotechnical borings included in the study
- Piezometer location

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Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11/15/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11/15/16	
HTS PROJECT NO.:	16-S-299			FIGURE: 2A

BORING LOCATIONS

Legend

Geotechnical Borings included in the study

HTS, Inc. Consultants

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	7/26/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	7/26/16	
HTS PROJECT NO.:	16-S-299			FIGURE: 2B

BORING LOCATIONS

Legend

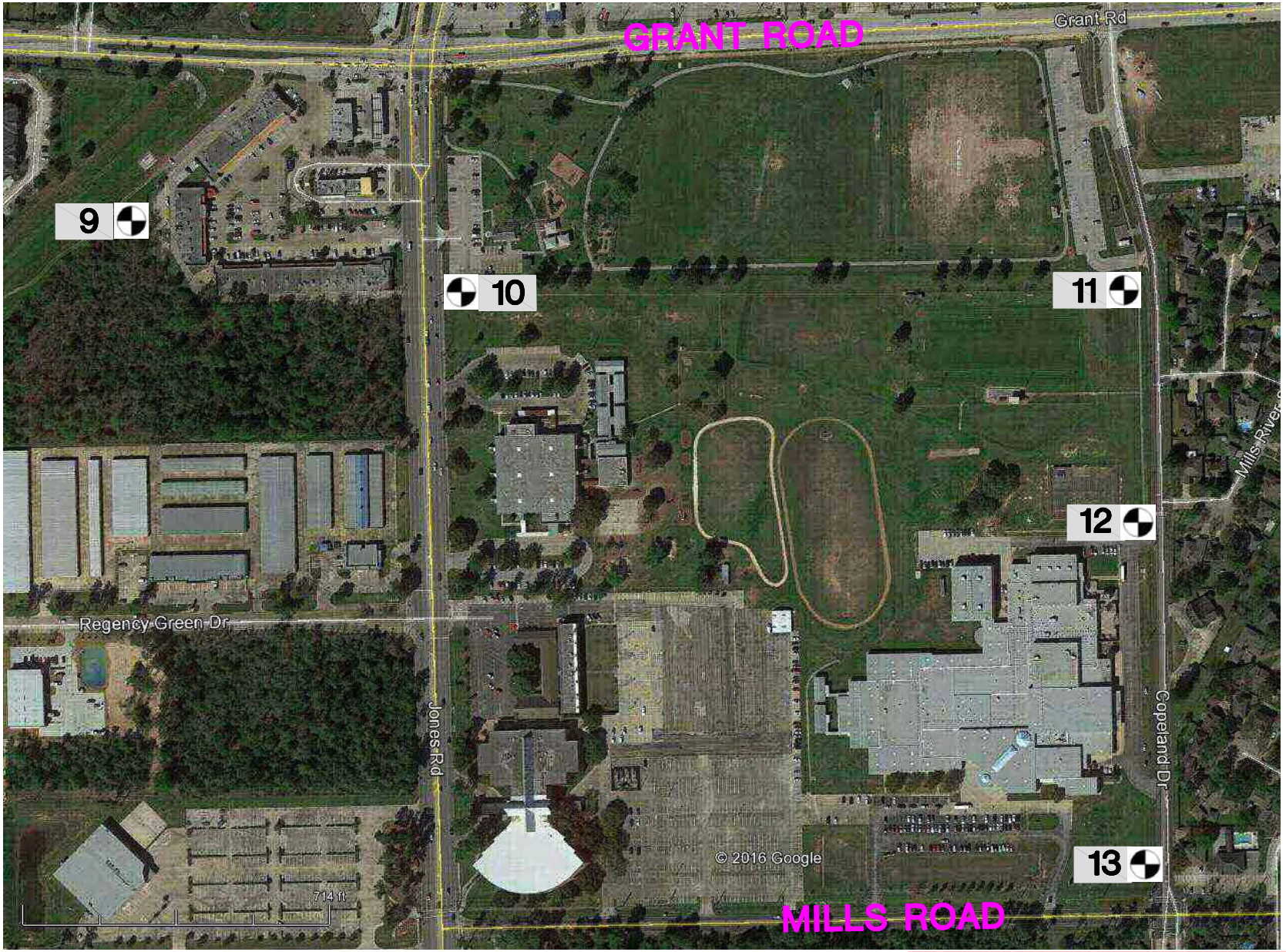
- Geotechnical borings included in the study
- Piezometer location

HTS, Inc. Consultants

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11/15/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11/15/16	
HTS PROJECT NO.:	16-S-299			FIGURE: 2C

BORING LOCATIONS



Legend

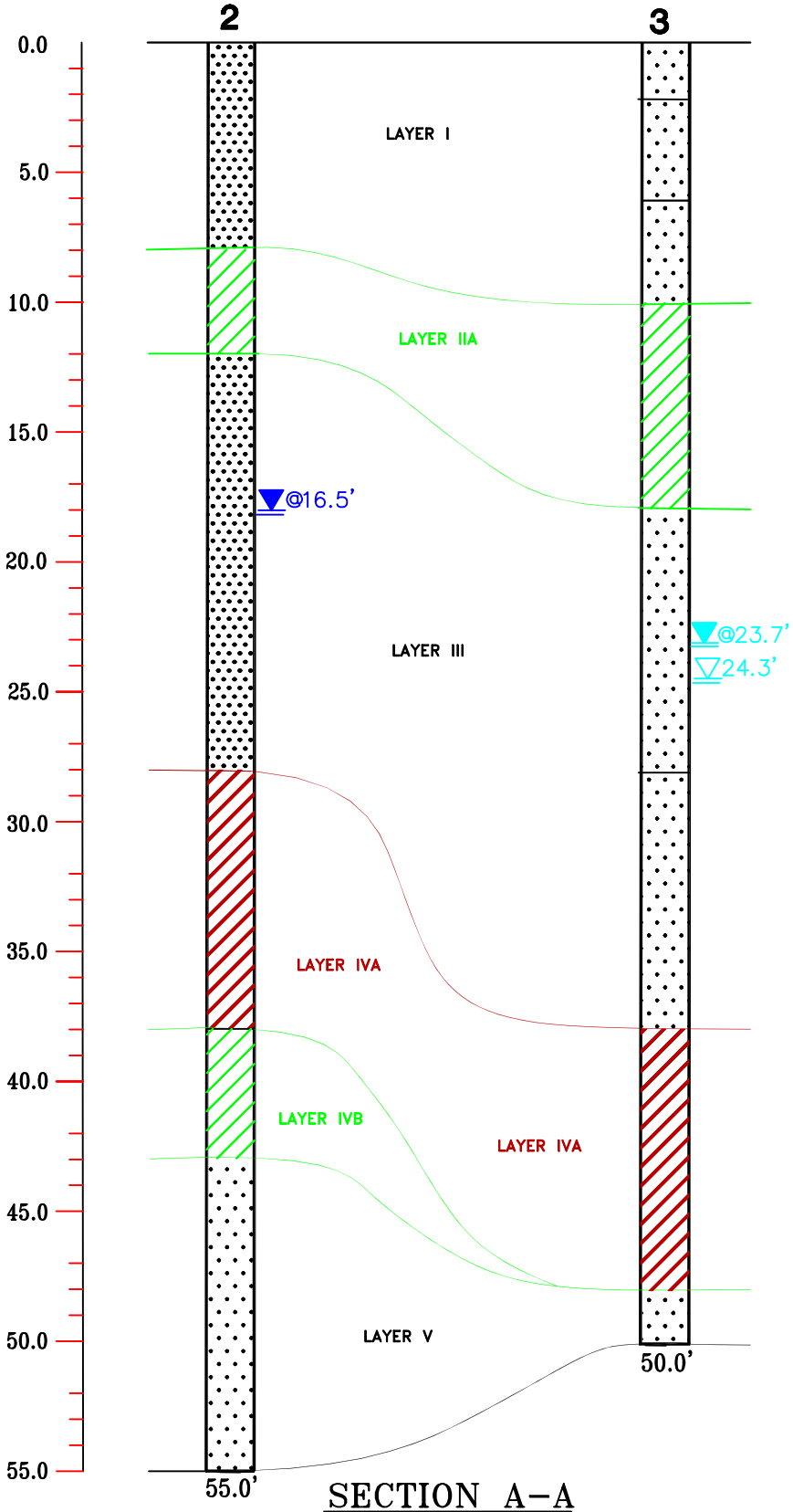
- Geotechnical borings included in the study

HTS, Inc. Consultants

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11/15/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11/15/16	
HTS PROJECT NO.:	16-S-299			FIGURE: 2D

BORING LOCATIONS



SECTION A–A

LAYER I

SANDY SOILS CONSISTING OF CLAYEY SAND, SILTY SAND, AND SILTY CLAYEY SAND, LOOSE TO DENSE.

LAYER II

CLAYEY SOILS CONSISTING OF SANDY LEAN CLAY, LEAN CLAY, SILTY CLAY, AND LEAN CLAY WITH SAND, STIFF TO HARD.

LAYER III

SANDY SOILS CONSISTING OF CLAYEY SAND, SILTY SAND, AND POORLY GRADED SAND WITH SILT, VERY LOOSE TO VERY DENSE.

LAYER IVA

CLAYEY SOILS CONSISTING OF FAT CLAY AND FAT CLAY WITH SAND, STIFF TO HARD.

LAYER IVB

CLAYEY SOILS CONSISTING OF LEAN CLAY AND SANDY LEAN CLAY, STIFF TO HARD.

LAYER V

SANDY SOILS CONSISTING OF SILTY SAND, DENSE TO VERY DENSE.

LEGEND

- GROUNDWATER MEASUREDD DURING DRILLING
- GROUNDWATER MEASURED 10 MINUTES AFTER IT WAS INITIALLY ENCOUNTERED
- GROUNDWATER MEASURED AFTER COMPLETION OF DRILLING

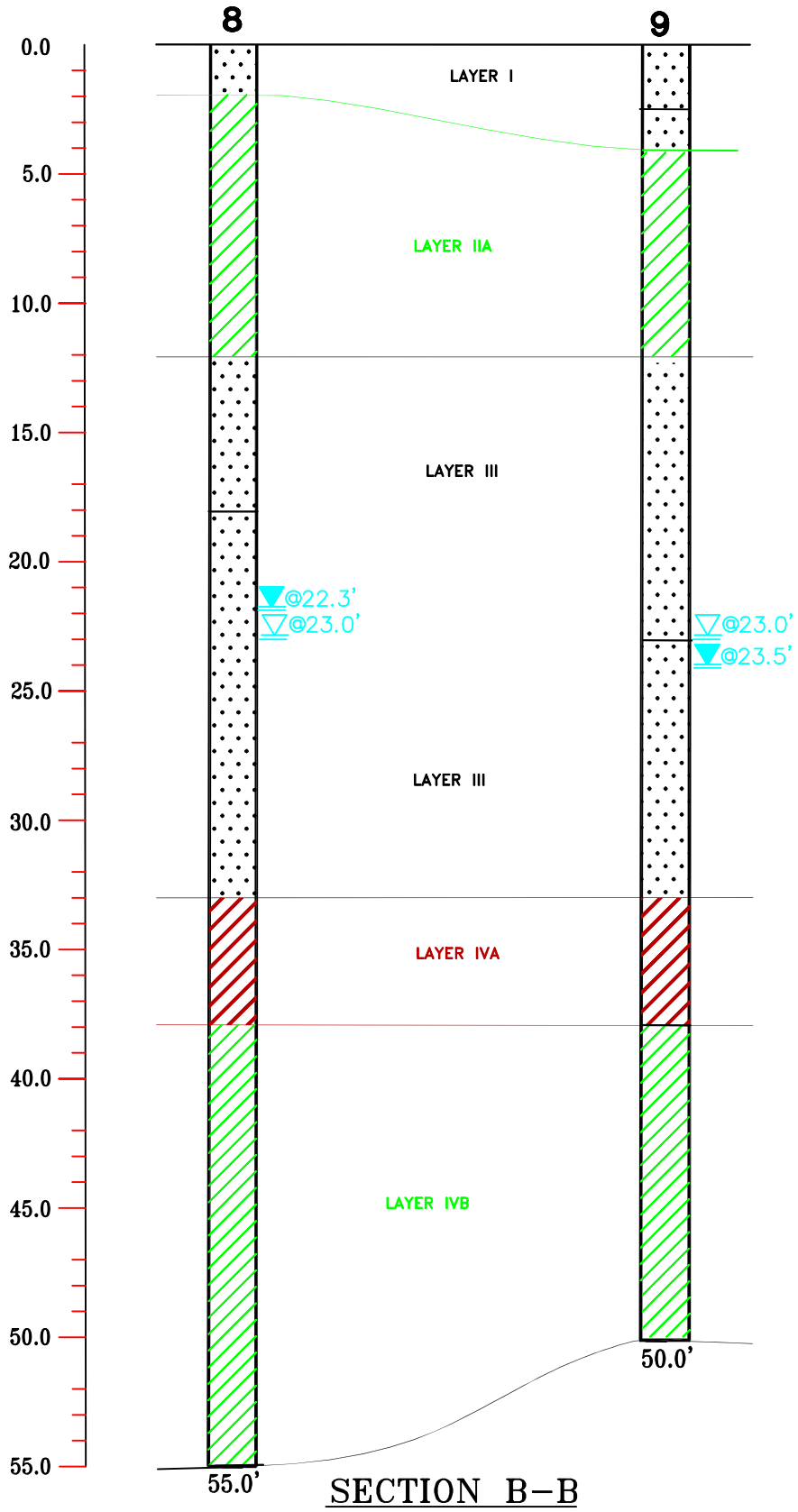
NOTES

1) SEE FIGURE 2A FOR LOCATION OF SECTION A–A.
2) THE STRATIFICATION LINES SHOWN ARE OUR ESTIMATION BETWEEN BORINGS AND DO NOT REPRESENT ACTUAL SUBSOIL CONDITIONS BETWEEN BORINGS.
3) SEE CORRESPONDING BORING LOGS FOR DETAILED SUBSOIL AND GROUNDWATER INFORMATION.

HTS, Inc. Consultants

Propose NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY: IAT	DATE: 12–15–16	SCALE: Hor.: NTS Vert.: As Shown	
CHECKED BY: BFM	DATE: 12–15–16		
HTS PROJECT NO.: 16-S-299		FIGURE: 3A	
Soil Profile Section A-A			



SECTION B–B

LAYER I

SANDY SOILS CONSISTING OF CLAYEY SAND, SILTY SAND, AND SILTY CLAYEY SAND, LOOSE TO DENSE.

LAYER II

CLAYEY SOILS CONSISTING OF SANDY LEAN CLAY, LEAN CLAY, SILTY CLAY, AND LEAN CLAY WITH SAND, STIFF TO HARD.

LAYER III

SANDY SOILS CONSISTING OF CLAYEY SAND, SILTY SAND, AND POORLY GRADED SAND WITH SILT, VERY LOOSE TO VERY DENSE.

LAYER IVA

CLAYEY SOILS CONSISTING OF FAT CLAY AND FAT CLAY WITH SAND, STIFF TO HARD.

LAYER IVB

CLAYEY SOILS CONSISTING OF LEAN CLAY AND SANDY LEAN CLAY, STIFF TO HARD.

LEGEND

- GROUNDWATER MEASUREDD DURING DRILLING
- GROUNDWATER MEASURED 10 MINUTES AFTER IT WAS INITIALLY ENCOUNTERED

NOTES

1) SEE FIGURE 2C FOR LOCATION OF SECTION B–B.
2) THE STRATIFICATION LINES SHOWN ARE OUR ESTIMATION BETWEEN BORINGS AND DO NOT REPRESENT ACTUAL SUBSOIL CONDITIONS BETWEEN BORINGS.
3) SEE CORRESPONDING BORING LOGS FOR DETAILED SUBSOIL AND GROUNDWATER INFORMATION.

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Propose NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY: IAT	DATE: 12–15–16	SCALE: Hor.: NTS Vert.: As Shown	
CHECKED BY: BFM	DATE: 12–15–16		
HTS PROJECT NO.: 16-S-299		FIGURE: 3B	
Soil Profile Section B-B			

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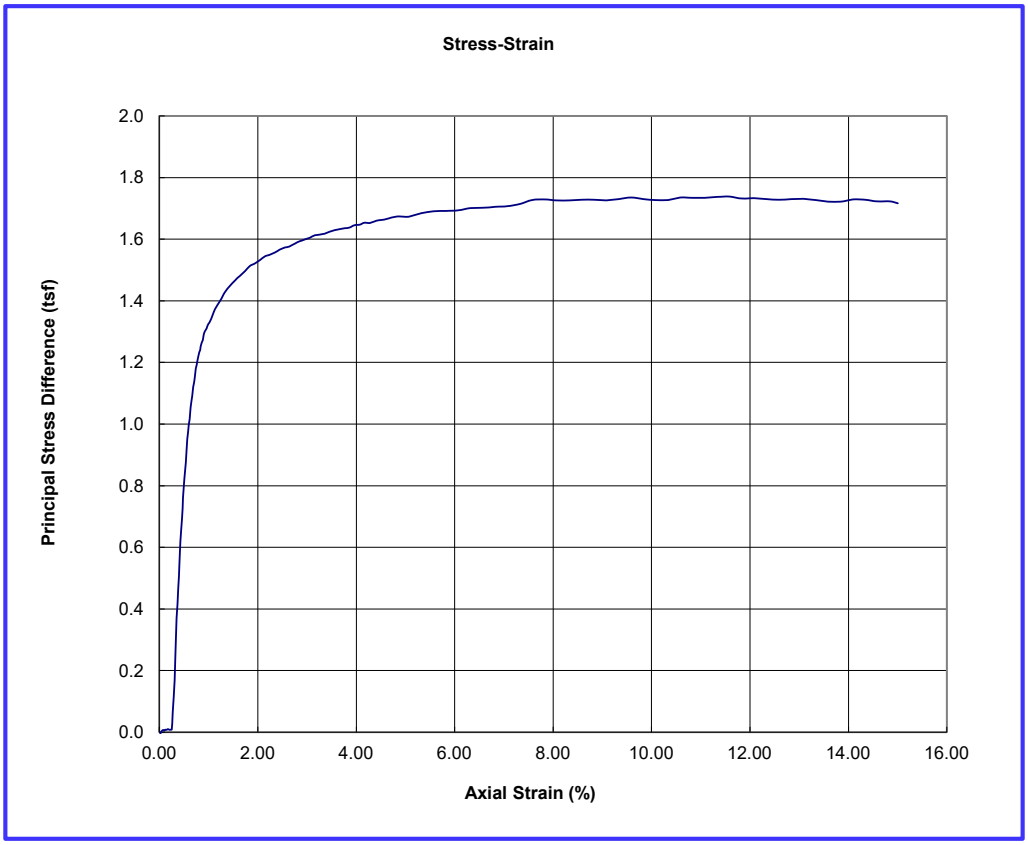
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

(ASTM D-2850)



Shear Stress (tsf)	**1.7**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**11.6**	**Moisture Content (%)***	**28.4**
Dry Density (pcf)	**92**	**Lateral Pressure (psi)**	**34**
Remarks: Sample failed along slickensides.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:	**85**	% Pass No. 200:	**88.8**
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:	**24**	Nat. Moisture (%):	**28.4**
Project No.:	**16-S-299**	Plasticity Index:	**61**	Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 2 (33'-35')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 4**	
Description:	**FAT CLAY (CH)**	Date Checked:	**11/10/2016**		

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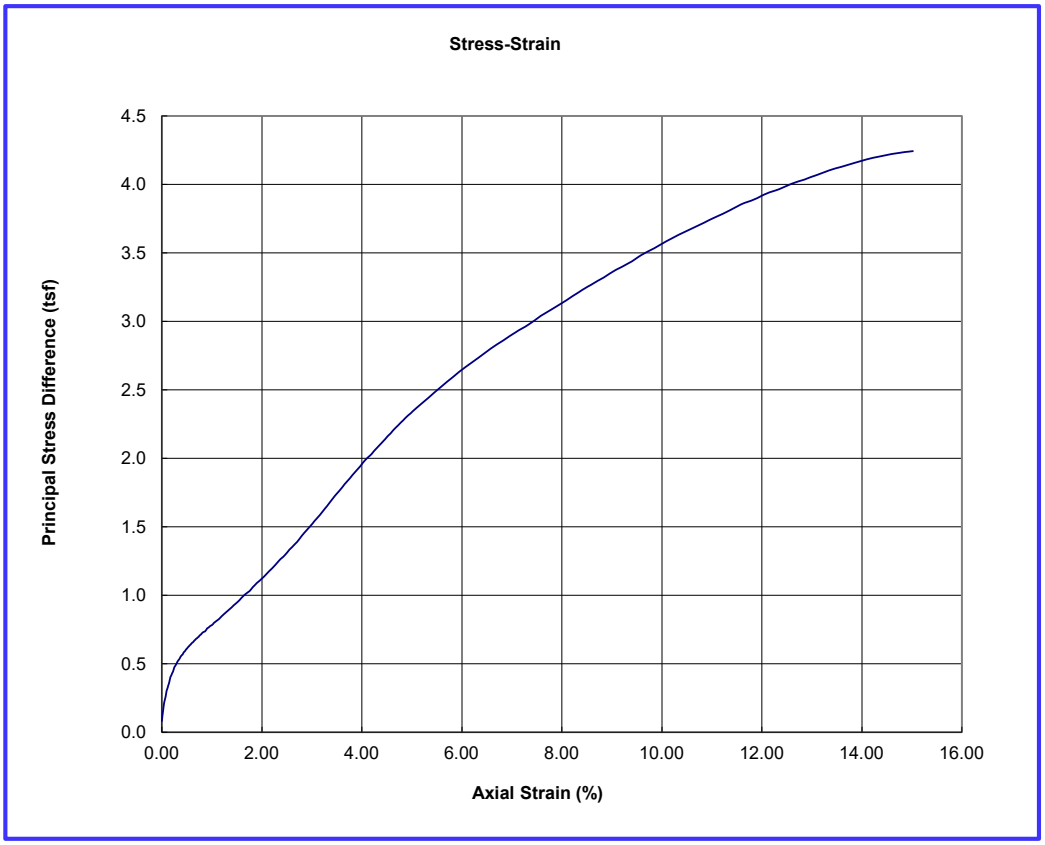
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

(ASTM D-2850)



Shear Stress (tsf)	**4.2**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**15.0**	**Moisture Content (%)***	**15.7**
Dry Density (pcf)	**116.7**	**Lateral Pressure (psi)**	**24**
Remarks: Sample bulged at failure.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:	**28**	% Pass No. 200:	**22.8**
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:	**15**	Nat. Moisture (%):	**15.7**
Project No.:	**16-S-299**	Plasticity Index:	**13**	Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 3 (23'-25')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 5**	
Description:	**Clayey Sand (SC)**	Date Checked:	**11/10/2016**		

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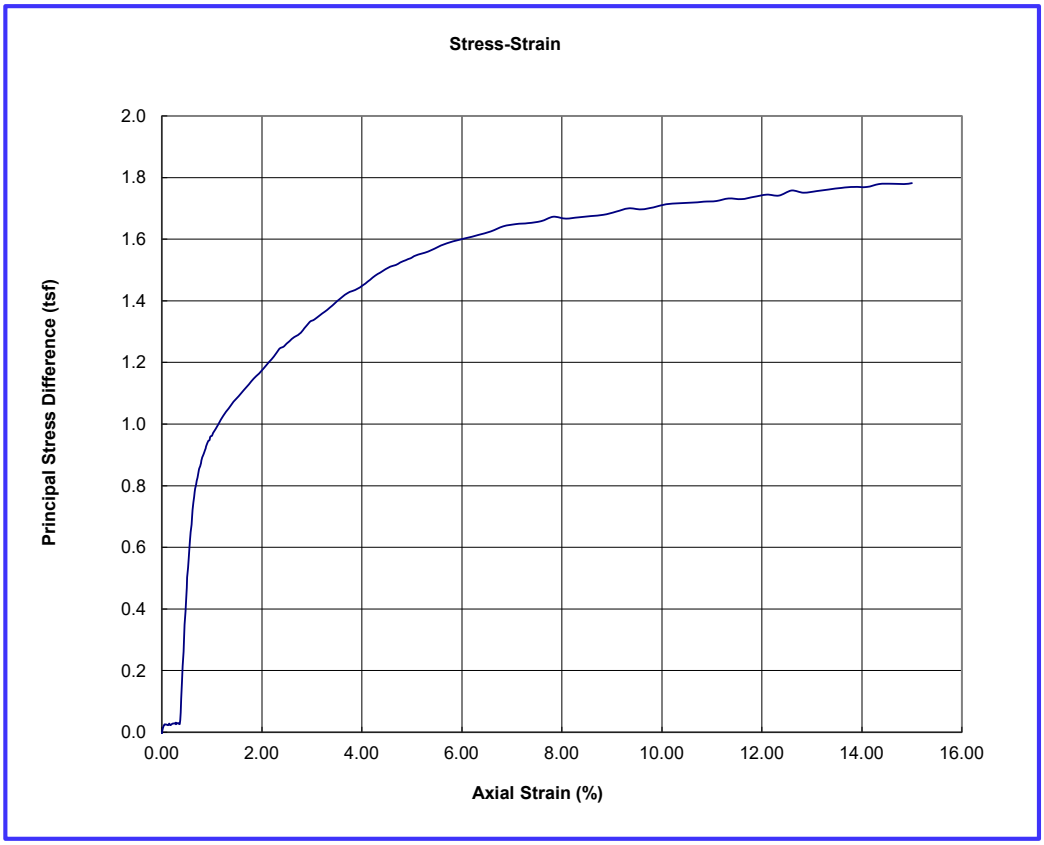
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

(ASTM D-2850)



Shear Stress (tsf)	**1.8**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**15.0**	**Moisture Content (%)***	**35.3**
Dry Density (pcf)	**87.1**	**Lateral Pressure (psi)**	**44**
Remarks: Sample failed along slickensides.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:	**76**	% Pass No. 200:	**90.1**
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:	**23**	Nat. Moisture (%):	**35.3**
Project No.:	**16-S-299**	Plasticity Index:	**53**	Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 3 (43'-45')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 6**	
Description:	**Fat Clay (CH)**	Date Checked:	**11/10/2016**		

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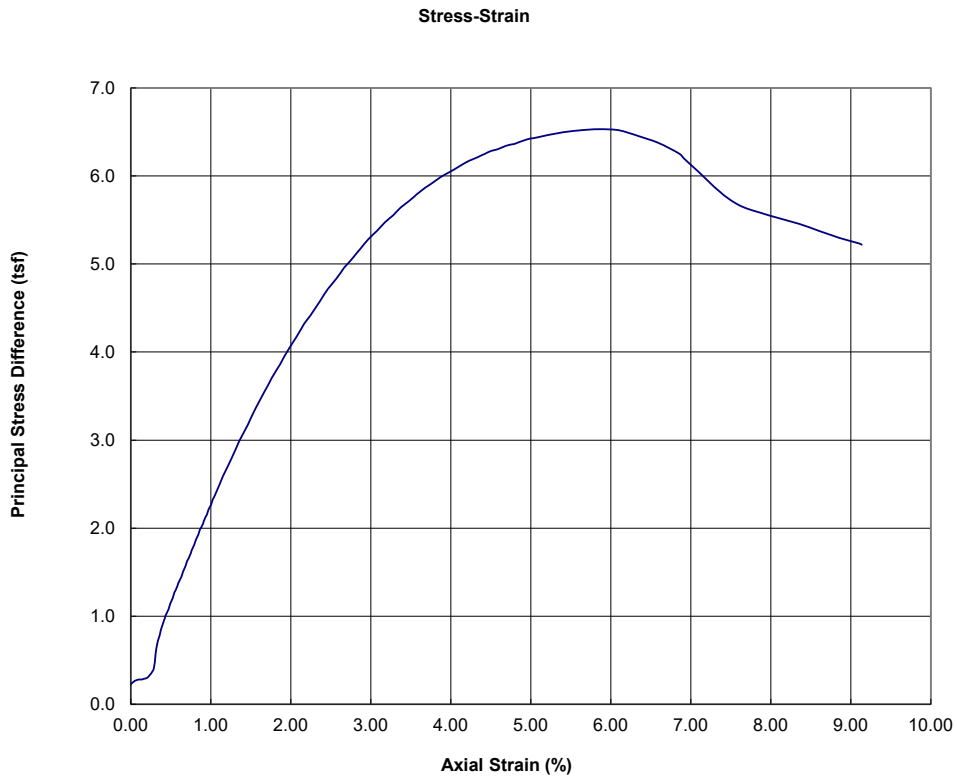
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

(ASTM D-2850)



Shear Stress (tsf)	**6.5**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**5.6**	**Moisture Content (%)***	**35.3**
Dry Density (pcf)	**117.8**	**Lateral Pressure (psi)**	**44**
Remarks: Sample bulged at failure.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:	**34**	% Pass No. 200:	**51.3**
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:	**16**	Nat. Moisture (%):	**9.7**
Project No.:	**16-S-299**	Plasticity Index:	**18**	Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 6 (10'-12')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 7**	
Description:	**Sandy Lean Clay (CL)**	Date Checked:	**11/10/2016**		

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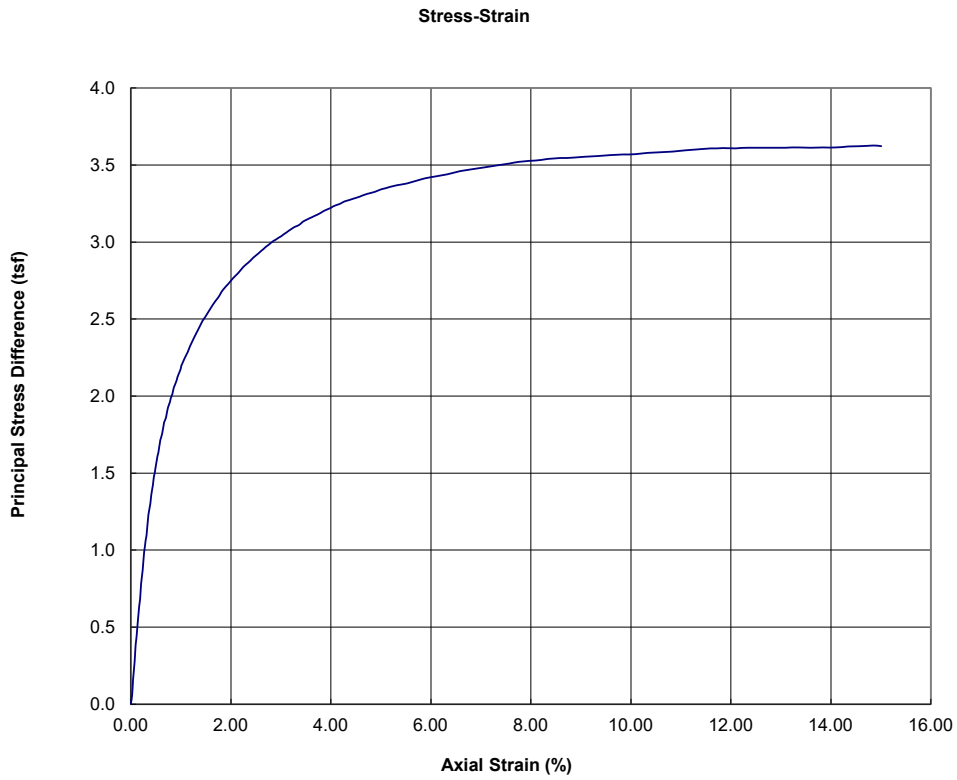
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

(ASTM D-2850)



Shear Stress (tsf)	**3.6**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**14.9**	**Moisture Content (%)***	**17.6**
Dry Density (pcf)	**112.9**	**Lateral Pressure (psi)**	**39**
Remarks: Sample bulged at failure.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:	**43**	% Pass No. 200:	**91.2**
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:	**21**	Nat. Moisture (%):	**17.6**
Project No.:	**16-S-299**	Plasticity Index:	**22**	Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 8 (38'-40')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 8**	
Description:	**Lean Clay (CL)**	Date Checked:	**11/10/2016**		

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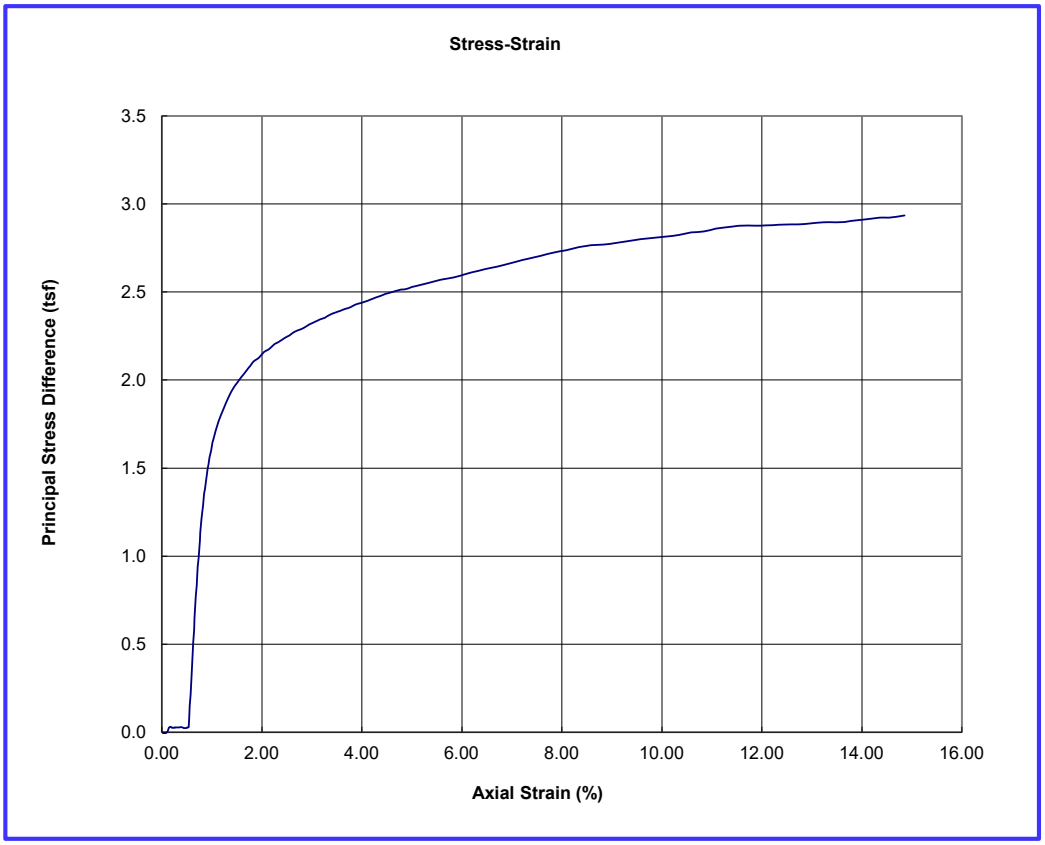
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

(ASTM D-2850)



Shear Stress (tsf)	**3.0**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**14.9**	**Moisture Content (%)***	**25.8**
Dry Density (pcf)	**105**	**Lateral Pressure (psi)**	**54**
Remarks: Sample failed along slickensides.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:		% Pass No. 200:	
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:		Nat. Moisture (%):	**25.8**
Project No.:	**16-S-299**	Plasticity Index:		Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 8 (53'-55')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 9**	
Description:	**Lean Clay (CL)**	Date Checked:	**11/10/2016**		

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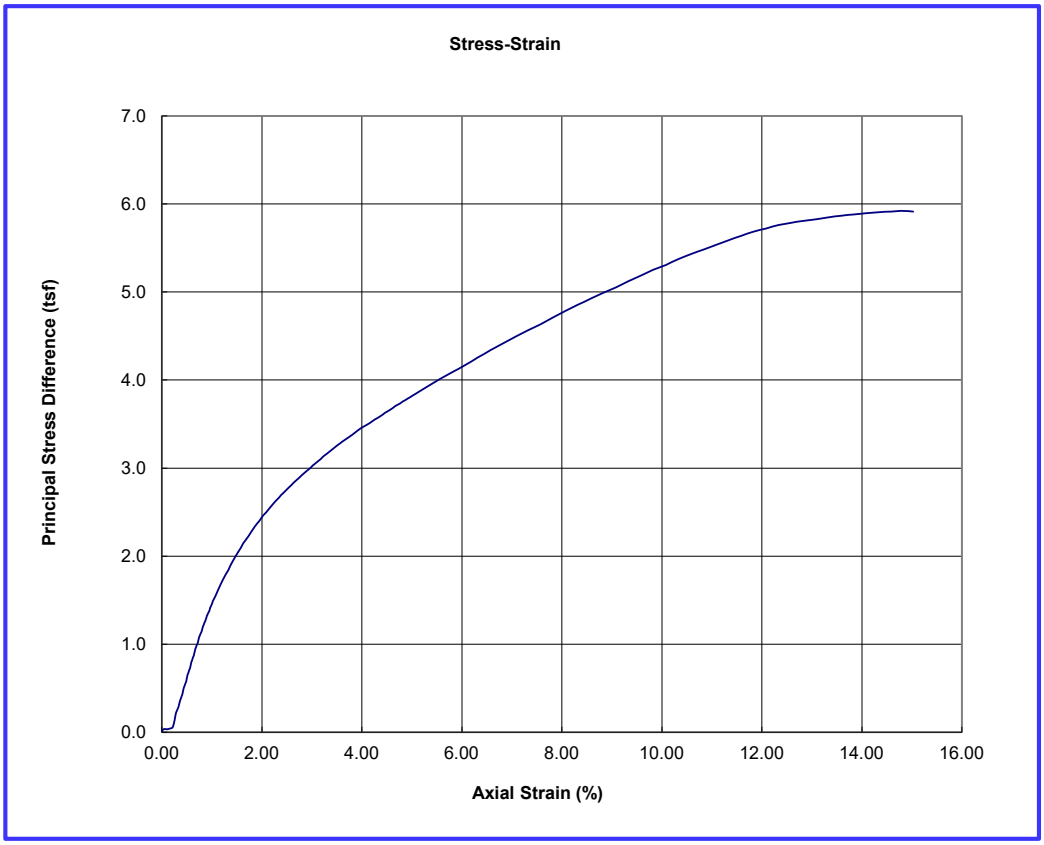
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

(ASTM D-2850)



Shear Stress (tsf)	**5.9**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**14.8**	**Moisture Content (%)***	**13.2**
Dry Density (pcf)	**117.3**	**Lateral Pressure (psi)**	**11**
Remarks: Sample bulged at failure.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:	**43**	% Pass No. 200:	**72.5**
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:	**19**	Nat. Moisture (%):	**13.2**
Project No.:	**16-S-299**	Plasticity Index:	**24**	Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 9 (10'-12')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 10**	
Description:	**Lean Clay With Sand (CL)**	Date Checked:	**11/10/2016**		

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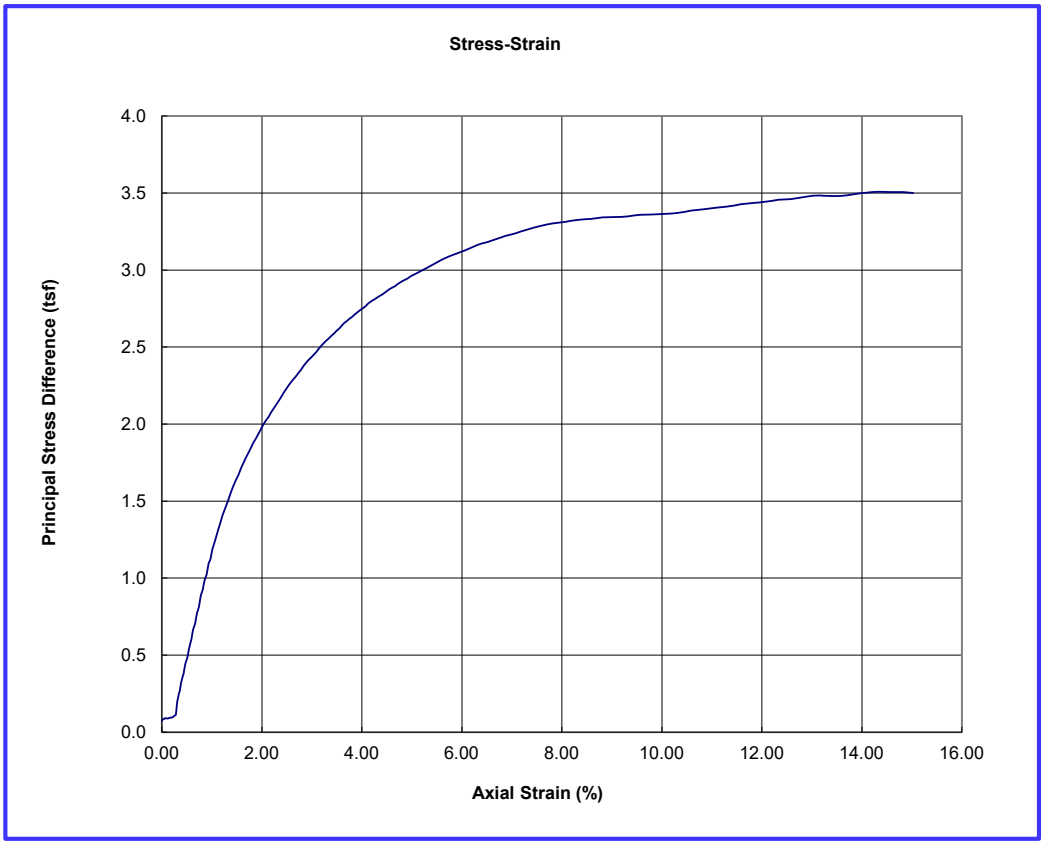
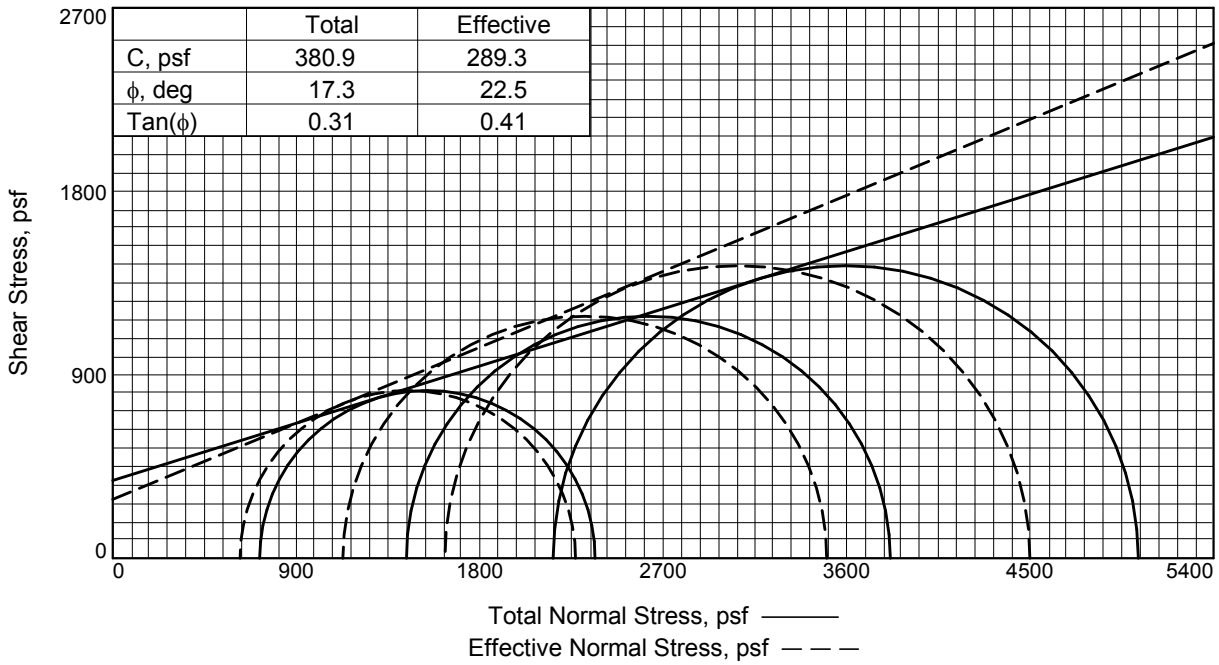
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

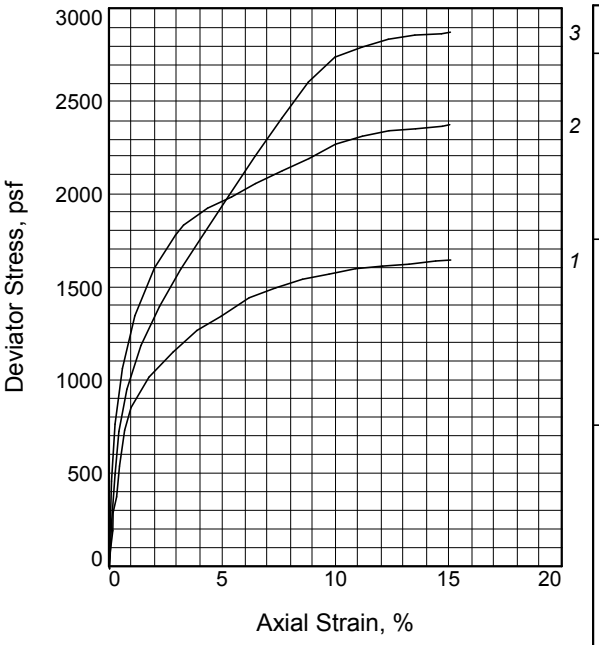
(ASTM D-2850)



Shear Stress (tsf)	**3.5**	**Strain rate (%/min)**	**1.0**
Failure Strain (%)	**14.3**	**Moisture Content (%)***	**15.1**
Dry Density (pcf)	**116.9**	**Lateral Pressure (psi)**	**5**
Remarks: Sample bulged at failure.			

Project:	**Proposed NHCRWA Contract No. 28-B**	Liquid Limit:	**42**	% Pass No. 200:	**70.7**
Client:	**NHCRWA and Dannenbaum Engineering Corp.**	Plastic Limit:	**20**	Nat. Moisture (%):	**15.1**
Project No.:	**16-S-299**	Plasticity Index:	**22**	Test Method:	**ASTM D-2850**
Sample ID:	**Boring No. 13 (4'-6')**	Tested By:	**MC**	Date Tested:	**11/4/2016**
Remarks:		Checked By:	**BHA**	**FIGURE 11**	
Description:	**Lean Clay With Sand (CL)**	Date Checked:	**11/10/2016**		





Sample No.		1	2	3
Initial	Water Content, %	12.2	12.4	14.5
	Dry Density, pcf	122.2	121.0	111.7
	Saturation, %	87.0	85.1	76.9
	Void Ratio	0.3793	0.3925	0.5093
	Diameter, in.	2.77	2.79	2.78
	Height, in.	5.70	5.72	5.69
At Test	Water Content, %	16.6	15.6	17.3
	Dry Density, pcf	116.3	118.7	114.9
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.4490	0.4205	0.4675
	Diameter, in.	3.08	3.06	2.97
	Height, in.	4.84	4.86	4.85
Strain rate, %/min.		0.01	0.01	0.01
Back Pressure, psi		38.000	38.000	38.000
Cell Pressure, psi		43.000	48.000	53.000
Fail. Stress, psf		1645.9	2374.0	2870.8
Total Pore Pr., psf		5567.9	5783.0	6003.5
Ult. Stress, psf		1645.9	2374.0	2870.8
Total Pore Pr., psf		5567.9	5783.0	6003.5
$\bar{\sigma}_1$ Failure, psf		2270.0	3502.9	4499.3
$\bar{\sigma}_3$ Failure, psf		624.1	1129.0	1628.5

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tubes

Description: Lean Clay With Sand (CL)
-200 Sieve=73.1%

LL= 43 **PL=** 19 **PI=** 24

Assumed Specific Gravity= 2.70

Remarks: Tested by: MC Date: 11/11/16
Checked by: GEV Date: 11/14/13

Figure 12

Client: Dannenbaum Engineering Corporation

Project: Proposed NHCRWA Contract NO. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

Sample Number: Boring No. 9 **Depth:** 6'-8'

Proj. No.: 16-S-299 **Date Sampled:** 10/10/16

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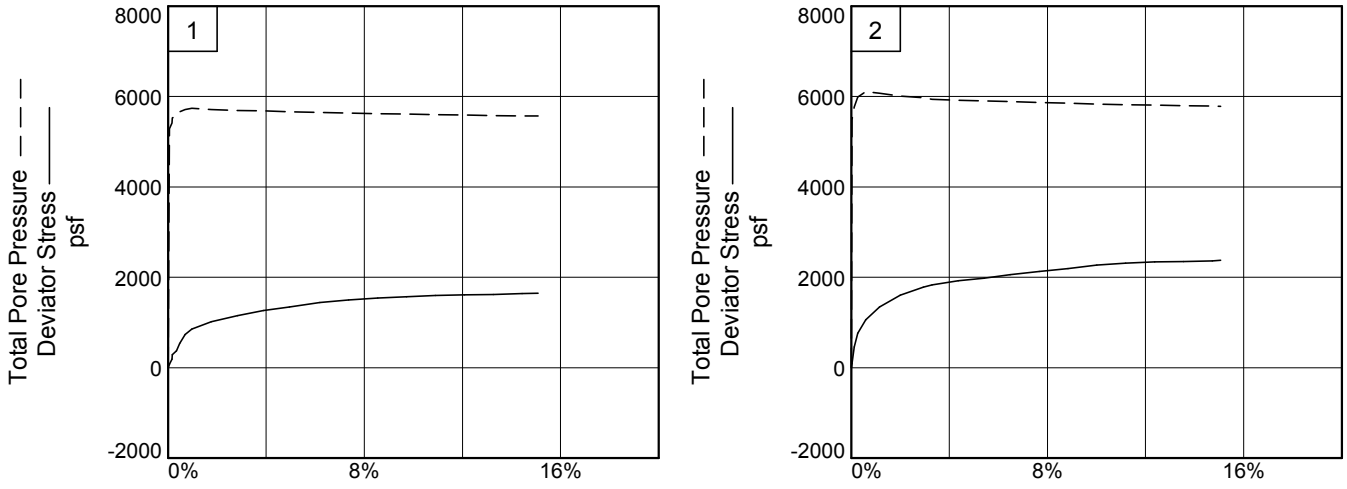

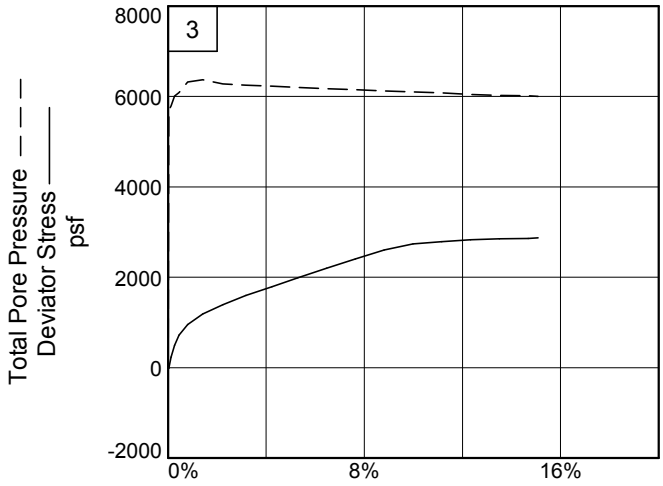

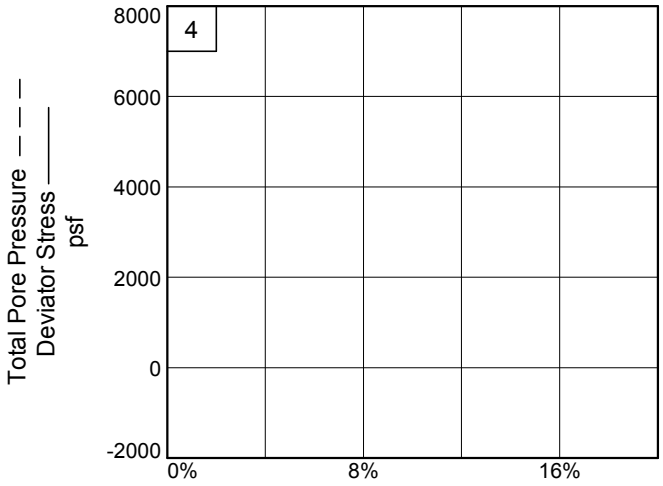

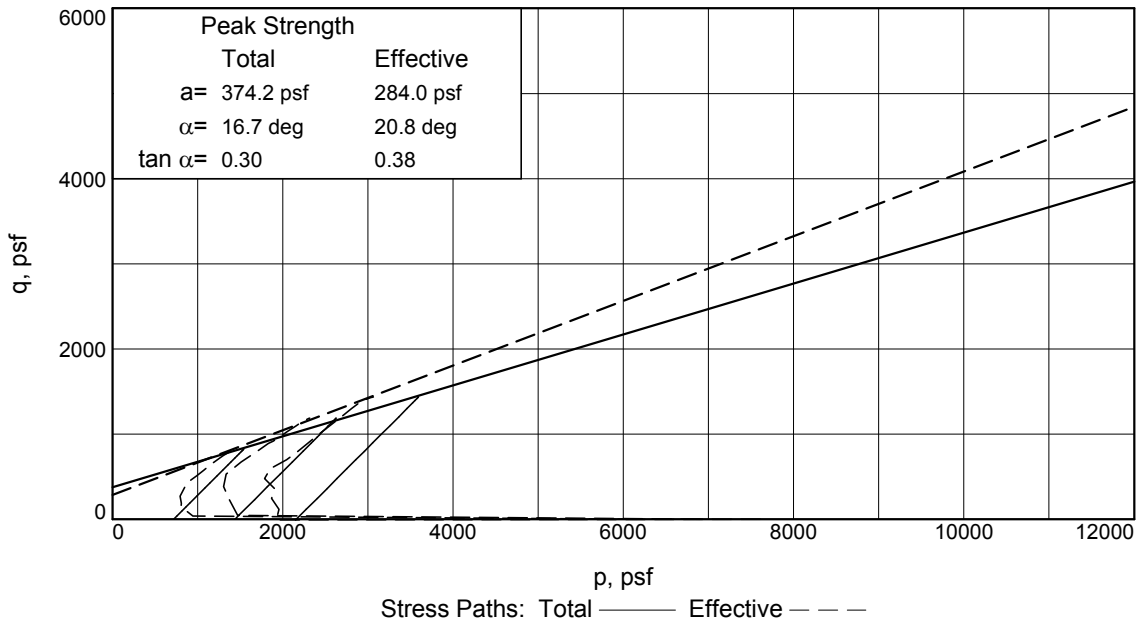

Client: Dannenbaum Engineering Corporation

Project: Proposed NHCRWA Contract NO. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

Depth: 6'-8' **Sample Number:** Boring No. 9

Project No.: 16-S-299 **Figure** 12A

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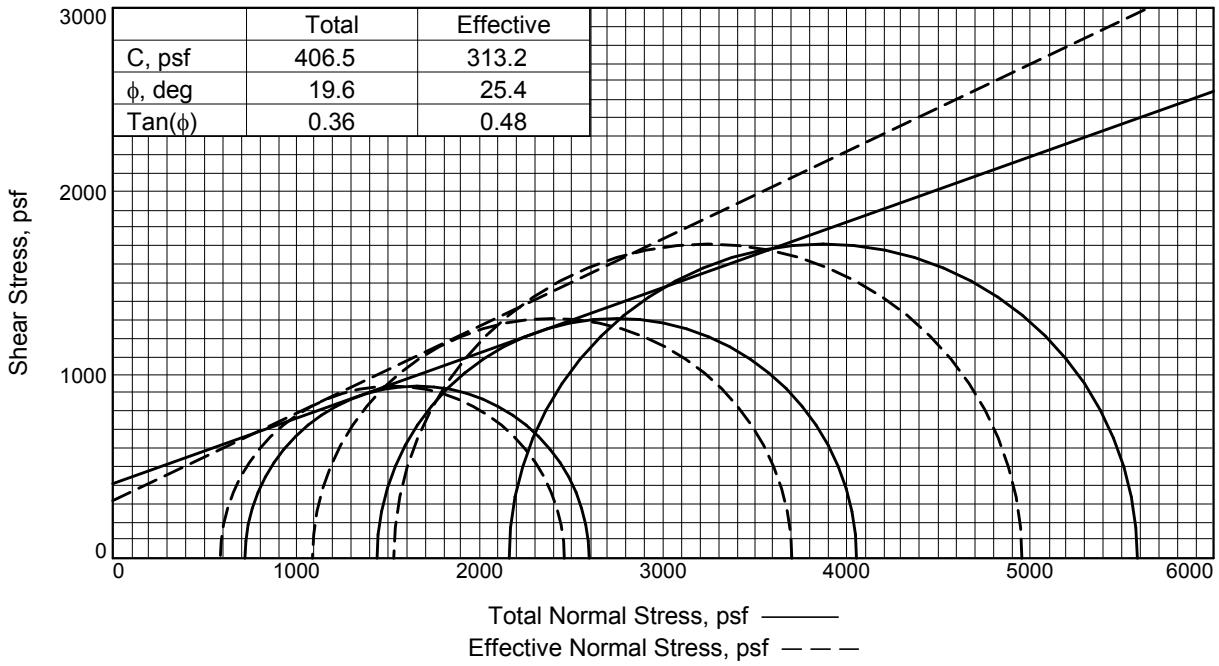

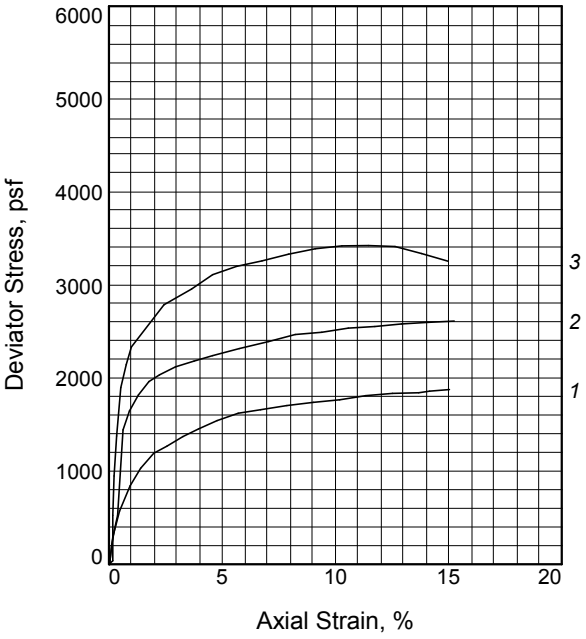

Sample No.		1	2	3
Initial	Water Content, %	15.7	22.1	16.7
	Dry Density, pcf	116.8	105.3	116.0
	Saturation, %	95.8	99.1	99.2
	Void Ratio	0.4436	0.6005	0.4534
	Diameter, in.	2.77	2.75	2.75
	Height, in.	5.78	5.49	5.76
At Test	Water Content, %	17.5	23.7	18.3
	Dry Density, pcf	114.6	102.7	112.7
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.4713	0.6409	0.4952
	Diameter, in.	3.02	3.02	3.03
	Height, in.	4.96	4.67	4.90
Strain rate, %/min.		0.01	0.01	0.01
Back Pressure, psi		38.000	38.000	38.000
Cell Pressure, psi		43.000	48.000	53.000
Fail. Stress, psf		1876.1	2614.1	3425.5
Total Pore Pr., psf		5606.6	5824.1	6101.1
Ult. Stress, psf		1876.1	2614.1	3425.5
Total Pore Pr., psf		5606.6	5824.1	6101.1
$\bar{\sigma}_1$ Failure, psf		2461.4	3702.0	4956.4
$\bar{\sigma}_3$ Failure, psf		585.4	1087.9	1530.9

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: Sandy Lean Clay (CL)
-200 Sieve=59.7%

LL= 47 **PL=** 17 **PI=** 30

Assumed Specific Gravity= 2.70

Remarks: Tested by: MC Date: 11/11/16
Checked by: GEV Date: 11/14/16

Figure 13

Client: Dannenbaum Engineering Corporation

Project: Proposed NHCRWA Contract NO. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

Sample Number: Boring No. 3 **Depth:** 16'-18'

Proj. No.: 16-S-299 **Date Sampled:** 10/13/16

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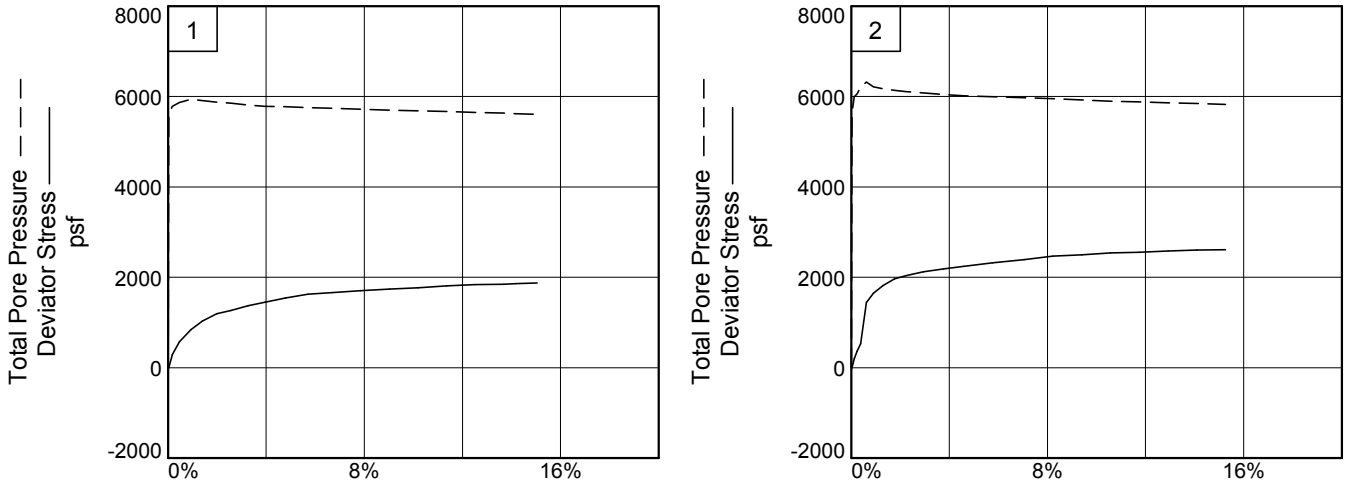

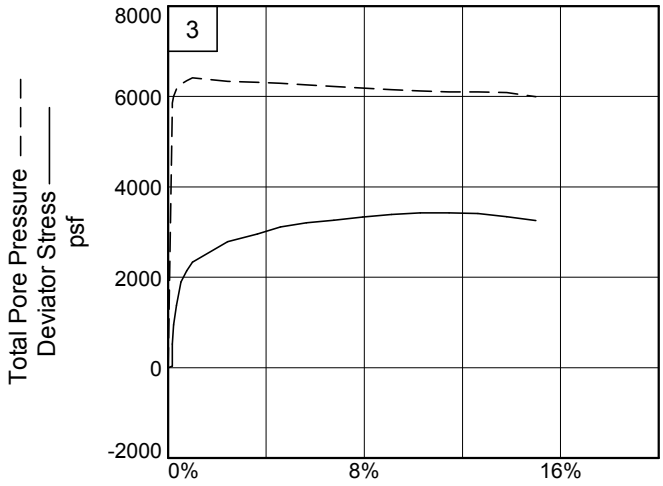

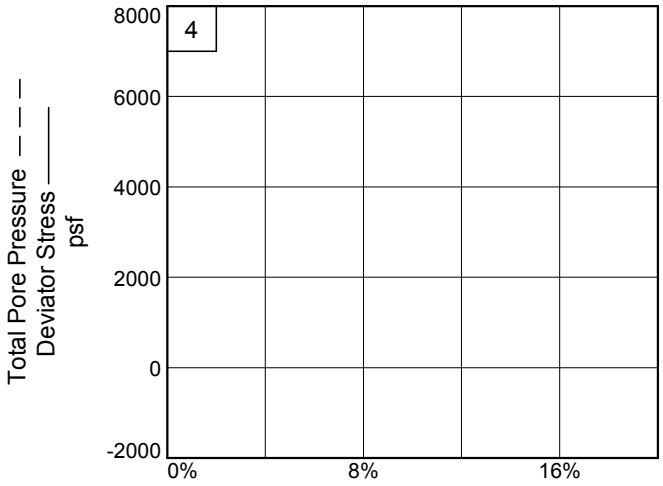

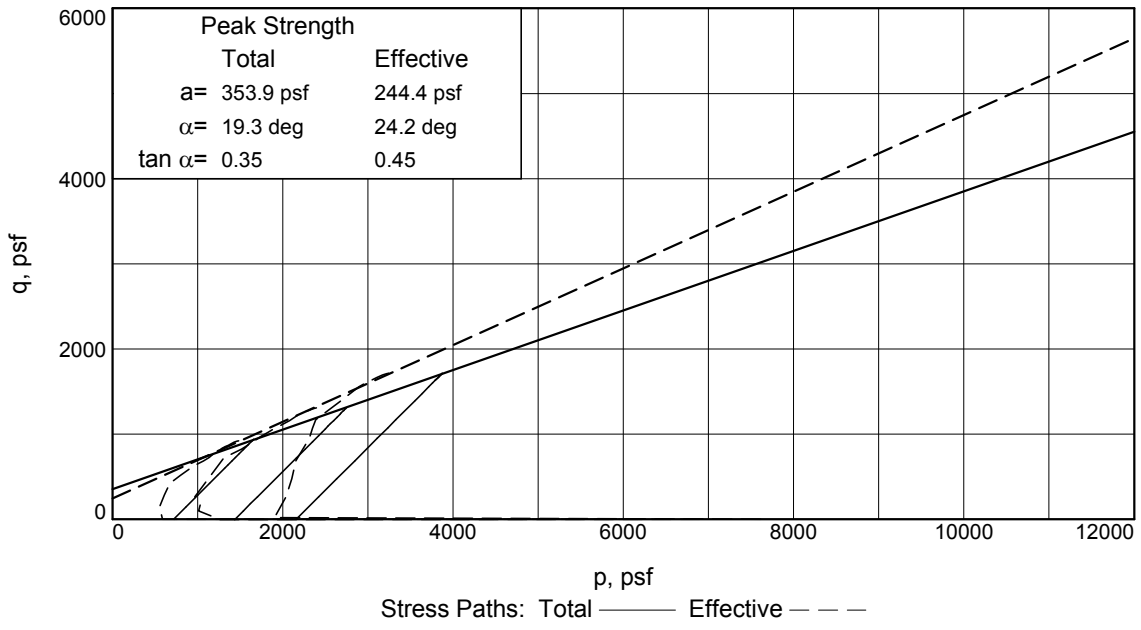

Client: Dannenbaum Engineering Corporation

Project: Proposed NHCRWA Contract NO. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

Depth: 16'-18' **Sample Number:** Boring No. 3

Project No.: 16-S-299 **Figure** 13A

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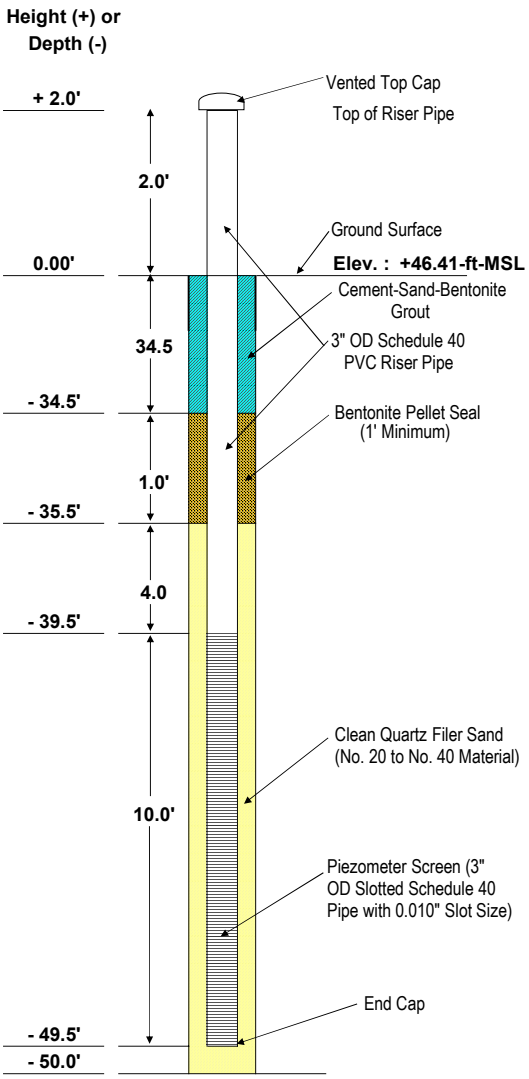
PIEZOMETER INSTALLATION DATA



Installation and Development Details

Piezometer No:	**PZ-1**	
Location:	**See Figure 2A**	
Installation Date:	**10/10/16**	
Drilling Method:	**Dry Auger**	x
	Wet Rotary	x
Development Date:	**11/09/16**	
Development Method:	**Pumping**	

Water Level Data	Depth Below Grade (ft)	Elevation (ft-MSL)
During Drilling:	**18.0**	**28.4**
11/9/2016	**27.7**	**18.7**
12/2/2016	**30.0**	**16.4**

NOTES: **Height above the ground surface is shown as a positive number (+) and depth below ground is shown as a negative number (-).**

Piezometer Installation Data

Proposed 2025 Water Distribution and Transmission System, NHCRWA Contract No. 28
Harris County, Texas

Drawn By: BHA	Date: 12/28/2016	Scale: Not To Scale
Checked By: BFM	Date: 12/28/2016	**Figure 14**
HTS Project No:	16-S-299	

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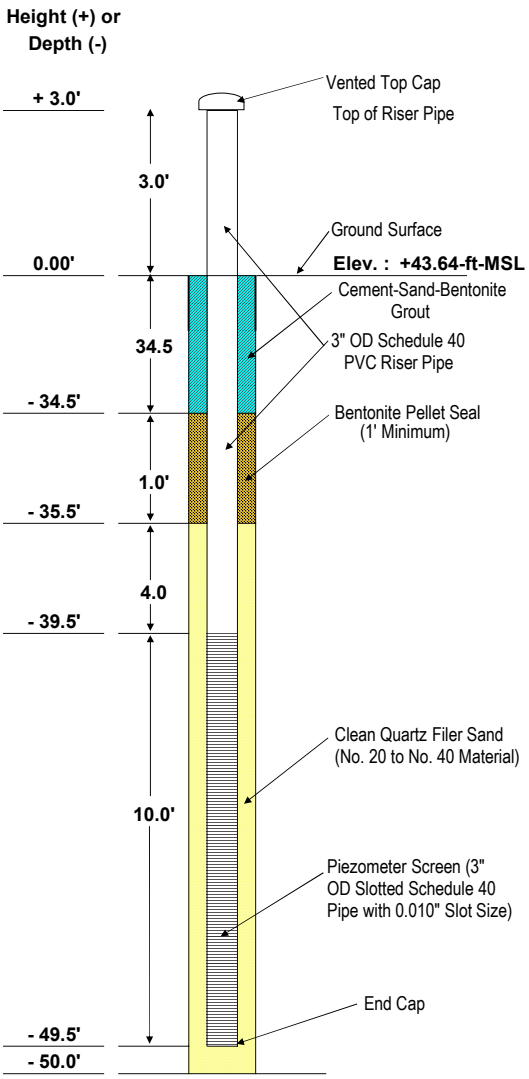
PIEZOMETER INSTALLATION DATA



Installation and Development Details

Piezometer No:	**PZ-2**	
Location:	**See Figure 2D**	
Installation Date:	**10/10/16**	
Drilling Method:	**Dry Auger**	x
	Wet Rotary	x
Development Date:	**10/25/16**	
Development Method:	**Pumping**	

Water Level Data	Depth Below Grade (ft)	Elevation (ft-MSL)
During Drilling:	**23.8**	**19.8**
########	**23.7**	**19.9**
########	**23.8**	**19.8**

NOTES: **Height above the ground surface is shown as a positive number (+) and depth below ground is shown as a negative number (-).**

Piezometer Installation Data

Proposed 2025 Water Distribution and Transmission System, NHCRWA Contract No. 28
Harris County, Texas

Drawn By: BHA	Date: 12/28/2016	Scale: Not To Scale
Checked By: BFM	Date: 12/28/2016	**Figure 15**
HTS Project No:	16-S-299	

APPENDIX A

BORING LOGS
(Boring Nos. 1 through 13)

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -20':

DATE 10/28/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 28.9" N
95° 36' 1.3" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SC	**CLAYEY SAND (SC),** dense, light gray	P = 4.50										
2'			P = 1.75										
	CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, light gray and tan	P = 1.75	114.4	0.65	9.6	0	16.8	31	15	16	61.6	(1)
5			P = 1.75										
			P = 1.50										
10													
12'	CH	**FAT CLAY (CH),** stiff to very stiff, light gray and tan, w/ sand pockets - w/ sand seams at 14'	P = 2.00	115.0	0.85	8.3	0	17.3	24	15	9	63.5	(1)
			P = 2.75										
15			P = 2.25										
16'	SM	**SILTY SAND (SM),** medium dense, light gray, w/ clay seams	P = 1.75										
18'	SC	**CLAYEY SAND (SC),** medium dese, light gray and tan	P = 1.75										
20'													
20		Boring terminated at 20'											

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 19.2'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure.

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Houston, Texas 77091

LOG OF BORING NO. 2

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20': Rotary: 20'-55'

DATE 10/10//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 25.3" N
95° 35' 57.7" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose to dense, light gray	N = 9	3.2				16.8	Non Plastic
			N = 12						
			N = 13						
8'	CL ML	**SANDY SILTY CLAY (CL-ML),** very stiff, light gray	N = 23						
12'	SM	**SILTY SAND (SM),** medium dense to dense, light gray	N = 29						
			N = 18	11.2				23.3	Non Plastic
		- w/ clay seams at 18'	N = 25						
			N = 31						
			N = 30						
			N = 22						
28'	CH	**FAT CLAY (CH),** stiff to very stiff, reddish brown and light gray	N = 17						

Field Strength Data: ● BLOW COUNT ● (20 40 60 80); ▲ C_u (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered prior to use of slurry during drilling. After completion, the water level was at 16.5' and boring was open to 24.9'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (*) See Figures for UU Triaxial Test (ASTM D 2850).

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LOG OF BORING NO. 2

DATE 10/10//16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20': Rotary: 20'-55'

LOCATION

GPS Coordinates:
29° 58' 25.3" N
95° 35' 57.7" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**FAT CLAY (CH),** stiff to very stiff, reddish brown and light gray - w/ slickensides at 33'											
35			P = 2.75	92.0	0.90	11.6	34	28.4	85	24	61	88.8	(2) * 33'-35' UU
38'	CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, light gray and tan, w/ sand seams, sand pockets, and ferrous nodules											
40			P = 1.75	107.7	1.10	15.0	0	20.3	45	19	26	63.3	(1)
43'	SM	**SILTY SAND (SM),** dense to very dense, light tan											
45			N = 60										
50			N = 42										
55'			N = 73										
		Boring terminated at 55'											

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered prior to use of slurry during drilling. After completion, the water level was at 16.5' and boring was open to 24.9'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (*) See Figures for UU Triaxial Test (ASTM D 2850).

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LOG OF BORING NO. 3

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -25' Rotary: 25'-50'

DATE 10/13//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 23" N
95° 35' 54.9" W
See Figure 2

DEPTH (ft.)	SAMPLES	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA (● BLOW COUNT 20 40 60 80; ▲ C_u (tsf) 1.0 2.0 3.0 4.0; ■ SS (tsf) 1.0 2.0 3.0 4.0; ◆ Torvane (psf) 200 400 600 800)	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	Natural Moisture Content and Atterberg Limits (Plastic Limit / Moisture Content / Liquid Limit; 20 40 60 80)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0		SM	**SILTY SAND (SM),** loose w/ concrete and brick pieces and roots, dark gray	P = 1.50											
2'		SC	**SILTY CLAYEY SAND (SC-SM),** loose to medium dense, light gray and light tan, w/ roots and concrete pieces - gray and light gray at 4'	P = 1.50	110.2	0.25	1.8	0		16.8	20	14	6	38.8	(3)
8'		CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, light tan and light gray, w/ ferrous nodules - light gray w/ silt pockets at 14' - tan and light gray w/ sand pockets at 16'	N = 22											
10				N = 16											
				P = 2.50						15.7	32	15	17	56.5	
				P = 1.75											
15				N = 8											16'-18' Grade 1 Non Dispersive ** 16'-18' CU $C_{eff.}$=313.2 psf $Ø_{eff}$=25.4° $C_{Tot.}$=406.5 psf $Ø_{Tot.}$=19.6°
18'		SC	**CLAYEY SAND (SC),** medium dense to dense, reddish brown, tan, and light gray	P = 3.00	**			**		22.1	47	17	30	59.7	
20				P = 3.50						16.7	37	16	21	37.1	18'-20' K=1.46E-07cm/s
			- light tan and light gray with gravel at 23'												
25				P = 4.50	116.7	2.15	15.0	24		15.7	28	15	13	22.8	(1) *23'-25' UU
28'		SM	**SILTY SAND (SM),** dense to very dense, light gray	N = 34											

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 24.3' during drilling and rose to 23.7' after 10 minutes. After completion, water was at 14.5' and boring was open to 23.4'.

Sample Key: ☒ SPT ☐ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850). See Figures for CU Triaxial Test (ASTM D 4767).

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LOG OF BORING NO. 3

DATE 10/13//16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -25' Rotary: 25'-50'

LOCATION

GPS Coordinates:
29° 58' 23" N
95° 35' 54.9" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**SILTY SAND (SM),** dense to very dense, light gray	N >50										
35													
38'	CH	**FAT CLAY (CH),** stiff to very stiff, reddish brown and tan, w/ ferrous nodules and slickensides	P = 4.00	96.6	0.55	2.6	0	28.2					(2)
40													
45			P = 4.00	87.1	0.95	15.0	44	35.3	76	23	53	90.1	(2) *43'-45' UU
48'	SM	**SILTY SAND (SM),** very dense, tan											
50'			N = 63										
50		Boring terminated at 50'											

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 24.3' during drilling and rose to 23.7' after 10 minutes. After completion, water was at 14.5' and boring was open to 23.4'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ◎ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850). See Figures for CU Triaxial Test (ASTM D 4767).

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LOG OF BORING NO. 4

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -20'

DATE 10/28//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 16.6" N
95° 35' 46.7" W
See Figure 2

DEPTH (ft.)	SAMPLES	USC	WATER LEVEL	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0		SM		**SILTY SAND (SM),** medium dense, light gray	P = 2.50										
2'															
		CL		**SANDY LEAN CLAY (CL),** very stiff to hard, light gray and tan	P = 4.50	119.8	1.55	3.7	0	10.0	32	14	18	60.6	(1)
5															
6'					P = 4.50										
		CL		**LEAN CLAY WITH SAND (CL),** very stiff to hard, light gray and tan, w/ ferrous nodules - w/ sand seams at 8'	P = 4.00										
10					P = 2.50										
12'					P = 4.50										
		SM		**SILTY SAND (SM),** loose to medium dense, light gray and tan	P = 1.00										
15			▼		N = 15					19.6				22.7	Non Plastic
			▽	- reddish brown and light gray w/ clay seams at 18'	N = 13										
20'					N = 21										
20				Boring terminated at 20'											

MATERIAL DESCRIPTION

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 16.0' during drilling and rose to 15.1' after 10 minutes. After completion of drilling, the boring caved at depth of 15.9'.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed ☐ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure.

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LOG OF BORING NO. 5

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/28//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 10.5" N
95° 35' 39.5" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** medium dense, light gray	P = 3.75										
2'													
	SC	**CLAYEY SAND (SC),** dense, light gray and tan, w/ ferrous nodules	P = 4.50										
4'													
	CL	**SANDY LEAN CLAY (CL),** hard, light gray and tan, w/ ferrous nodules and calcareous nodules - w/ sand fissures at 6'	P = 4.50										
5			P = 4.50	124.0	3.45	3.2	0	10.7	37	15	22	65.8	(3)
10'			P = 4.50										
	SC	**CLAYEY SAND (SC),** dense, light gray and tan, w/ ferrous nodules and calcareous nodules	P = 4.50										
12'													
	SM	**SILTY SAND (SM),** medium dense to dense, light gray, w/ clay seams	P = 4.50										
15			P = 4.50										
		- light gray and tan at 18'	N = 28										
20'			N = 37										
20		Boring terminated at 20'											

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 18.8'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(3) Sample failed along sand fissures.

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LOG OF BORING NO. 6

DATE 10/07//16

SURFACE ELEVATION

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

LOCATION

GPS Coordinates:
29° 58' 0.1" N
95° 35' 25.9" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose, light tan, w/ roots	P = 0.50										
2'													
	CL	**SANDY LEAN CLAY (CL),** hard, light gray and tan, w/ sand fissures	P = 4.50										
5			P = 4.50	>>4.5	29.0	5.05	6.0	0	11.3	42	17	25	63.4	(3)
		- light gray and light tan at 10'	P = 4.50										
10			P = 4.50										
12'			P = 4.50		117.8	3.30	5.9	11	9.7	34	16	18	51.3	(1) *10'-12' UU
	SM	**SILTY SAND (SM),** medium dense, light gray and light tan	N = 27										
15			N = 21										
			N = 25						22.1	47	17	30	59.7	
20'			N = 22						16.7	37	16	21	37.1	
20		Boring terminated at 20'												

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 19.2'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures.

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LOG OF BORING NO. 7

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0'-20'

DATE 10/29/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 0" N
95° 35' 17.2" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0		**SANDY LEAN CLAY (FILL),** stiff, gray, light gray, and tan, w/ roots	P = 1.75					17.1	28	15	13	61.7	
			P = 1.75										
5		6'	P = 1.75										
	CL	**LEAN CLAY WITH SAND (CL),** very stiff to hard, light gray and tan, w/ sand fissures	P = 4.25										
		10'	P = 4.50	116.8	1.65	7.8	0	16.2	46	18	28	74.0	(1)
10	CH	**FAT CLAY (CH),** stiff to very stiff, light gray and tan, w/ sand pockets and sand fissures											
		12'	P = 2.00										
	SC	**CLAYEY SAND (SC),** medium dense, light gray											
		14'	P = 2.25										
15	SM	**SILTY SAND (SM),** very loose to medium dense, light gray and tan	P = 0.25										
		- w/ clay seams at 18'	N = 21										
		20'	N = 18										
20		Boring terminated at 20'											

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

BLOW COUNT ● 20 40 60 80
C_u (tsf) ▲ 1.0 2.0 3.0 4.0
SS (tsf) ■ 1.0 2.0 3.0 4.0
Torvane (psf) ◆ 200 400 600 800

Water Level Est.: ▽ Measured: ▼ Perched: ▼
Water Observations: GW was not encountered during drilling. After completion, the boring was dry and open to a depth of 19.2'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure.

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LOG OF BORING NO. 8

DATE 10/11/16

SURFACE ELEVATION

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23': Rotary: 23'-55'

LOCATION

GPS Coordinates:
29° 57' 58.2" N
95° 35' 16.2" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose, gray, w/ clay pockets											
2'													
	CL	**SANDY LEAN CLAY (CL),** hard, tan, light tan, and light gray, w/ sand pockets, ferrous nodules, and sand fissures	P = 4.50										
5		- tan and light gray at 6'	P = 4.50										
		- gray, tan, and light gray at 8'	P = 4.50					9.5	40	17	23	63.3	6'-8' Grade 1 Non Dispersive
10			P = 4.50					10.8	42	18	24	68.1	8'-10' K=6.33E-08cm/s
12'			P = 4.50					10.8	39	17	22	62.1	
	SC	**CLAYEY SAND (SC),** medium dense to dense, tan, light tan, and light gray	N = 34										
15		- tan and light gray at 14'	N = 26										
		- w/ clay pockets at 16'	N = 32					6.3	25	16	9	43.8	
18'													
	SM	**SILTY SAND (SM),** medium dense to very dense, tan and light gray	N = 26										
20													
			N = 21										
25		- tan at 28'											
			N = 83										

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23' during drilling and rose to 22.3' after 10 minutes. After completion, the water was at 18' and boring was open to 21.8'.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed ☐ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850).

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 8

DATE 10/11/16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23': Rotary: 23'-55'

LOCATION

GPS Coordinates:
29° 57' 58.2" N
95° 35' 16.2" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**SILTY SAND (SM),** medium dense to dense, tan and light gray											
33'													
	CH	**FAT CLAY WITH SAND (CH),** hard, tan and light gray	N = 39					17.3				80.6	
35													
38'													
	CL	**LEAN CLAY (CL),** very srtiff to hard, light tan and light gray, w/ ferrous nodules and sand seams	P = 4.50	112.9	1.85	14.8	39	17.6	43	18	25	91.2	(1) *38'-40' UU
40													
43'													
	CL	**SANDY LEAN CLAY (CL),** very stiff to hard, gray and light tan, w/ sand fissures	P = 4.50	122.0	1.20	11.3	0	13.2	24	15	9		(3)
45													
48'													
	CH	**LEAN CLAY (CL),** very stiff to hard, gray and light tan, w/ ferrous nodules	P = 4.50										
50													
		- reddish brown and light gray at 53'											
55'			N = 73	105.0	1.50	14.9	54	25.8					(2) *53'-55' UU
		Boring terminated at 55'											

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23' during drilling and rose to 22.3' after 10 minutes. After completion, the water was at 18' and boring was open to 21.8'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850).

LOG OF BORING NO. 9

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23' Rotary: 23'-55'

DATE 10/10/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 56.7" N
95° 35' 14.5" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose, gray and light gray, w/ roots											
2'													
	SC	**CLAYEY SAND (SC),** medium dense, light gray and tan											
4'			N = 27										
	CL	**LEAN CLAY WITH SAND (CL),** hard, light gray and tan, w/ sand fissures											
5		- w/ ferrous nodules at 6'	P = 4.50					11.3	33	17	16	70.1	
			P = 4.50					12.4	43	19	24	73.1	** 6'-8' CU $C_{eff.}$=289.3 psf $Ø_{eff}$=22.5° $C_{Tot.}$=380.9 psf $Ø_{Tot.}$=17.4° (1)
		- light gray at 10'	P = 4.50										
10			P = 4.50	117.3	2.95	14.8	11	13.2	43	19	24	72.5	*10'-12' UU
12'													
	SC	**CLAYEY SAND (SC),** medium dense to dense, light gray	N = 38										
15		- w/ clay seams at 16'	N = 40										
			N = 31										
20			N = 28					3.9	37	17	20	21.7	18'-20' Grade 1 Non Dispersive
23'													
	SM	**SILTY SAND (SM),** medium dense to very dense, tan											
25			N = 22										
			N = 50					19.4				18.9	Non Plastic

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23.0' during drilling and dropped to 23.5' after 10 minutes. After completion, the water was at 16.9' and boring was open to 22.8'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (*) See Figures for UU Triaxial Test (ASTM D 2850).

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LOG OF BORING NO. 9

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23' Rotary: 23'-55'

DATE 10/10/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 56.7" N
95° 35' 14.5" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**SILTY SAND (SM),** medium dense to very dense, tan											
33'													
	CH	**FAT CLAY (CH),** very stiff, light gray and tan, w/ silt pockets	N = 29										
35													
38'													
	CL	**LEAN CLAY (CL),** stiff to hard, light gray and tan	N >50										
40													
			P = 4.50					13.7	22	14	8		
45		- w/ sand pockets and sand fissures at 48'											
50'			P = 4.50	115.6	0.60	6.0	0	15.4					(1)
50		Boring terminated at 50'											

FIELD STRENGTH DATA: ● BLOW COUNT ● (20 40 60 80); ▲ C_u (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23.0' during drilling and dropped to 23.5' after 10 minutes. After completion, the water was at 16.9' and boring was open to 22.8'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (*) See Figures for UU Triaxial Test (ASTM D 2850).

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Houston, Texas 77091

LOG OF BORING NO. 10

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/07/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 54.96" N
95° 35' 6.17" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION
0	SM	**SILTY SAND (SM),** medium dense, gray, w clay pockets
2'	CL	**LEAN CLAY WITH SAND (CL),** hard, gray and tan, w/ sand fissures
4'	CL	**SANDY LEAN CLAY (CL),** hard, light gray and tan, w/ sand fissures
10'	SC	**CLAYEY SAND (SC),** medium dense to dense, light gray and light tan - light tan at 12'
14'	SP SM	**POORLY GRADED SAND WITH SILT (SP-SM),** medium dense, light tan
20'		Boring terminated at 20'

FIELD STRENGTH DATA: ● BLOW COUNT ● (20 40 60 80); ▲ C_u (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits (Plastic Limit, Moisture Content, Liquid Limit; 20 40 60 80)

FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
P = 3.00										
P = 4.50	122.4	2.35	4.2	0	11.4	29	16	13	72.4	(3)
P = 4.50										
P = 4.50										
P = 4.50	119.1	2.95	4.9	0	15.0	42	17	25	69.7	(3)
P = 4.50										
P = 2.75										
N = 13										
N = 15					6.0				11.2	Non Plastic
N = 15										

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 18.6'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(3) Sample failed along sand fissures.

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LOG OF BORING NO. 11

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/03/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 54.9" N
95° 34' 48.3" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SC	**CLAYEY SAND (SC),** dense, gray and light gray	P = 4.50										
2'	CL	**SANDY LEAN CLAY (CL),** very stiff, light gray and tan, w/ sand fissures	P = 3.25	120.6	1.05	8.1	0	12.8					(3)
4'	CL	**LEAN CLAY WITH SAND (CL),** hard, light gray and tan, w/ sand fissures	P = 4.50										
8'	CH	**FAT CLAY (CH),** very stiff, light gray and tan, w/ sand pockets and sand fissures - w/ silt seams at 10' - light gray and reddish brown at 13'	P = 4.50	108.9	2.15	5.9	0	14.8	39	18	21	71.6	(3)
			P = 3.25										
			P = 2.75										
			P = 2.75	110.2	1.20	7.2	0	24.4	63	21	42	95.8	(1)
18'	SM	**SILTY SAND (SM),** very loose, light gray, w/ clay seams											
20'		Boring terminated at 20'	P = 0.25										

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion, of drilling, the boring was dry and open to a depth of 19.0'.

Sample Key: SPT, Shelby Tube, Disturbed, No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures.

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LOG OF BORING NO. 12

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/03/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 49.8" N
95° 34' 48.1" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY CLAYEY SAND (SC-SM),** dense, gray and light gray	P = 4.50					4.2	21	17	4	42.9	
2'	CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, gray and tan, w/ sand fissures	P = 2.25										
5			P = 3.25	118.6	0.90	7.9	0	15.5	46	20	26	62.3	(3)
8'	CH	**FAT CLAY (CH),** very stiff, light gray and tan, w/ sand fissures	P = 2.75										
10			P = 3.25	116.2	1.90	9.2	0	18.8					(1)
13'	SM	**SILTY SAND (SM),** very loose to medium dense, light gray, w/ clay seams	P = 2.50										
15			P = 2.00										
			P = 0.25										
20'		Boring terminated at 20'	P = 0.25										
20													

FIELD STRENGTH DATA: ● BLOW COUNT ● (20 40 60 80); ▲ C_u (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 19.0'.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed ☐ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures.

LOG OF BORING NO. 13

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE: 10/03/16

SURFACE ELEVATION:

LOCATION

GPS Coordinates:
29° 57' 41.7" N
95° 34' 47.9" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	1' **SILTY SAND (SM),** loose, light gray, w/ roots	P = 1.50										
	CL	**LEAN CLAY WITH SAND (CL),** very stiff to hard, tan and light gray - w/ sand fissures at 4'	P = 2.50										
5			P = 4.00	116.9	1.75	14.3	5	15.1	42	19	23	70.7	(1)*4'-6' UU
			P = 4.50	124.6	2.30	12.0	0	12.8					(1)
10	SM	10' **SILTY SAND (SM),** very loose to medium dense, light gray, w/ clay seams	P = 3.00										
			P = 2.00	112.9	0.35	5.7	0	17.0	28	15	13	39.8	(3)
15			P = 0.25										
20		20' Boring terminated at 20'	P = 0.25										

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 18.8'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures. See Figures for UU Triaxial Test (ASTM D 2850).

APPENDIX B

TRENCH EXCAVATION REPORT

TRENCH EXCAVATION REPORT
PROPOSED NHCRWA CONTRACT NO. 28-B
2025 WATER DISTRIBUTION AND TRANSMISSION SYSTEM
HARRIS COUNTY, TEXAS

PREPARED FOR:

Dannenbaum Engineering Corporation
3100 West Alabama
Houston, Texas 77098

PREPARED BY:

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091-3312

HTS Project No. 16-S-299

May 27, 2020

TABLE OF CONTENTS

ATTACHMENTS

TRENCH EXCAVATION REPORT
PROPOSED NHCRWA CONTRACT NO. 28-B
2025 WATER DISTRIBUTION AND TRANSMISSION SYSTEM
HARRIS COUNTY, TEXAS

1.0 INTRODUCTION

This report presents HTS, Inc. Consultants (HTS) trench excavation report for the above referenced project. The geotechnical investigation report pertaining to the design and construction of a portion of the water distribution and transmission system planned by the North Harris County Regional Water Authority (NHCRWA) in Harris County, Texas is presented in the main geotechnical report.

Based on information provided by Dannenbaum Engineering Corporation (DEC), the proposed waterline project will require the construction of approximately ±9,800 l.f. of 54-inch and 60-inch water line replacement along Grant Road starting from Lakewood Forest Drive, crossing Cypress Creek (HCFCD Unit No. K100-00-00), to Anderson Wood Drive, then crossing Anderson Ditch (HCFCD Unit No. K143-00-00), Jones Road, and Matzke Park, then along Copeland Drive to Mills Road in Harris County, Texas. The proposed water transmission and distribution system will generally be installed by open-cut methods except where it crosses underground pipelines, roadway crossings, and water channels where tunneling will be used for installation. The location of the proposed water distribution and transmission system is shown in the attached Plates 1 and 2A through 2D.

The scope of this report is to present general information and safety guidelines for the proposed excavations and trenching associated with open cut and tunneling construction for the proposed water transmission line.

2.0 FIELD INVESTIGATION

2.1 Geotechnical Borings

A total of 13 geotechnical borings (Boring Nos. 1 through 13) were drilled for this geotechnical investigation on October 3, 7, 10, 11, 13, 28, and 29, 2016 at the locations shown on Plates 2A through 2D. Piezometers were installed at the locations of Boring Nos. 2 and 9 to a depth of 50 feet beneath the existing ground surface. Piezometer installation details are provided in the attached Plates 4A and 4B.

2.2 Drilling and Sampling Methods

Drilling, sampling, and testing were performed in accordance with applicable ASTM procedures by using a truck-mounted drill rig and conventional auger and wet rotary methods. Van and Sons Drilling Company performed drilling under contract to HTS and under the supervision of an HTS engineering technician.

Soil sampling during the drilling of the geotechnical borings consisted of continuous sampling to between 12 and 20 feet, depending on the purpose of the boring, and intermittent sampling thereafter, with both disturbed and relatively undisturbed samples being obtained.

Disturbed samples of soil were taken from the auger of the sampler or in conjunction with standard penetration test procedures. The standard penetration test (SPT) blow count is defined as the number of SPT hammer blows that are required to advance a split spoon sampler 1 foot into the soil. One SPT hammer blow consists of a 140-pound hammer free falling for a distance of 30 inches. The results of the standard penetration test provide a basis for estimating the relative strength and compressibility of the soil profile components. The samples recovered were removed from the auger of the sampler or the split spoon sampler and placed into airtight plastic bags.

Relatively undisturbed samples were obtained by hydraulically forcing sections of 3-inch O.D. tubing (Shelby tube) into the subsoils. The tube samples were extruded in the field, sealed with foil, and placed into airtight plastic bags. Estimates of the unconfined compressive strengths and undrained shear strengths of the cohesive soils were obtained with pocket penetrometer readings being taken on the tube samples.

The soils samples were visually classified in accordance with ASTM D 2488 standards and methods. All samples were transported to HTS' laboratory for purposes of performing laboratory tests on selected samples.

3.0 LABORATORY TESTING

For the current geotechnical study, a laboratory testing program was conducted to obtain engineering properties for use in performing engineering analyses and to adjust field soil classifications. The following laboratory tests were performed:

LABORATORY TEST	TEST STANDARD
Moisture Content of Soils	ASTM D 2216
Dry Density of Soils	ASTM D 2937
Percent Soil Particles Passing a No. 200 Sieve	ASTM D 1140
Liquid Limit, Plastic Limit, and Plasticity Index	ASTM D 4318
Unconfined Compressive Strength of Cohesive Soils	ASTM D 2166
Unconsolidated Undrained Triaxial Compression Test	ASTM D 2850
Consolidated Undrained Triaxial Compression Test (with pore pressure measurements – 3 stages)	ASTM D 4767
Crumb Testing	ASTM D 6572

LABORATORY TEST	TEST STANDARD
Pinhole Testing	ASTM D 4647
Permeability Testing (Falling Head Method)	ASTM D 5084

The test results are presented on the attached Boring Logs (presented herein as Plates 5 through 17) as well as in Tables 1 through 4B and Figures 4 through 13 in the main geotechnical investigation report.

4.0 SUBSURFACE SOIL AND GROUND WATER CONDITIONS

The subsurface soils and ground water conditions along the route of the proposed water distribution and transmission system are defined in our geotechnical borings and are discussed below.

4.1 Subsurface Soil Conditions

Based on our geotechnical borings that were drilled along the route of the proposed water transmission line, the subsurface soils encountered can be generalized into 5 separate layers as described below:

LAYER	DEPTH BELOW GROUND SURFACE (FT)	SOIL DESCRIPTION
I	0 – 8	Light gray, dark gray, gray, tan, and light tan CLAYEY SAND, SILTY SAND, and SILTY CLAYEY SAND, loose to dense with ferrous nodules, clay pockets, concrete and brick pieces, and roots (not encountered in Boring No. 7).
IIa	1 – 18	Light gray, gray, light tan, and tan SANDY LEAN CLAY, LEAN CLAY, SANDY SILTY CLAY, and LEAN CLAY WITH SAND, stiff to hard with ferrous nodules, calcareous nodules, sand fissures, silt pockets, sand seams, and sand pockets. Note: A layer of fill material consisting of gray, light gray, and tan SANDY LEAN CLAY, stiff with roots was encountered in Boring No. 7 from the surface to a depth of 6 feet below the ground surface.
IIb	8 – 18	Light gray, reddish brown, and tan FAT CLAY, stiff to very stiff with sand fissures, sand pockets, sand seams, and silt seams (only encountered in Boring Nos. 1, 7, 11, and 12).

LAYER	DEPTH BELOW GROUND SURFACE (FT)	SOIL DESCRIPTION
III	10 – 38	Light gray, reddish brown, tan, and light tan CLAYEY SAND, SILTY SAND, and POORLY GRADED SAND WITH SILT, very loose to very dense with ferrous nodules, calcareous nodules, clay seams, clay pockets, clay seams, and gravel.
IVa	28 – 48	Light gray, reddish tan, and tan FAT CLAY and FAT CLAY WITH SAND, stiff to hard with ferrous nodules, silt pockets, and slickensides (only encountered in Boring Nos. 2, 3, 8, and 9).
IVb	38 – 55	Gray, light gray, light tan, reddish brown, and tan LEAN CLAY and SANDY LEAN CLAY, stiff to hard with ferrous nodules, sand seams, sand pockets, and sand fissures (only encountered in Boring Nos. 2, 8, and 9).
V	43 – 55	Light tan and tan SILTY SAND, dense to very dense.

Detailed subsurface soil information is presented in the individual boring logs presented in the attached Plates 5 through 17. The general subsurface soil stratigraphy along the proposed water transmission line alignment is shown in the soil profiles presented in the attached Plate 3.

4.2 Ground Water Conditions

Groundwater measurements were obtained during drilling, and after completion of drilling as applicable. Due to use of wet rotary, groundwater readings were obtained 10 minutes after water was initially encountered, as applicable, for Boring Nos. 2, 3, 8, and 9. The results of the groundwater measurements are presented in the table below:

BORING NO.	TOTAL DEPTH OF BORING (FT.)	DEPTH TO WATER DURING DRILLING (FT.)	DEPTH TO WATER APPROXIMATELY 10 MINUTES AFTER WATER WAS INITIALLY ENCOUNTERED (FT.)	DEPTH TO WATER AFTER COMPLETION OF DRILLING (FT.)	DEPTH TO OBSTRUCTION AFTER SECOND GROUNDWATER MEASUREMENT (FT.)
1	20	Dry	--	Dry	19.2
2	55	Dry to 20*	--	16.5**	24.9
3	50	24.3	23.7	14.5**	23.4
4	20	16.0	15.1	Dry	15.9
5	20	Dry	--	Dry	18.8
6	20	Dry	--	Dry	19.2
7	20	Dry	--	Dry	19.2

BORING NO.	TOTAL DEPTH OF BORING (FT.)	DEPTH TO WATER DURING DRILLING (FT.)	DEPTH TO WATER APPROXIMATELY 10 MINUTES AFTER WATER WAS INITIALLY ENCOUNTERED (FT.)	DEPTH TO WATER AFTER COMPLETION OF DRILLING (FT.)	DEPTH TO OBSTRUCTION AFTER SECOND GROUNDWATER MEASUREMENT (FT.)
8	55	23.0	22.3	8.0**	21.8
9	50	23.0	23.5	6.9**	22.8
10	20	Dry	--	Dry	18.6
11	20	Dry	--	Dry	19.0
12	20	Dry	--	Dry	19.0
13	20	Dry	--	Dry	18.8

Note: Depths are referenced from the existing ground surface elevation at the time the borings were drilled.
* Prior to the use of the drilling fluid.
** Likely influenced by drilling fluid used to keep an open boring.
-- Not applicable.

The borings were backfilled with cement grout after the groundwater measurements were obtained.

Piezometers were installed at the locations of Boring Nos. 2 and 9 to define ground water level conditions in a longer period of time. The water levels were measured at 2 weeks and 1 month after installation and the results are as provided below:

BORING NO. (PIEZOMETER NO.)	2-WEEKS AFTER INSTALLATION		1 MONTH AFTER INSTALLATION	
	DEPTH TO GROUNDWATER (FT.)	ELEVATION (FT.-MSL)	DEPTH TO GROUNDWATER (FT.)	ELEVATION (FT.-MSL)
2 (PZ-1)	27.7	+18.71	30.0	+16.41
9 (PZ-2)	23.7	+19.94	23.8	+19.84

Groundwater depths will fluctuate depending on seasonal rainfall and other climatic events. In the event that there is heavy rain prior to or during construction, the groundwater table may be higher than indicated in this report; higher seepage is also likely and may require a more extensive groundwater control program.

The need for groundwater control will depend on the depth of excavation relative to the groundwater depth at the time of construction. The contractor should be responsible for selecting, designing, constructing, maintaining and monitoring a groundwater control system and adapting his operations to ensure the stability of the excavations. We recommend that the contractor verify the groundwater depths and seepage rates and existence of pressurized groundwater prior to and during construction and retain the services of a dewatering expert to assist him/her in identifying the most suitable and cost-effective method of controlling groundwater. The contractor should take necessary precautions to avoid distressing existing structures as a result of dewatering. Groundwater control should be in accordance with Section 01578 titled "Control of Ground and Surface Water" of the most recent version of COH-DPWE Specifications.

4.3 Subsurface Variations

The information in this report summarizes conditions found on the dates the geotechnical borings were drilled and the dates the ground water levels were monitored. It should be noted that the ground water data and soil moisture contents will vary with environmental variations/fluctuations such as the frequency, duration, and magnitude of rainfall as well as the time of year when construction is in progress.

Clay soils in the Harris County area typically exhibit secondary features such as slickensides and sand or silt fissures/lenses/pockets/seams. Data gathered and presented in our boring logs are based on a 3-inch diameter soil samples obtained during our field investigation. Due to the sampling size, a detailed description of the secondary features may not have been observed/encountered and not indicated on the boring logs. Therefore, while some of our boring logs show soil secondary features, it should not be assumed that these secondary features are absent where not indicated on the boring logs.

5.0 EXCAVATION SAFETY RECOMMENDATIONS

This project will consist of the installation of approximately ±9,800 l.f. of 54-inch and 60-inch water line. The proposed water transmission and distribution line will generally be installed by open-cut methods except where it crosses underground pipelines, roadway crossings, and water channels where tunneling will be used for installation.

5.1 OSHA Soil Types

The Occupational Safety and Health Administration (OSHA) requires that an adequate protective system be designed to protect workers in an excavation from cave-ins. Excavations less than 5 feet deep should be checked by a competent person to have no cave-in potential and should be appropriately protected when an indication of hazardous ground movement is anticipated. Trench excavations with depths between 5 and 20 feet should be shored, sheeted and braced, or laid back to a stable slope for the safety of workers, public and adjacent structures. For trenches deeper than 20

feet, OSHA requires that shoring or bracing be designed by a licensed professional engineer.

If OSHA Standards and Interpretations, 29 CFR 1926, Subpart P, "Excavations" are used for the design of temporary excavation protection systems, the clay layers should be categorized as Type B soils while the fill materials and the sands/silts should be categorized as Type C soils. The definitions of Type B and Type C soils are provided in Appendix A of the OSHA Standards and Interpretations, 29 CFR 1926, Subpart P, "Excavations" (www.osha.gov). In order to eliminate the potential for caving of trench excavations, trench safety shall be implemented for trench excavations that are deeper than 5 feet.

Recommended design soil parameters, including OSHA Soil Types are presented on the attached Plates 18 through 20. HTS recommends that excavated materials should not be allowed to stockpile near the excavation wall. We recommend that excavated materials should be placed away a distance of half the excavation depth on both sides of the trench. The maximum allowable slopes in OSHA Soil Types A, B and C for excavations less than 20 feet are illustrated on the attached Plate 21. If space is limited for the required open trench side slopes, anticipated to apply to the entire route of the proposed water transmission line project, the trench excavations may be protected using a combination of bracing and open-cut as illustrated in the attached Plate 22.

5.2 Critical Height

Critical Height is defined as the height a slope will stand unsupported for a short time in cohesive soils, it is used to estimate the maximum depth of open-cuts at given side slopes. Critical Height may be calculated using the soil cohesion. Values for various slopes and cohesion are shown in the attached Plate 23. Cautions listed below should be exercised in use of Critical Height applications.

1. **No more than 50 percent of the Critical Height computed should be used for vertical slopes. Unsupported vertical slopes are not recommended where granular soils or soils that will slough when not laterally supported are encountered within the excavation depth.**

2. **If tension cracks occur, no cohesion should be assumed for the soils within the depth of the crack. The depth of the first waler should not exceed the depth of the potential tension crack. Struts should be installed before lateral displacement occurs.**

3. **Shoring should be provided for excavations where limited space precludes adequate side slopes, e.g., where granular soils will not stand on stable slopes and/or for deep open cuts.**

4. **All excavation, trenching and shoring should be designed and constructed by qualified professionals and personnel in accordance with Occupational Safety and Health Administration (OSHA) requirements.**

5.3 Computation of Bracing Pressures

Lateral pressures resulting from construction equipment, traffic loads, or other surcharge loads should be taken into account by adding the equivalent uniformly distributed surcharge to the design lateral pressures. Hydrostatic pressure, if any, should also be considered. The active earth pressure at depth z can be determined by Equation (1) as provided below using the design soil parameters presented in the attached Plates 18 through 20.

$$p_a = (q_s + \gamma h_1 + \gamma' h_2)\, K_a - 2c\sqrt{K_a} + \gamma_w h_2 \qquad \text{Equation (1)}$$

where,

p_a	=	active earth pressure, psf.
q_s	=	uniform surcharge pressure, psf.
γ, γ'	=	wet unit weight and buoyant unit weight of soil.
h_1	=	depth from ground surface to ground water table.
h_2	=	$z-h_1$, depth from ground water table to the point under consideration.
z	=	depth below ground surface for the point under consideration.
K_a	=	coefficient of active earth pressure.
c	=	cohesion of clayey soils.
γ_w	=	unit weight of water, 62.4 pcf.

Pressure distribution for the design of struts in open cuts for clays and sands are illustrated in the attached Plates 24 through 26. If there is water behind the bracing, hydrostatic pressure should be included in the design.

If excavations are located close to existing structures, we recommend using the coefficient of at-rest earth pressure (K_0) for design instead of the use of active earth pressure coefficient (K_a) to reduce the potential for distress to the existing structures. The active earth pressure at depth (z) can be determined by the same Equation (1) above.

5.4 Excavation Bottom Stability

In open-cuts, the possibility of the bottom failing by heaving, due to the removal of the weight of excavated soils, must be considered. In clays, heave normally does not occur unless the ratio of Critical Height to Depth of Cut approaches one. In silty clays and granular soils, heave can occur if an artificially large head of water is created through the use of impervious sheeting in bracing the cut. This can be mitigated if the ground water is lowered below the excavation by dewatering the area. Equations and parameters for evaluating bottom stability are presented on the attached Plate 27.

If the excavation is carried out below the ground water table and a significant amount of the soils at or near the bottom of the excavation are sands or silts or low-plasticity clays, the bottom can fail by blow-out (boiling) at the bottom when a sufficient hydraulic head exists. The potential for boiling or in-flow of granular soils increases where the ground water level is high. If this condition is present during the construction activities, it is recommended that the ground water level be lowered to at least 3 feet below the excavation in order to reduce the potential for boiling of excavation terminating in granular soils below ground water. In extreme conditions, mechanical or chemical stabilization of the granular soils may be required.

5.5 Excavation Dewatering

Groundwater was encountered at depths ranging from 16.0 to 24.3 feet during drilling in only 4 of the 13 borings. Groundwater was encountered only in Boring Nos. 3, 4, 8, and 9 and the rest of the borings were dry, except in Boring No. 2 where the boring was dry to 20 feet and caved in before drilling fluid was used. Approximately 10 minutes after water was initially encountered, groundwater was measured at depths ranging from 15.1 to 23.7 feet below the existing surface in the same 4 borings. Accordingly, it is not expected that groundwater will be present for excavations that are no deeper than about 14 feet beneath the surface. However, the Layer III sands may be part of a water bearing stratum that could hold water after prolonged wet periods or after heavy rainfall events. The use of sumps and pumps may be adequate for clayey soil above the groundwater levels previously provided. The use of well points, vacuum well points, or a comparable dewatering system may be required to dewater the excavations extending below the groundwater levels where the exposed soils consist of the site sands. Control of groundwater and surface water during the installation of the underground utilities should be performed in accordance with Section 01578 of the most recent version of COH-DPWE Standard Specifications.

5.6 Trenchless Excavation

It is our understanding that the waterline installation at the roadways, existing pipelines, Anderson Ditch, and Cypress Creek crossings will be performed using underground tunneling with steel casing. Depending on tunneling depths and ground water fluctuations, groundwater could be expected within the tunneling path during the installation of the casing. It is recommended that the groundwater levels within the installation areas be monitored prior to the installation activities. Additionally, test pits on both ends of the installation alignment may also be excavated prior to the construction activities in order to determine the actual groundwater levels. If the groundwater level is within the path of the tunneling operation, the water level must be lowered to at least 2 feet beneath the bottom of the proposed casing. Groundwater dewatering may be accomplished using well points, vacuum well points, or any other suitable dewatering system where sandy materials are encountered.

Tunneling operations for the installation of the proposed water line under the roadways, existing pipelines, Anderson Ditch, and Cypress Creek shall conform with applicable guidelines and regulations of the governing agency within the project area; and/or the guidelines and requirements of Item 431 titled "Jacking, Boring or Tunneling Pipe" and Item 432 titled "Tunnel Construction" of the most recent Harris County Engineering Department (HCED) Specifications titled "Specifications for the Construction of Roads and Bridges within Harris County, Texas" or Subchapter F titled "Water Line Crossings" in Chapter 7 titled " Water Line Design Requirements" of City of Houston Infrastructure Design Manual dated July 01, 2016 and in accordance with the Section 02425 entitled "Tunnel Excavation and Primary Liner" of the 2016 COH-DPWE Standard Specifications.

5.7 Tunnel Shafts in Trenchless Excavation

In trenchless excavation for the portion of the water line under the existing roadway, tunnel shafts will be required. These shafts need to be shored because the side walls are normally cut vertical because of space limitation and/or to conserve space. Tunnel shafts should be designed as braced excavations in accordance with the applicable previous sections for open cut excavations. Tunnel shafts should be constructed in accordance with Section 02400 entitled "Tunnel Shafts" of the 2016 COH-DPWE Standard Specifications.

6.0 CLOSING REMARKS

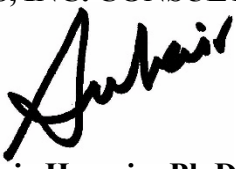
HTS, Inc. Consultants has prepared this trench excavation report pertaining to the design and construction of a portion of the water distribution and transmission system planned by the NHCRWA in Harris County, Texas. This report has been prepared for the exclusive use of DEC and NHCRWA in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.

In the event that changes are made in the nature, design, or location of the proposed facilities, the conclusions, parameters, and recommendations contained in this report shall not be considered valid unless the changes are reviewed and the findings/recommendations of this report are modified or verified in writing. The analyses and recommendations presented in this report are based upon data obtained from 13 geotechnical borings drilled on October 3, 7, 10, 11, 13, 28, and 29, 2016. The nature and extent of variations within the subsurface materials may not become evident until after construction is initiated. If significant variations in the subsurface materials are encountered during construction, it may be necessary to re-evaluate the recommendations provided in this report.

It was a pleasure being of service to you on this project. Should you have any questions or require clarification of this report, please do not hesitate to contact us at your convenience.

Sincerely,

HTS, INC. CONSULTANTS



Jubair Hossain, Ph.D., P.E.`
Vice President

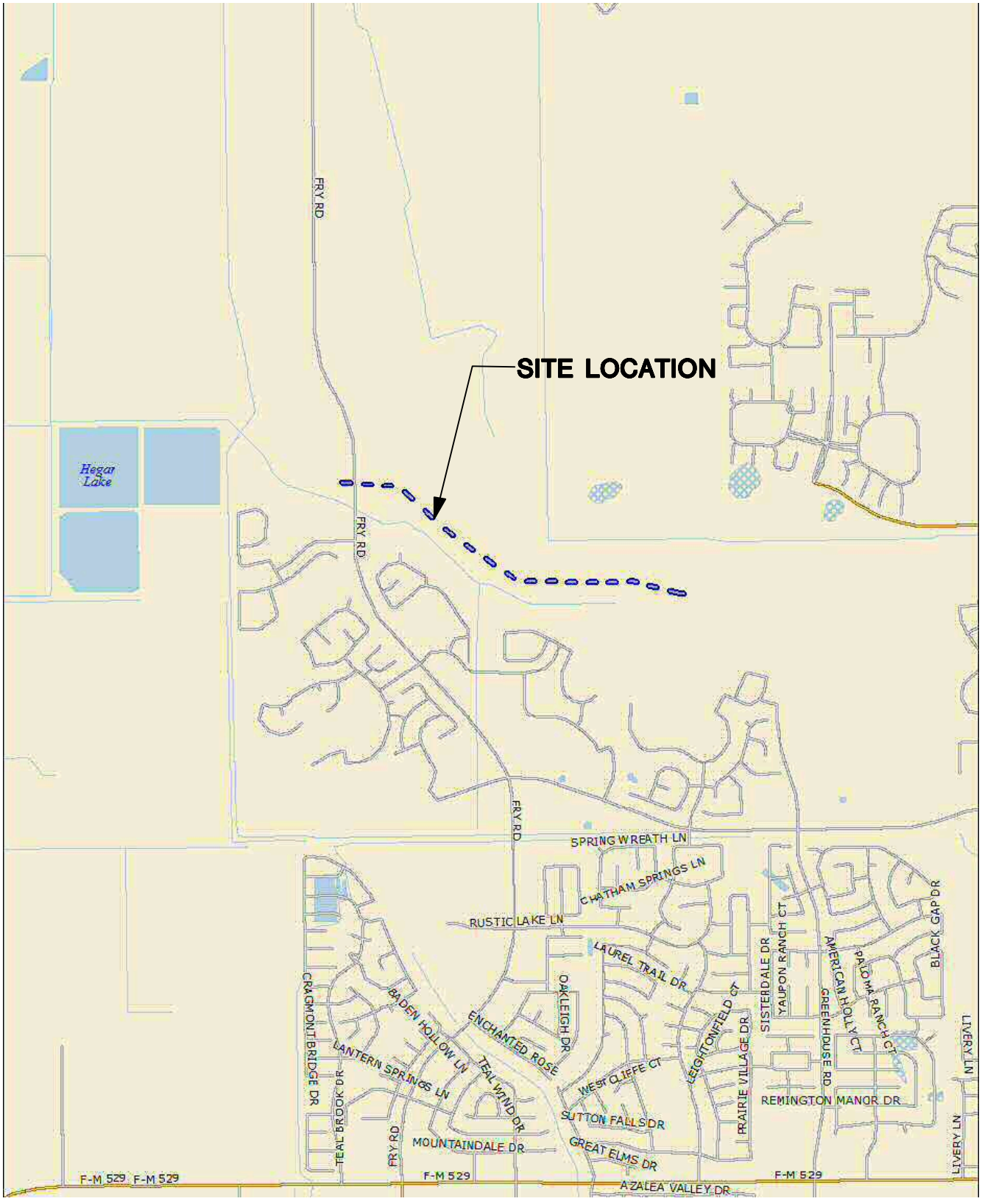
5-27-20

HTS, Inc. Consultants
F-3478

BFM/ba/JH:cg

S:\2016\250-299\16-S-299\16-299 Trench Safety Report.docx

ATTACHMENTS

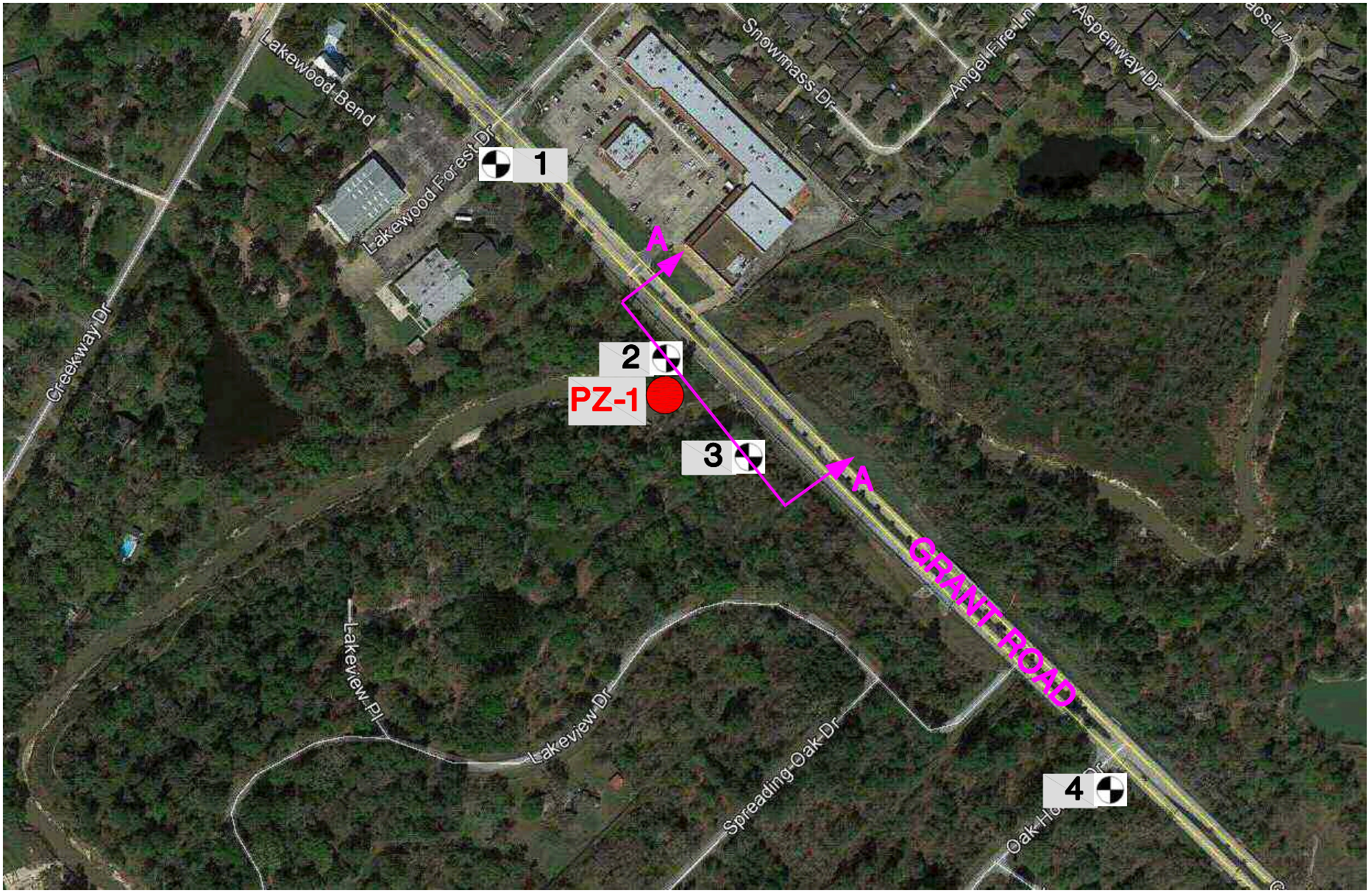


HTS, Inc. Consultants

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution
and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11-21-16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11-21-16	
HTS PROJECT NO.:	16-S-299			PLATE: 1

VICINITY MAP



Legend

- Geotechnical borings included in the study
- Piezometer location

HTS, Inc. Consultants

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11/15/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11/15/16	
HTS PROJECT NO.:	16-S-299			PLATE: 2A

BORING LOCATIONS

Legend

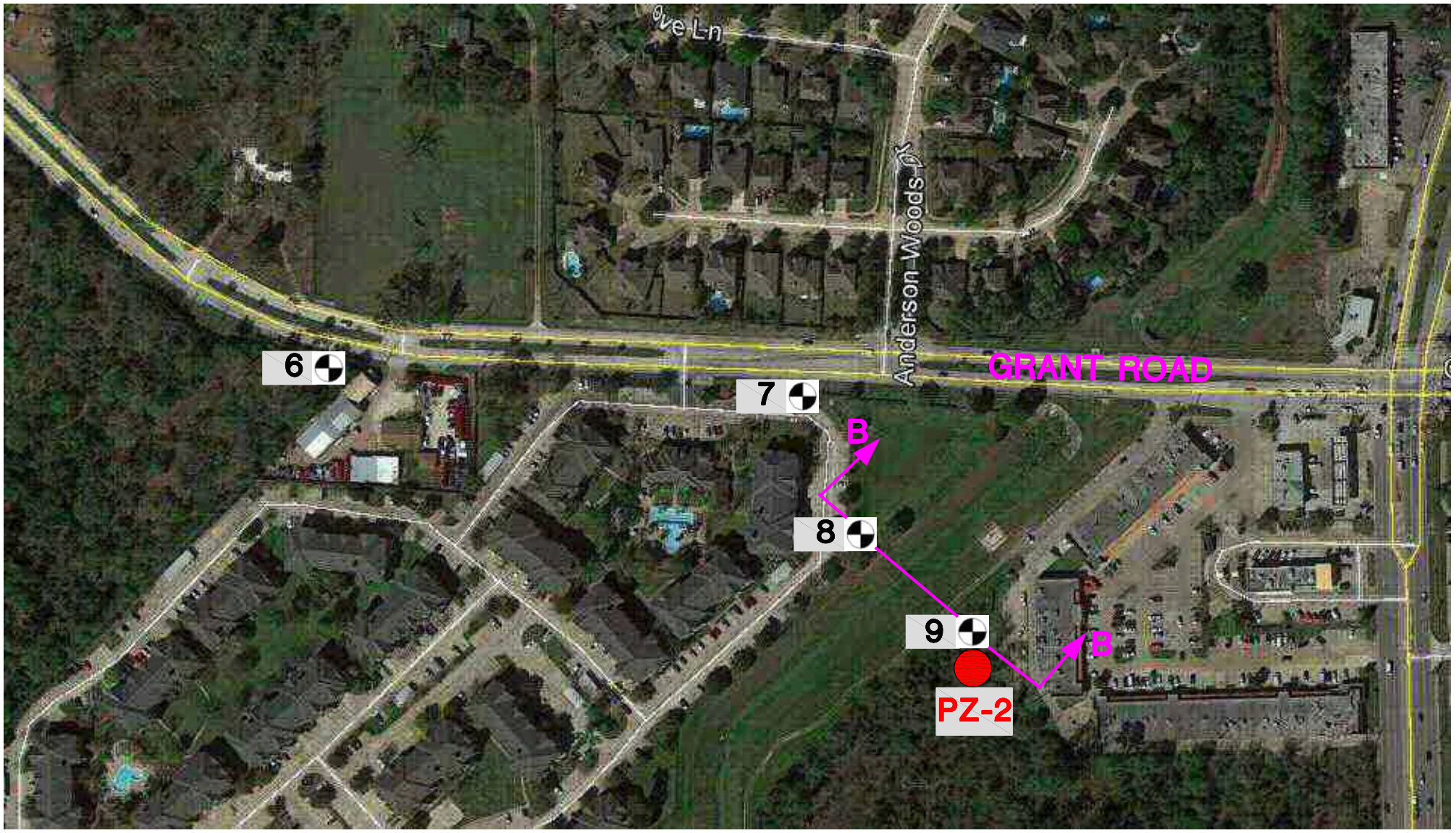
Geotechnical Borings included in the study

HTS, Inc. Consultants

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	7/26/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	7/26/16	
HTS PROJECT NO.:	16-S-299			PLATE: 2B

BORING LOCATIONS



Legend

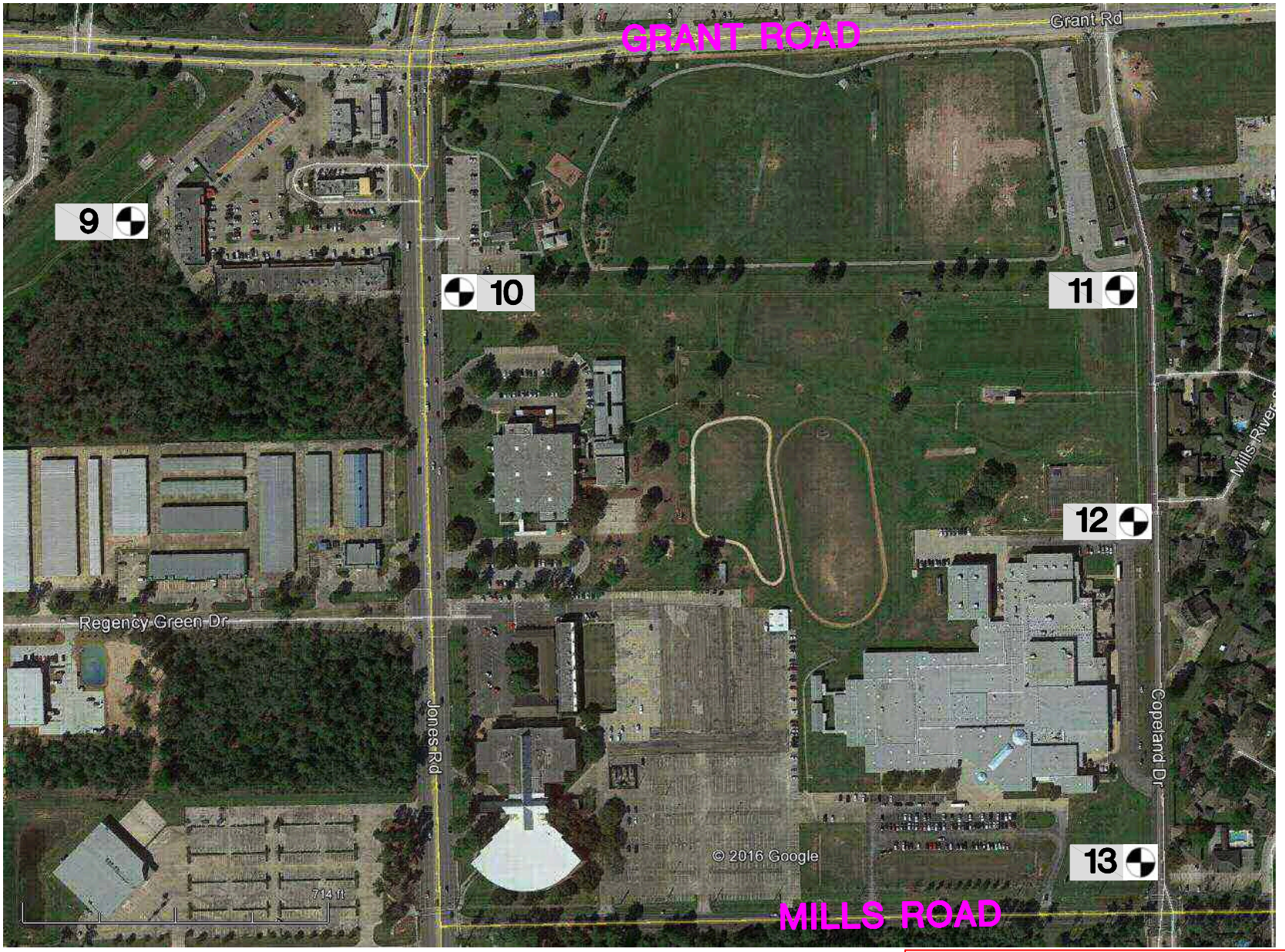
- Geotechnical borings included in the study
- Piezometer location

HTS, Inc. Consultants

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11/15/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11/15/16	
HTS PROJECT NO.:	16-S-299			PLATE: 2C

BORING LOCATIONS



HTS, Inc. Consultants

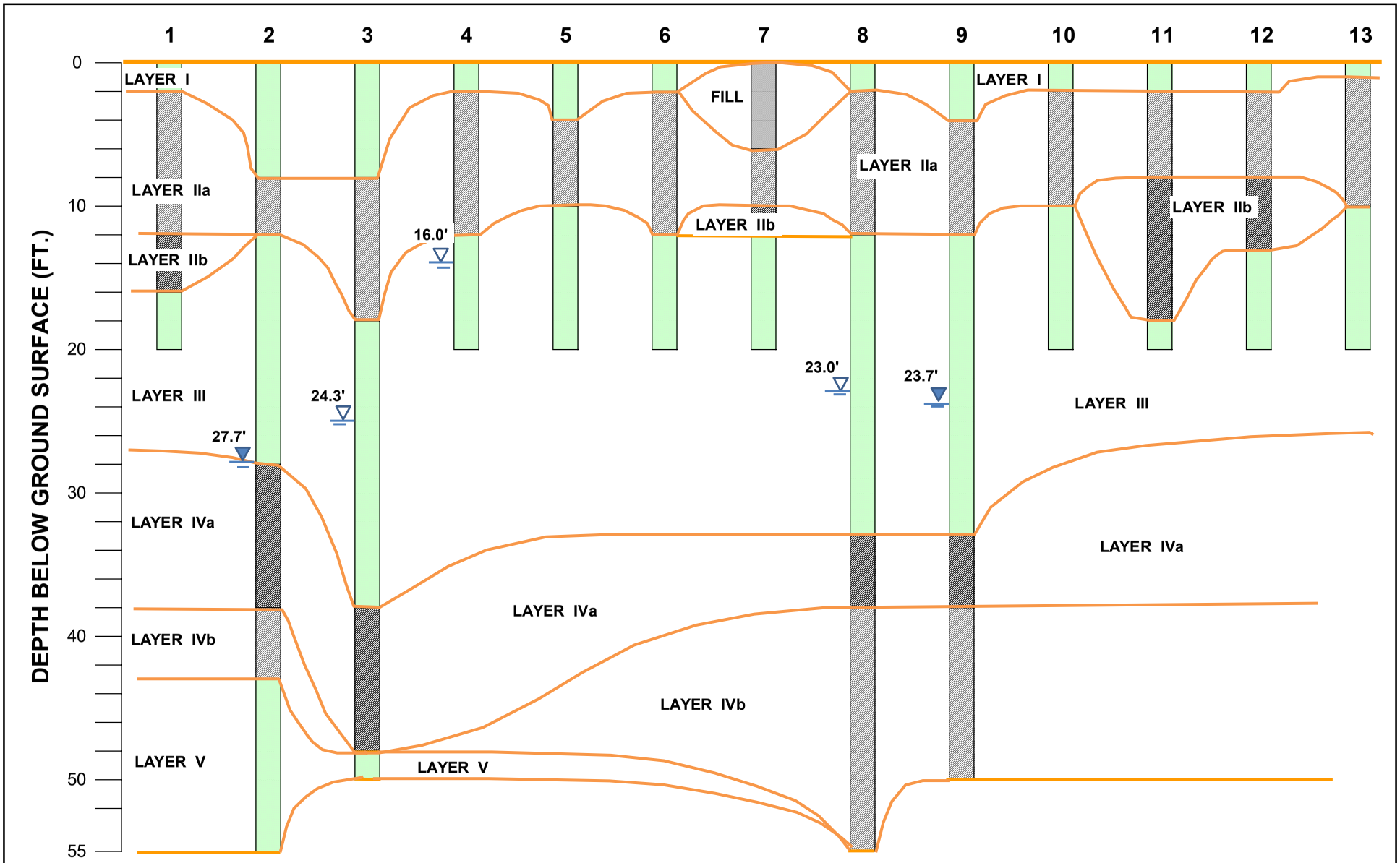
Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

DRAWN BY:	IAT	DATE:	11/15/16	SCALE: NTS
CHECKED BY:	BFM	DATE:	11/15/16	
HTS PROJECT NO.:	16-S-299			PLATE: 2D

BORING LOCATIONS

Legend

- Geotechnical borings included in the study



HTS, INC. Consultants

LEGENDS:

- Clayey Sands and Silty Sands
- Lean Clays and Silty Clays
- Fat Clays
- Fill
- Piezometer Reading
- Groundwater Reading During Drilling

SOIL PROFILE

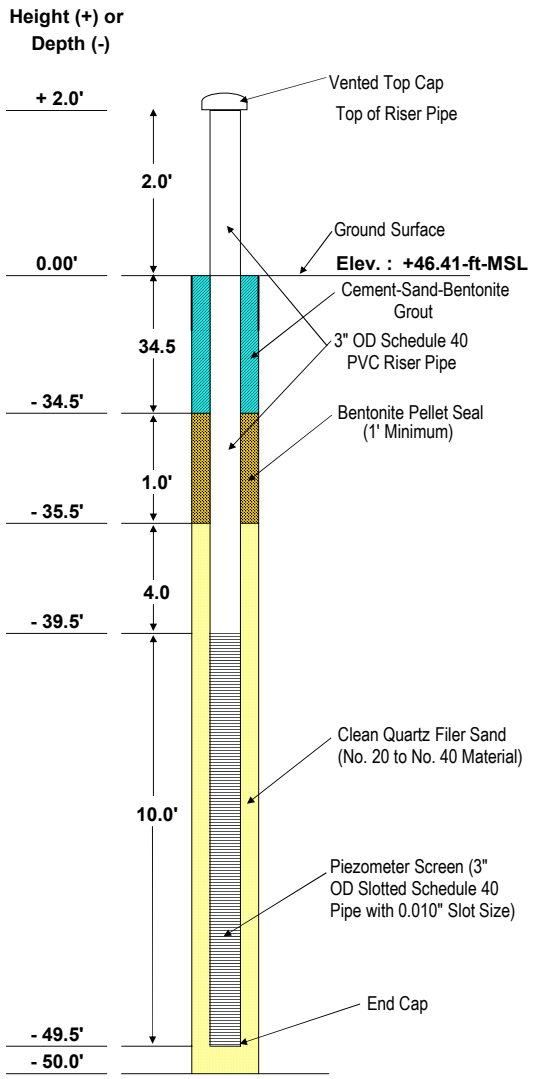
Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

Date: 12/30/2016	Report No: 16-S-299	Plate 3

HTS, Inc. Consultants

416 Pickering, Houston, Texas 77091
Tel: (713) 692-8373 Fax: (713) 692-8502

PIEZOMETER INSTALLATION DATA



Installation and Development Details

Piezometer No:	**PZ-1**	
Location:	**See Plate 2A**	
Installation Date:	**10/10/16**	
Drilling Method:	**Dry Auger**	x
	Wet Rotary	x
Development Date:	**11/09/16**	
Development Method:	**Pumping**	

Water Level Data	Depth Below Grade (ft)	Elevation (ft-MSL)
During Drilling:	**18.0**	**28.4**
11/9/2016	**23.7**	**22.7**
12/2/2016	**30.0**	**16.4**

NOTES: **Height above the ground surface is shown as a positive number (+) and depth below ground is shown as a negative number (-).**

Piezometer Installation Data

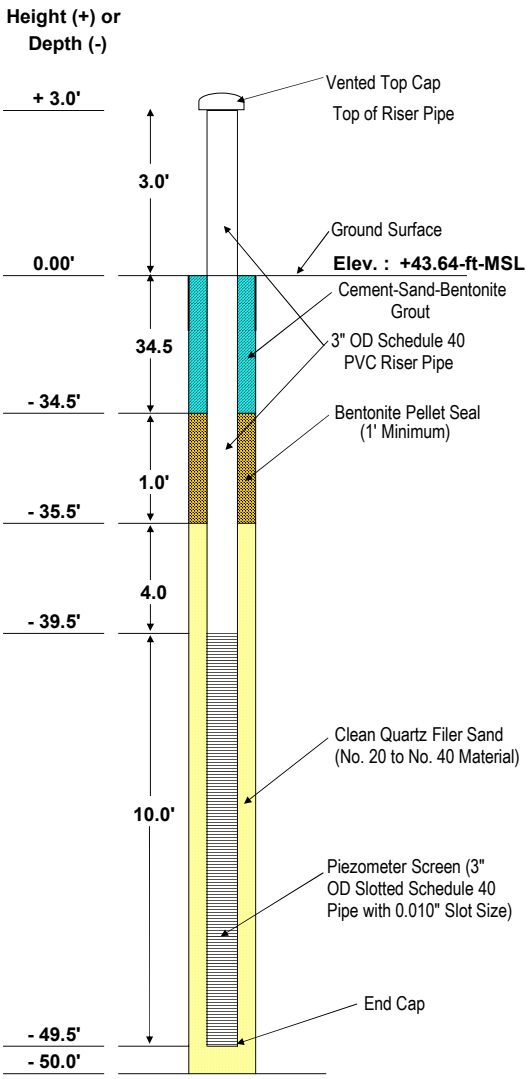
Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

Drawn By: BHA	Date: 12/28/2016	Scale: Not To Scale
Checked By: BFM	Date: 12/28/2016	**Plate 4A**
HTS Project No:	16-S-299	

HTS, Inc. Consultants

416 Pickering, Houston, Texas 77091
Tel: (713) 692-8373 Fax: (713) 692-8502

PIEZOMETER INSTALLATION DATA



Installation and Development Details

Piezometer No:	**PZ-2**	
Location:	**See Plate 2D**	
Installation Date:	**10/10/16**	
Drilling Method:	**Dry Auger**	x
	Wet Rotary	x
Development Date:	**10/25/16**	
Development Method:	**Pumping**	

Water Level Data	Depth Below Grade (ft)	Elevation (ft-MSL)
During Drilling:	**23.8**	**19.8**
########	**23.7**	**19.9**
########	**23.8**	**19.8**

NOTES: **Height above the ground surface is shown as a positive number (+) and depth below ground is shown as a negative number (-).**

Piezometer Installation Data

Proposed NHCRWA Contract No. 28-B
2025 Water Distribution and Transmission System
Harris County, Texas

Drawn By: BHA	Date: 12/28/2016	Scale: Not To Scale
Checked By: BFM	Date: 12/28/2016	**Plate 4B**
HTS Project No:	16-S-299	

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -20':

DATE 10/28/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 28.9" N
95° 36' 1.3" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SC	**CLAYEY SAND (SC),** dense, light gray	P = 4.50										
2'			P = 1.75										
	CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, light gray and tan	P = 1.75	114.4	0.65	9.6	0	16.8	31	15	16	61.6	(1)
5			P = 1.75										
			P = 1.50										
10													
12'	CH	**FAT CLAY (CH),** stiff to very stiff, light gray and tan, w/ sand pockets - w/ sand seams at 14'	P = 2.00	115.0	0.85	8.3	0	17.3	24	15	9	63.5	(1)
			P = 2.75										
15			P = 2.25										
16'	SM	**SILTY SAND (SM),** medium dense, light gray, w/ clay seams	P = 1.75										
18'	SC	**CLAYEY SAND (SC),** medium dese, light gray and tan	P = 1.75										
20'													
20		Boring terminated at 20'											

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 19.2'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure.

PLATE 5

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 2

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20': Rotary: 20'-55'

DATE 10/10//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 25.3" N
95° 35' 57.7" W
See Figure 2

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA (BLOW COUNT / C_u (tsf) / SS (tsf) / Torvane (psf))	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	Natural Moisture Content and Atterberg Limits	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose to dense, light gray	N = 9						3.2				16.8	Non Plastic
5			N = 12											
			N = 13											
8'	CL ML	**SANDY SILTY CLAY (CL-ML),** very stiff, light gray	N = 23											
10			N = 29											
12'	SM	**SILTY SAND (SM),** medium dense to dense, light gray	N = 18						11.2				23.3	Non Plastic
15			N = 25											
		- w/ clay seams at 18'	N = 31											
20			N = 30											
25			N = 22											
28'	CH	**FAT CLAY (CH),** stiff to very stiff, reddish brown and light gray	N = 17											

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered prior to use of slurry during drilling. After completion, the water level was at 16.5' and boring was open to 24.9'.

Sample Key: SPT Shelby Tube Disturbed No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (*) See Figures for UU Triaxial Test (ASTM D 2850).

PLATE 6

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 2

DATE 10/10//16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20': Rotary: 20'-55'

LOCATION

GPS Coordinates:
29° 58' 25.3" N
95° 35' 57.7" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**FAT CLAY (CH),** stiff to very stiff, reddish brown and light gray - w/ slickensides at 33'											
35			P = 2.75	92.0	0.90	11.6	34	28.4	85	24	61	88.8	(2) * 33'-35' UU
38'	CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, light gray and tan, w/ sand seams, sand pockets, and ferrous nodules	P = 1.75	107.7	1.10	15.0	0	20.3	45	19	26	63.3	(1)
43'	SM	**SILTY SAND (SM),** dense to very dense, light tan	N = 60										
45													
50			N = 42										
55'		Boring terminated at 55'	N = 73										

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered prior to use of slurry during drilling. After completion, the water level was at 16.5' and boring was open to 24.9'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (*) See Figures for UU Triaxial Test (ASTM D 2850).

PLATE 6

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 3

DATE 10/13//16

SURFACE ELEVATION

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -25' Rotary: 25'-50'

LOCATION

GPS Coordinates:
29° 58' 23" N
95° 35' 54.9" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose w/ concrete and brick pieces and roots, dark gray											
2'	SC	**SILTY CLAYEY SAND (SC-SM),** loose to medium dense, light gray and light tan, w/ roots and concrete pieces - gray and light gray at 4'	P = 1.50										
5			P = 1.50	110.2	0.25	1.8	0	16.8	20	14	6	38.8	(3)
8'	CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, light tan and light gray, w/ ferrous nodules - light gray w/ silt pockets at 14' - tan and light gray w/ sand pockets at 16'	N = 22										
			N = 16										
10			P = 2.50					15.7	32	15	17	56.5	
			P = 1.75										
15			N = 8										16'-18' Grade 1 Non Dispersive ** 16'-18' CU $C_{eff.}$=313.2 psf $Ø_{eff}$=25.4° $C_{Tot.}$=406.5 psf $Ø_{Tot.}$=19.6°
18'	SC	**CLAYEY SAND (SC),** medium dense to dense, reddish brown, tan, and light gray	P = 3.00	**			**	22.1	47	17	30	59.7	
			P = 3.50					16.7	37	16	21	37.1	18'-20' K=1.46E-07cm/s
20		- light tan and light gray with gravel at 23'											
			P = 4.50	116.7	2.15	15.0	24	15.7	28	15	13	22.8	(1) *23'-25' UU
25													
28'	SM	**SILTY SAND (SM),** dense to very dense, light gray	N = 34										

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

BLOW COUNT (20 40 60 80); C_u (tsf) (1.0 2.0 3.0 4.0); SS (tsf) (1.0 2.0 3.0 4.0); Torvane (psf) (200 400 600 800)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 24.3' during drilling and rose to 23.7' after 10 minutes. After completion, water was at 14.5' and boring was open to 23.4'.

Sample Key: SPT, Shelby Tube, Disturbed, No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850). See Figures for CU Triaxial Test (ASTM D 4767).

PLATE 7

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 3

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -25' Rotary: 25'-50'

DATE 10/13//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 23" N
95° 35' 54.9" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**SILTY SAND (SM),** dense to very dense, light gray	N >50										
35													
38'	CH	**FAT CLAY (CH),** stiff to very stiff, reddish brown and tan, w/ ferrous nodules and slickensides	P = 4.00	96.6	0.55	2.6	0	28.2					(2)
40													
45			P = 4.00	87.1	0.95	15.0	44	35.3	76	23	53	90.1	(2) *43'-45' UU
48'	SM	**SILTY SAND (SM),** very dense, tan											
50'			N = 63										
50		Boring terminated at 50'											

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 24.3' during drilling and rose to 23.7' after 10 minutes. After completion, water was at 14.5' and boring was open to 23.4'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850). See Figures for CU Triaxial Test (ASTM D 4767).

PLATE 7

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 4

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' -20'

DATE 10/28//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 16.6" N
95° 35' 46.7" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** medium dense, light gray	P = 2.50										
2'													
	CL	**SANDY LEAN CLAY (CL),** very stiff to hard, light gray and tan	P = 4.50	119.8	1.55	3.7	0	10.0	32	14	18	60.6	(1)
5													
6'			P = 4.50										
	CL	**LEAN CLAY WITH SAND (CL),** very stiff to hard, light gray and tan, w/ ferrous nodules - w/ sand seams at 8'	P = 4.00										
10			P = 2.50										
12'			P = 4.50										
	SM	**SILTY SAND (SM),** loose to medium dense, light gray and tan	P = 1.00										
15			N = 15					19.6				22.7	Non Plastic
		- reddish brown and light gray w/ clay seams at 18'	N = 13										
20'			N = 21										
20		Boring terminated at 20'											

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 16.0' during drilling and rose to 15.1' after 10 minutes. After completion of drilling, the boring caved at depth of 15.9'.

Sample Key: SPT, Shelby Tube, Disturbed, No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure.

PLATE 8

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 5

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/28//16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 10.5" N
95° 35' 39.5" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION
0	SM	**SILTY SAND (SM),** medium dense, light gray
2'	SC	**CLAYEY SAND (SC),** dense, light gray and tan, w/ ferrous nodules
4'	CL	**SANDY LEAN CLAY (CL),** hard, light gray and tan, w/ ferrous nodules and calcareous nodules - w/ sand fissures at 6'
10'	SC	**CLAYEY SAND (SC),** dense, light gray and tan, w/ ferrous nodules and calcareous nodules
12'	SM	**SILTY SAND (SM),** medium dense to dense, light gray, w/ clay seams - light gray and tan at 18'
20'		Boring terminated at 20'

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

DEPTH (ft.)	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	P = 3.75										
	P = 4.50										
5	P = 4.50										
	P = 4.50	124.0	3.45	3.2	0	10.7	37	15	22	65.8	(3)
10	P = 4.50										
	P = 4.50										
	P = 4.50										
15	N = 28										
	N = 37										
20											

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 18.8'.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed ☐ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(3) Sample failed along sand fissures.

PLATE 9

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 6

DATE 10/07//16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

LOCATION

GPS Coordinates:
29° 58' 0.1" N
95° 35' 25.9" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose, light tan, w/ roots	P = 0.50										
2'													
	CL	**SANDY LEAN CLAY (CL),** hard, light gray and tan, w/ sand fissures	P = 4.50										
5			P = 4.50	>>4.5	29.0	5.05	6.0	0	11.3	42	17	25	63.4	(3)
		- light gray and light tan at 10'	P = 4.50										
10			P = 4.50										
12'			P = 4.50		117.8	3.30	5.9	11	9.7	34	16	18	51.3	(1) *10'-12' UU
	SM	**SILTY SAND (SM),** medium dense, light gray and light tan	N = 27										
15			N = 21										
			N = 25						22.1	47	17	30	59.7	
20'			N = 22						16.7	37	16	21	37.1	
20		Boring terminated at 20'												

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 19.2'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures.

PLATE 10

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 7

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0'-20'

DATE 10/29/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 58' 0" N
95° 35' 17.2" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA (BLOW COUNT / C_u (tsf) / SS (tsf) / Torvane (psf))	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	Natural Moisture Content and Atterberg Limits	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0		**SANDY LEAN CLAY (FILL),** stiff, gray, light gray, and tan, w/ roots	P = 1.75						17.1	28	15	13	61.7	
			P = 1.75											
5			P = 1.75											
6'	CL	**LEAN CLAY WITH SAND (CL),** very stiff to hard, light gray and tan, w/ sand fissures	P = 4.25											
10'			P = 4.50	116.8	1.65	7.8	0		16.2	46	18	28	74.0	(1)
10	CH	**FAT CLAY (CH),** stiff to very stiff, light gray and tan, w/ sand pockets and sand fissures												
12'	SC	**CLAYEY SAND (SC),** medium dense, light gray	P = 2.00											
14'	SM	**SILTY SAND (SM),** very loose to medium dense, light gray and tan	P = 2.25											
15			P = 0.25											
		- w/ clay seams at 18'	N = 21											
20'			N = 18											
20		Boring terminated at 20'												

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion, the boring was dry and open to a depth of 19.2'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure.

PLATE 11

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 8

DATE 10/11/16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23': Rotary: 23'-55'

LOCATION

GPS Coordinates:
29° 57' 58.2" N
95° 35' 16.2" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose, gray, w/ clay pockets											
2'													
	CL	**SANDY LEAN CLAY (CL),** hard, tan, light tan, and light gray, w/ sand pockets, ferrous nodules, and sand fissures	P = 4.50										
5		- tan and light gray at 6'	P = 4.50										
		- gray, tan, and light gray at 8'	P = 4.50					9.5	40	17	23	63.3	6'-8' Grade 1 Non Dispersive
10			P = 4.50					10.8	42	18	24	68.1	8'-10' K=6.33E-08cm/s
12'			P = 4.50					10.8	39	17	22	62.1	
	SC	**CLAYEY SAND (SC),** medium dense to dense, tan, light tan, and light gray	N = 34										
15		- tan and light gray at 14'	N = 26										
		- w/ clay pockets at 16'	N = 32					6.3	25	16	9	43.8	
18'													
	SM	**SILTY SAND (SM),** medium dense to very dense, tan and light gray	N = 26										
20													
			N = 21										
25		- tan at 28'											
			N = 83										

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23' during drilling and rose to 22.3' after 10 minutes. After completion, the water was at 18' and boring was open to 21.8'.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed ☐ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850).

PLATE 12

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 8

DATE 10/11/16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23': Rotary: 23'-55'

LOCATION

GPS Coordinates:
29° 57' 58.2" N
95° 35' 16.2" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**SILTY SAND (SM),** medium dense to dense, tan and light gray											
		33'											
	CH	**FAT CLAY WITH SAND (CH),** hard, tan and light gray	N = 39					17.3				80.6	
35													
		38'											
	CL	**LEAN CLAY (CL),** very srtiff to hard, light tan and light gray, w/ ferrous nodules and sand seams	P = 4.50	112.9	1.85	14.8	39	17.6	43	18	25	91.2	(1) *38'-40' UU
40													
		43'											
	CL	**SANDY LEAN CLAY (CL),** very stiff to hard, gray and light tan, w/ sand fissures	P = 4.50	122.0	1.20	11.3	0	13.2	24	15	9		(3)
45													
		48'											
	CH	**LEAN CLAY (CL),** very stiff to hard, gray and light tan, w/ ferrous nodules	P = 4.50										
50													
		- reddish brown and light gray at 53'											
		55'	N = 73	105.0	1.50	14.9	54	25.8					(2) *53'-55' UU
55		Boring terminated at 55'											

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

ATTERBERG LIMITS(%): LL, PL, PI

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23' during drilling and rose to 22.3' after 10 minutes. After completion, the water was at 18' and boring was open to 21.8'.

Sample Key: ☒ SPT ☐ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (2) Sample failed along slickensides. (3) Sample failed along sand fissures. (*) See Figures for UU Triaxial Test (ASTM D 2850).

PLATE 12

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 9

DATE 10/10/16

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

SURFACE ELEVATION

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23' Rotary: 23'-55'

LOCATION

GPS Coordinates:
29° 57' 56.7" N
95° 35' 14.5" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA (BLOW COUNT / C_u (tsf) / SS (tsf) / Torvane (psf))	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	Natural Moisture Content and Atterberg Limits	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** loose, gray and light gray, w/ roots												
2'														
	SC	**CLAYEY SAND (SC),** medium dense, light gray and tan	N = 27											
4'														
	CL	**LEAN CLAY WITH SAND (CL),** hard, light gray and tan, w/ sand fissures	P = 4.50						11.3	33	17	16	70.1	
5		- w/ ferrous nodules at 6'	P = 4.50						12.4	43	19	24	73.1	** 6'-8' CU $C_{eff.}$=289.3 psf $Ø_{eff}$=22.5° $C_{Tot.}$=380.9 psf $Ø_{Tot.}$=17.4° (1)
			P = 4.50											
10		- light gray at 10'	P = 4.50											
12'														
	SC	**CLAYEY SAND (SC),** medium dense to dense, light gray	P = 4.50	117.3	2.95	14.8	11		13.2	43	19	24	72.5	*10'-12' UU
			N = 38											
15		- w/ clay seams at 16'	N = 40											
			N = 31											
20			N = 28						3.9	37	17	20	21.7	18'-20' Grade 1 Non Dispersive
23'														
	SM	**SILTY SAND (SM),** medium dense to very dense, tan	N = 22											
25														
			N = 50						19.4				18.9	Non Plastic

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23.0' during drilling and dropped to 23.5' after 10 minutes. After completion, the water was at 16.9' and boring was open to 22.8'.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed ☐ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (*) See Figures for UU Triaxial Test (ASTM D 2850).

PLATE 13

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 9

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 23' Rotary: 23'-55'

DATE 10/10/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 56.7" N
95° 35' 14.5" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
30		**SILTY SAND (SM),** medium dense to very dense, tan											
33'													
35	CH	**FAT CLAY (CH),** very stiff, light gray and tan, w/ silt pockets	N = 29										
38'													
40	CL	**LEAN CLAY (CL),** stiff to hard, light gray and tan	N >50										
45		- w/ sand pockets and sand fissures at 48'	P = 4.50					13.7	22	14	8		
50'													
50		Boring terminated at 50'	P = 4.50	115.6	0.60	6.0	0	15.4					(1)

FIELD STRENGTH DATA: ● BLOW COUNT ● (20 40 60 80); ▲ C_u (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW = 23.0' during drilling and dropped to 23.5' after 10 minutes. After completion, the water was at 16.9' and boring was open to 22.8'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (*) See Figures for UU Triaxial Test (ASTM D 2850).

PLATE 13

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 10

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/07/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 54.96" N
95° 35' 6.17" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY SAND (SM),** medium dense, gray, w clay pockets	P = 3.00										
2'	CL	**LEAN CLAY WITH SAND (CL),** hard, gray and tan, w/ sand fissures	P = 4.50	122.4	2.35	4.2	0	11.4	29	16	13	72.4	(3)
4'	CL	**SANDY LEAN CLAY (CL),** hard, light gray and tan, w/ sand fissures	P = 4.50										
5			P = 4.50										
			P = 4.50										
10'	SC	**CLAYEY SAND (SC),** medium dense to dense, light gray and light tan - light tan at 12'	P = 4.50	119.1	2.95	4.9	0	15.0	42	17	25	69.7	(3)
10			P = 4.50										
14'	SP SM	**POORLY GRADED SAND WITH SILT (SP-SM),** medium dense, light tan	P = 2.75										
15			N = 13										
			N = 15					6.0				11.2	Non Plastic
20'			N = 15										
20		Boring terminated at 20'											

FIELD STRENGTH DATA: ● BLOW COUNT ● (20 40 60 80); ▲ C_u (tsf) ▲ (1.0 2.0 3.0 4.0); ■ SS (tsf) ■ (1.0 2.0 3.0 4.0); ◆ Torvane (psf) ◆ (200 400 600 800)

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit (20 40 60 80)

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 18.6'.

Sample Key: ☒ SPT ☐ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(3) Sample failed along sand fissures.

PLATE 14

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 11

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/03/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 54.9" N
95° 34' 48.3" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SC	**CLAYEY SAND (SC),** dense, gray and light gray	P = 4.50										
2'	CL	**SANDY LEAN CLAY (CL),** very stiff, light gray and tan, w/ sand fissures	P = 3.25	120.6	1.05	8.1	0	12.8					(3)
4'	CL	**LEAN CLAY WITH SAND (CL),** hard, light gray and tan, w/ sand fissures	P = 4.50										
5			P = 4.50	108.9	2.15	5.9	0	14.8	39	18	21	71.6	(3)
8'	CH	**FAT CLAY (CH),** very stiff, light gray and tan, w/ sand pockets and sand fissures - w/ silt seams at 10'	P = 3.25										
10			P = 2.75										
		- light gray and reddish brown at 13'	P = 2.75	110.2	1.20	7.2	0	24.4	63	21	42	95.8	(1)
15													
18'	SM	**SILTY SAND (SM),** very loose, light gray, w/ clay seams	P = 0.25										
20'		Boring terminated at 20'											
20													

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion, of drilling, the boring was dry and open to a depth of 19.0'.

Sample Key: ☒ SPT ⧄ Shelby Tube ▤ Disturbed ▣ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures.

PLATE 15

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 12

PAGE 1 OF 1

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/03/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 49.8" N
95° 34' 48.1" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	**SILTY CLAYEY SAND (SC-SM),** dense, gray and light gray	P = 4.50					4.2	21	17	4	42.9	
2'	CL	**SANDY LEAN CLAY (CL),** stiff to very stiff, gray and tan, w/ sand fissures	P = 2.25										
5			P = 3.25	118.6	0.90	7.9	0	15.5	46	20	26	62.3	(3)
8'	CH	**FAT CLAY (CH),** very stiff, light gray and tan, w/ sand fissures	P = 2.75										
10			P = 3.25	116.2	1.90	9.2	0	18.8					(1)
13'	SM	**SILTY SAND (SM),** very loose to medium dense, light gray, w/ clay seams	P = 2.50										
15			P = 2.00										
			P = 0.25										
20'		Boring terminated at 20'	P = 0.25										
20													

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 19.0'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures.

PLATE 16

HTS, Inc. Consultants
416 Pickering Street
Houston, Texas 77091

LOG OF BORING NO. 13

PROJECT: Proposed NHCRWA Contract No. 28-B, 2025 Water Distribution and Transmission System, Harris County, Texas

PROJECT NO.: 16-S-299 BORING TYPE: Auger: 0' - 20'

DATE 10/03/16

SURFACE ELEVATION

LOCATION

GPS Coordinates:
29° 57' 41.7" N
95° 34' 47.9" W
See Figure 2

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	FIELD STRENGTH DATA	DRY DENSITY (pcf)	SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	ATTERBERG LIMITS(%) LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	SM	1' **SILTY SAND (SM),** loose, light gray, w/ roots											
	CL	**LEAN CLAY WITH SAND (CL),** very stiff to hard, tan and light gray - w/ sand fissures at 4'	P = 1.50										
			P = 2.50										
5			P = 4.00	116.9	1.75	14.3	5	15.1	42	19	23	70.7	(1)*4'-6' UU
			P = 4.50	124.6	2.30	12.0	0	12.8					(1)
10	SM	10' **SILTY SAND (SM),** very loose to medium dense, light gray, w/ clay seams	P = 3.00										
			P = 2.00	112.9	0.35	5.7	0	17.0	28	15	13	39.8	(3)
15			P = 0.25										
20		20' Boring terminated at 20'	P = 0.25										

FIELD STRENGTH DATA: ● BLOW COUNT ● 20 40 60 80; ▲ C_u (tsf) ▲ 1.0 2.0 3.0 4.0; ■ SS (tsf) ■ 1.0 2.0 3.0 4.0; ◆ Torvane (psf) ◆ 200 400 600 800

Natural Moisture Content and Atterberg Limits: Plastic Limit — Moisture Content — Liquid Limit; 20 40 60 80

Water Level Est.: ▽ Measured: ▼ Perched: ▼

Water Observations: GW was not encountered during drilling. After completion of drilling, the boring was dry and open to a depth of 18.8'.

Sample Key: ☒ SPT ☒ Shelby Tube ☒ Disturbed ☒ No Recovery

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
C_u - Undrained Cohesion (tsf)
SS - Shear Strength (P/2, tsf)

Notes:
(1) Sample bulged at failure. (3) Sample failed along sand fissures. See Figures for UU Triaxial Test (ASTM D 2850).

PLATE 17

Recommended Geotechnical Design Parameters

RECOMMENDED GEOTECHNICAL DESIGN PARAMETERS

Geotechnical Sub Consultant: HTS, Inc. Consultants

PROJECT NAME: 2025 Water Transmission and Ditribution System
NHCRWA Contract No. 28, Harris County, Texas
HTS PROJECT No.: 16-S-299

Boring No.	Sample Depth (feet)	Type of Material	OSHA TYPE	γ (pcf)	γ' (pcf)	SHORT TERM					LONG TERM
						C (psf)	ϕ (deg)	K_a	K_o	K_p	For Long Term Condition, refer to Section 1.4.5 of the report.
1	0-2	Dense: SC	C	129	67	0	32	0.31	0.45	3.25	
	2-6	Stiff: CL	B	134	71	1300	0	1.00	1.00	1.00	
	6-12	Stiff: CL	B	135	73	1700	0	1.00	1.00	1.00	
	12-16	Very stiff: CH	B	138	76	2000	0	1.00	1.00	1.00	
	16-20	Medium dense: SM, SC	C	134	72	0	30	0.33	1.99	3.00	
2	0-8	Loose to Medium Dense: SM	C	132	70	0	28	0.36	0.73	2.77	
	8-12	Very stiff: CL-ML	B	134	72	1800	0	1.00	1.00	1.00	
	13.5-15	Medium dense to dense: SM	C	134	72	0	30	0.33	1.99	3.00	
	28-38	Stiff to very stiff: CH	B	129	67	1800	0	1.00	1.00	1.00	
	38-43	Stiff to very stiff: CL	B	130	67	2200	0	1.00	1.00	1.00	
	43-55	Dense to very dense: SM	C	134	72	0	32	0.31	0.45	3.25	
3	0-8	Loose to medium dense, SM, SC-SM	C	129	66	0	28	0.36	0.73	2.77	
	8-16	Stiff to very stiff: CL	B	135	72	1800	0	1.00	1.00	1.00	
	16-18	Very stiff: CL	B	135	72	2500	0	1.00	1.00	1.00	
	18-23	Medium dense: SC	C	135	72	0	30	0.33	1.99	3.00	
	23-25	Dense to very dense: SC, SM	C	135	73	0	32	0.31	0.45	3.25	
	38-40	Stiff to very stiff: CH	B	124	61	1100	0	1.00	1.00	1.00	
	40-48	Stiff to very stiff: CH	B	118	55	1900	0	1.00	1.00	1.00	
	48-50	Very dense: SM	C	134	72	0	32	0.31	0.45	3.25	
4	0-2	Medium dense: SM	C	129	67	0	30	0.33	1.99	3.00	
	2-12	Very stiff to hard: CL	B	132	70	3000	0	1.00	1.00	1.00	
	14.5-16	Loose to medium dense: SM	C	132	70	0	28	0.36	0.73	2.77	

Note:

1) γ = Unit Weight for soil above water level,
2) CL = Lean Clays; CH = Fat Clays
3) Cu = Ultimate cohesion of soil, ϕu = friction angle of soil, for short term;
4) Ka = Coefficient of active earth pressure Ko = Coefficient of static earth pressure
   Kp = Coefficient of passive earth pressure
5) OSHA Soil Types:
   - A: Cohesive soils with q_u = 1.5 tsf or greater (q_u = Unconfined Compressive Strength of the soil)
   - B: Cohesive soils with q_u = 0.5 tsf or greater
   - C: Cohesive soils with q_u = less than 0.5 tsf, granular soils, submerged soils or soils with significant weak secondary structure.

PLATE 18

Recommended Geotechnical Design Parameters

RECOMMENDED GEOTECHNICAL DESIGN PARAMETERS Geotechnical Sub Consultant: HTS, Inc. Consultants						PROJECT NAME: 2025 Water Transmission and Ditribution System NHCRWA Contract No. 28, Harris County, Texas HTS PROJECT No.: 16-S-299					Page: 2 of 3
Boring No.	Sample Depth (feet)	Type of Material	OSHA TYPE	γ (pcf)	γ' (pcf)	SHORT TERM					LONG TERM
						C (psf)	ϕ (deg)	K_a	K_o	K_p	For Long Term Condition, refer to Section 1.4.5 of the report.
5	0-4	Medium dense to dense: SM, SC	C	129	67	0	30	0.33	1.99	3.00	
	4-10	Hard: CL	B	137	75	3000	0	1.00	1.00	1.00	
	10-20	Medium dense to dense: SM, SC	C	129	67	0	30	0.33	1.99	3.00	
6	0-2	Loose: SM	C	129	67	0	28	0.36	0.73	2.77	
	2-12	Hard: CL	B	144	82	3000	0	1.00	1.00	1.00	
	12-20	Medium dense: SM	C	129	67	0	30	0.33	1.99	3.00	
7	0-6	Stiff: CL FILL	C	134	72	1700	0	1.00	1.00	1.00	
	6-10	Very stiff to hard: CL	B	136	74	3000	0	1.00	1.00	1.00	
	10-12	Stiff to very stiff: CH	B	118	56	2000	0	1.00	1.00	1.00	
8	0-2	Loose: SM	C	129	67	0	28	0.36	0.73	2.77	
	2-12	Hard: CL	B	134	72	3000	0	1.00	1.00	1.00	
	12-33	Medium dense to very dense: SC, SM	C	132	70	0	32	0.31	0.45	3.25	
	33-38	Hard: CH	B	120	58	3000	0	1.00	1.00	1.00	
	38-55	Very stiff to hard: CL	B	138	76	2400	0	1.00	1.00	1.00	
9	0-4	Loose to Medium: SM, SC	C	129	67	0	28	0.36	0.73	2.77	
	4-12	Hard: CL	B	134	72	3000	0	1.00	1.00	1.00	
	12-33	Medium dense to very dense: SC, SM	C	132	70	0	32	0.31	0.45	3.25	
	33-38	Very Stiff: CH	B	120	58	2500	0	1.00	1.00	1.00	
	38-50	Stiff to hard: CL	B	133	71	1200	0	1.00	1.00	1.00	

Note:

1) γ = Unit Weight for soil above water level,
2) CL = Lean Clays; CH = Fat Clays
3) Cu = Ultimate cohesion of soil, ϕu = friction angle of soil, for short term;
4) Ka = Coefficient of active earth pressure Ko = Coefficient of static earth pressure
   Kp = Coefficient of passive earth pressure
5) OSHA Soil Types:
   - A: Cohesive soils with q_u = 1.5 tsf or greater (q_u = Unconfined Compressive Strength of the soil)
   - B: Cohesive soils with q_u = 0.5 tsf or greater
   - C: Cohesive soils with q_u = less than 0.5 tsf, granular soils, submerged soils or soils with significant weak secondary structure.

PLATE 19

Recommended Geotechnical Design Parameters

RECOMMENDED GEOTECHNICAL DESIGN PARAMETERS Geotechnical Sub Consultant: HTS, Inc. Consultants						PROJECT NAME: 2025 Water Transmission and Ditribution System NHCRWA Contract No. 28, Harris County, Texas HTS PROJECT No.: 16-S-299					Page: 3 of 3
Boring No.	Sample Depth (feet)	Type of Material	OSHA TYPE	γ (pcf)	γ' (pcf)	SHORT TERM					LONG TERM
						C (psf)	ϕ (deg)	K_a	K_o	K_p	For Long Term Condition, refer to Section 1.4.5 of the report.
10	0-2	Medium dense: SM	C	132	70	0	30	0.33	1.99	3.00	
	2-10	Hard: CL	B	137	75	3000	0	1.00	1.00	1.00	
	10-20	Medium dense to dense: SC, SP-SM	C	132	70	0	30	0.33	1.99	3.00	
11	0-2	Dense: SC	C	132	70	0	32	0.31	0.45	3.25	
	2-8	Very stiff to hard: CL	B	135	73	2100	0	1.00	1.00	1.00	
	8-18	Very stiff: CH	B	137	75	2400	0	1.00	1.00	1.00	
	18-20	Very loose: SM	C	132	70	0	28	0.36	0.73	2.77	
12	0-2	Very dense: SC-SM	C	132	70	0	32	0.31	0.45	3.25	
	2-8	Stiff to very stiff: CL	B	134	72	1800	0	1.00	1.00	1.00	
	8-13	Very stiff: CH	B	138	76	3000	0	1.00	1.00	1.00	
	13-20	Very loose to medium dense: SM	C	132	70	0	28	0.36	0.73	2.77	
13	0-1	Loose: SM	C	132	70	0	28	0.36	0.73	2.77	
	1-10	Very stiff to hard: CL	B	141	78	3000	0	1.00	1.00	1.00	
	10-20	Very loose to medium dense: SM	C	132	70	0	28	0.36	0.73	2.77	

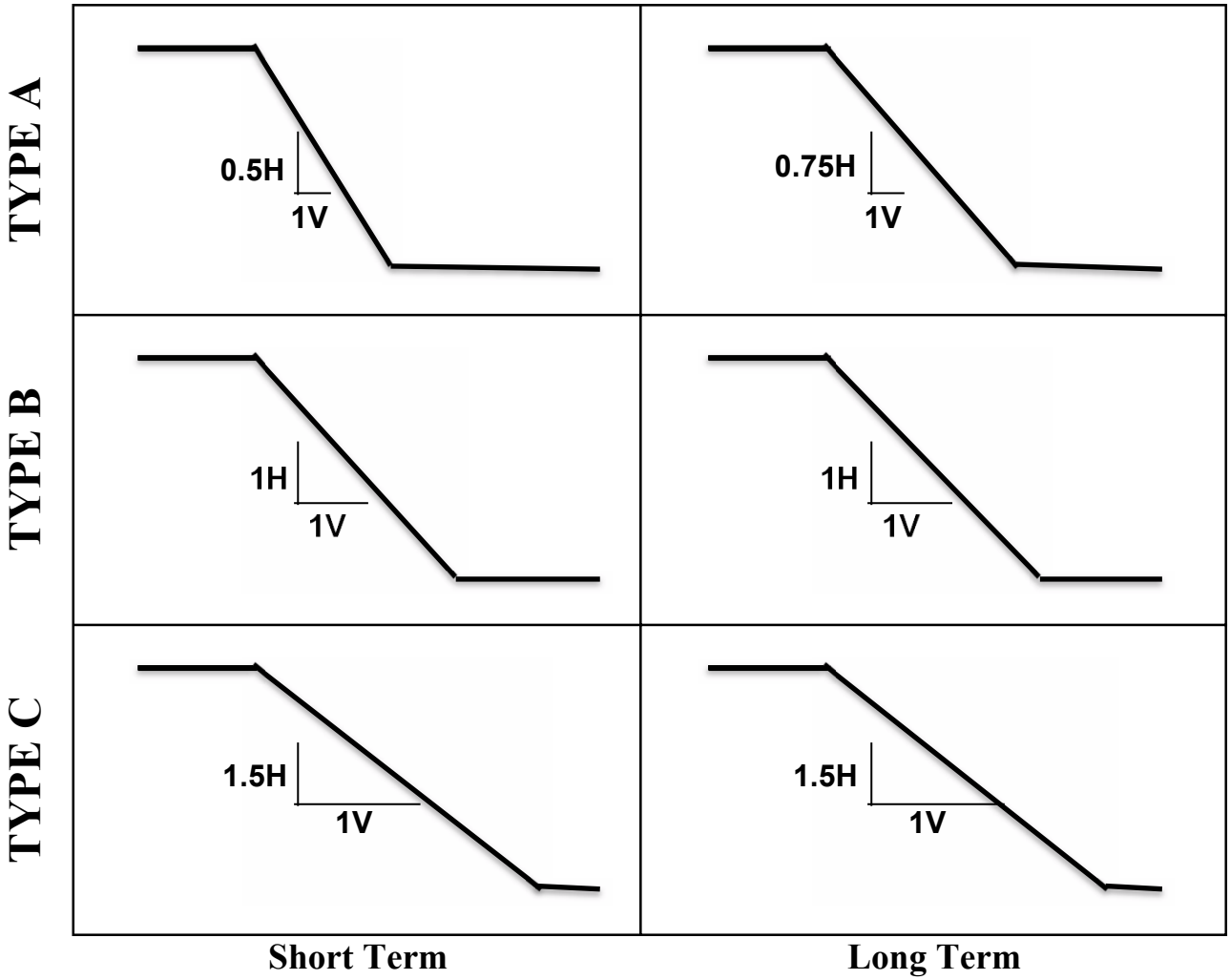
Note:

1) γ = Unit Weight for soil above water level,
2) CL = Lean Clays; CH = Fat Clays
3) Cu = Ultimate cohesion of soil, ϕu = friction angle of soil, for short term;
4) Ka = Coefficient of active earth pressure Ko = Coefficient of static earth pressure
   Kp = Coefficient of passive earth pressure
5) OSHA Soil Types:
   - A: Cohesive soils with q_u = 1.5 tsf or greater (q_u = Unconfined Compressive Strength of the soil)
   - B: Cohesive soils with q_u = 0.5 tsf or greater
   - C: Cohesive soils with q_u = less than 0.5 tsf, granular soils, submerged soils or soils with significant weak secondary structure.

PLATE 20

MAXIMUM ALLOWABLE SLOPES

For Open Trench Excavation



NOTES:

(1) For Type A soils, a short term maximum allowable slope of 0.5 H : 1 V is allowed in excavations that are 12 feet or less in depth; short term maximum allowable slopes for excavations greater than 12 feet in depth shall be 0.75 H : 1 V.

(2) Maximum depth for above slopes is 20 feet, For slopes greater than 20 feet, trench protection should be designed by the Contractor's professional engineer.

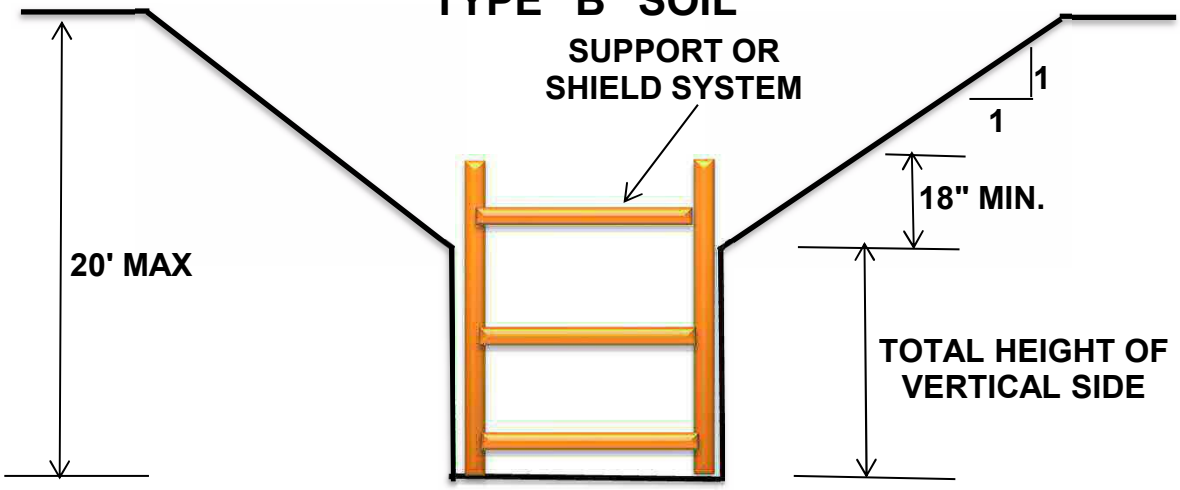
Reference: OSHA, Safety and Health Regulations for Construction, 1926, Subpart A

Maximum Allowable Slopes for Open Trench Excavation	
Proposed NHCRWA Contract No. 28-B 2025 Water Transmission and Distribution System Harris County, Texas	
HTS Project No.: 16-S-299	PLATE 21

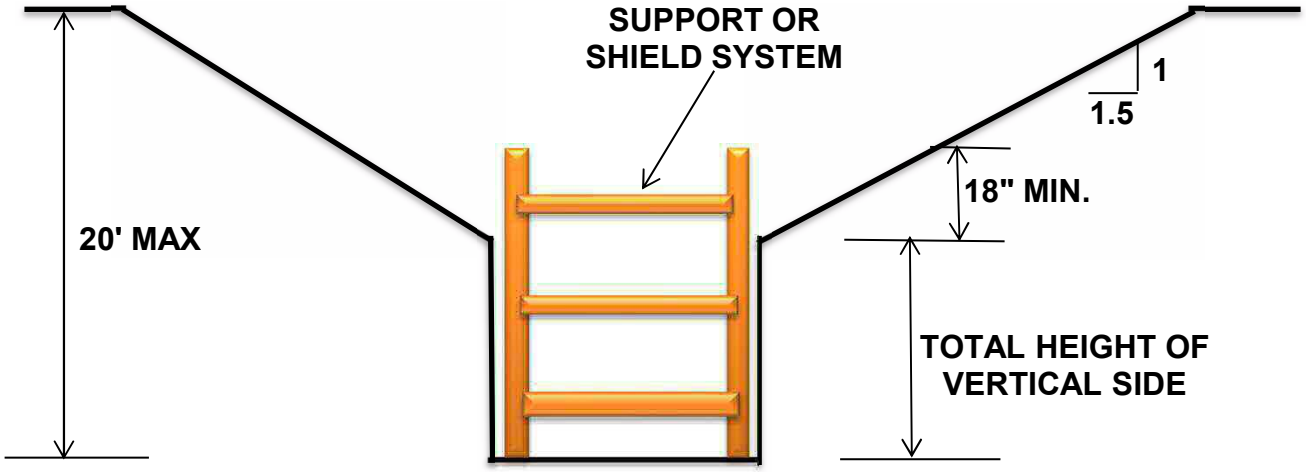
COMBINATION OF BRACING AND OPEN CUTS

For Open Trench Excavation

TYPE "B" SOIL



TYPE "C" SOIL



Reference: OSHA, Safety and Health Regulations for Construction, 1926, Subpart A

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Combination of Bracing and Open Cuts for Open Trench Excavation	
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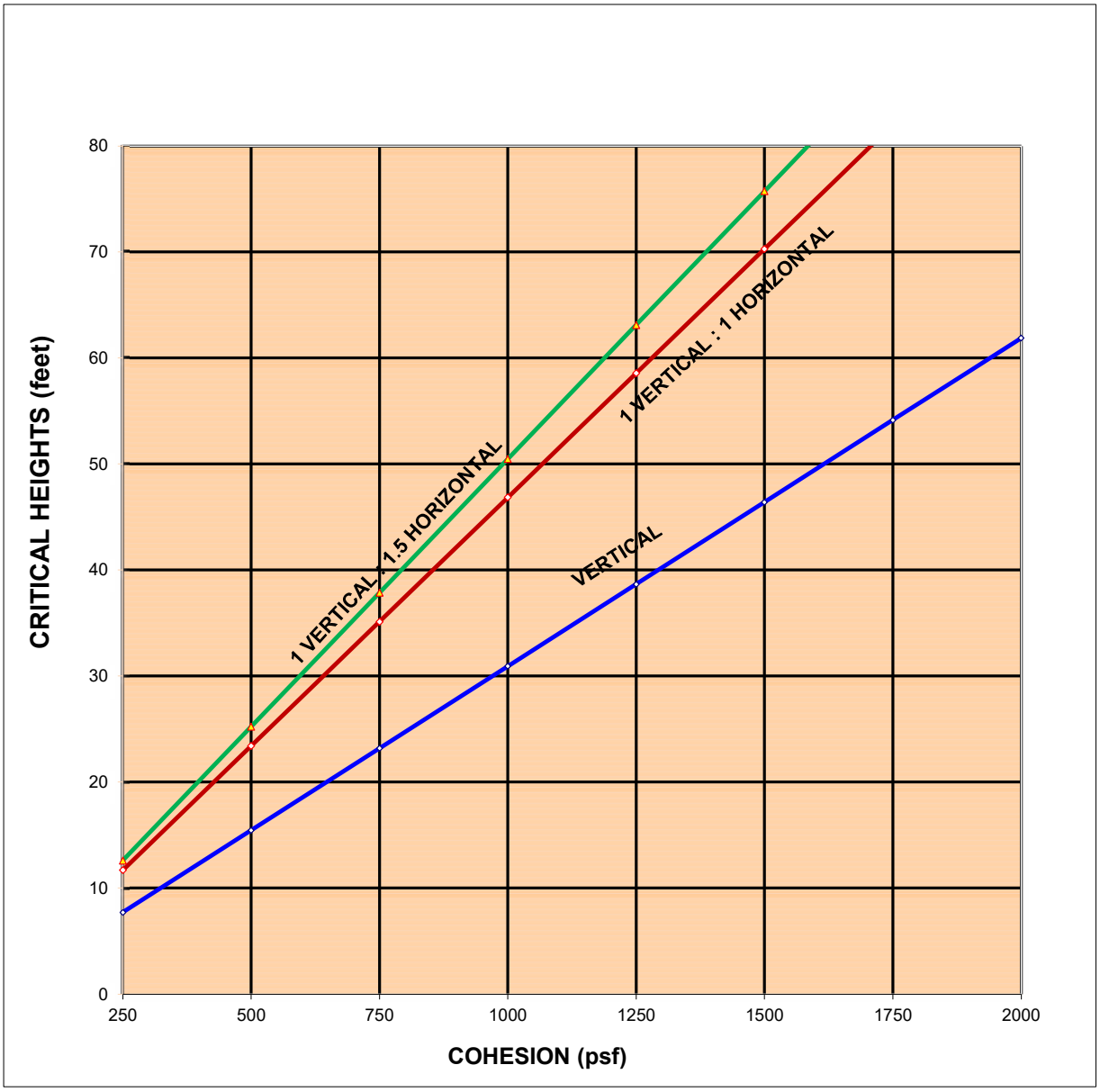
CRITICAL HEIGHTS OF CUT IN NONFISSURED CLAYS



Note: The charts are calculated based on NAVFAC DM-7.1, Page-319, assuming the circles are toe circles and the unit wet weight of soils = 125 pcf

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Critical Heights of Cut in Non-Fissured Clays	
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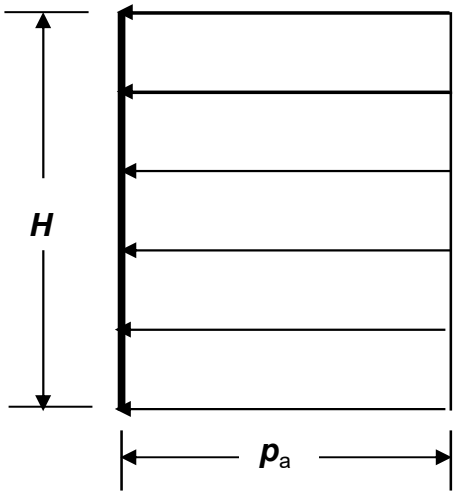
PRESSURE ENVELOPES FOR BRACED-CUT DESIGN

Cuts in Sands

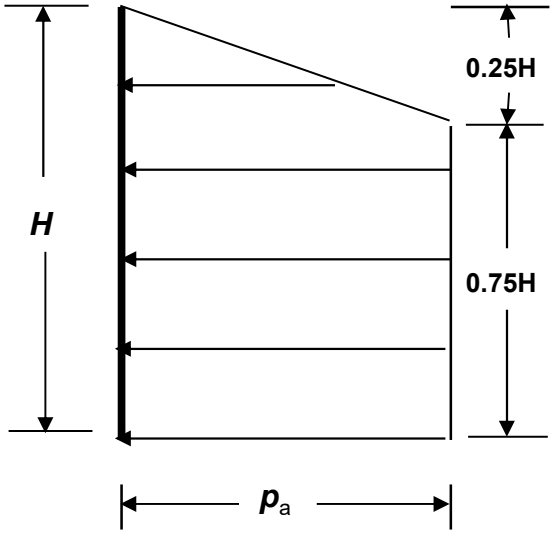


$$p_a = 0.65 * \gamma * H * K_a$$

where:

H = height of the cut
Ka = Rankine active pressure coefficient
= $\tan^2 (45 - \phi / 2)$
γ = unit weight of soil
ϕ = 30° (recommended)

Cuts in Soft to Medium Clays



Condition: $\frac{\gamma H}{c} > 4$

$$p_a = \gamma * H \left[1 - \left(\frac{4c}{\gamma * H} \right) \right]$$

OR

$$p_a = 0.3 * \gamma * H$$

whichever is larger

where: c = undrained cohesion ($\phi = 0$)
γ = unit weight of clay

Reference: Pages 521 - 523, Principles of Foundation Engineering, 4th Edition, Braja Das

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Pressure Envelopes for Braced-Cut Design (Cuts in Sands and Soft to Medium Clays)	
Proposed 2025 Water Transmission and System, NHCRWA Contract No. 28 Harris County, Texas	
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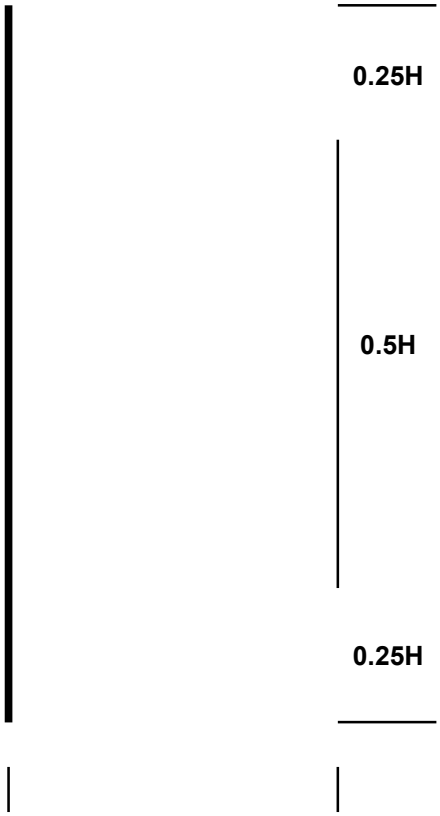
PRESSURE ENVELOPE FOR BRACED-CUT DESIGN

Cuts in Stiff Clays



Condition: γ H / c

$p_a = 0.2 * \gamma * H$ to $0.4 * \gamma * H$

(with an average of 0.3 γ H)

where: c = undrained cohesion ($\phi = 0$)

γ = unit weight of clay

Reference: Pages 522 and 523, Principles of Foundation Engineering, 4th Edition, Braja Das

Pressure Envelope for Braced-Cut Design (Cuts in Stiff Clays)	
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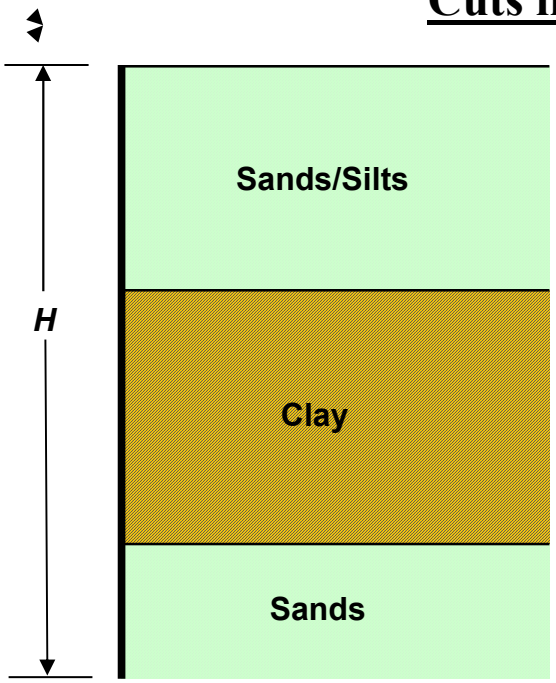
PRESSURE ENVELOPE FOR BRACED-CUT DESIGN

Cuts in Layered Soils



When layers of both sands and clays are encountered and a braced cut is being constructed, it is proposed that an equivalent value of cohesion ($\phi = 0$ concept) should be determined in accordance with the following manner.

$$c_{av} = \frac{1}{2H}[\gamma_s K_s H_s \tan \phi_s + (H - H_s) n' q_u]$$

where: H = total height of the cut
γ_s = unit weight of sand
H_s = height of the sand layer
K_s = a lateral earth pressure coefficient for the sand layer (≈1.0)
ϕ_s = angle of friction of sand
q_u = unconfined compression strength of clay
n' = a coefficient of progressive failure (ranging from 0.5 to 1.0; average value of 0.75)

The average unit weight, γ_a, of the layers may be obtained using the following equation:

$$\gamma_a = \frac{1}{H}[\gamma_s H_s + (H - H_s) \gamma_c]$$

where: γ_c = saturated unit weight of clay layer

Once the average values of cohesion and unit weight are determined, the pressure envelopes in clay can be used to design the cuts.

When several clay layers are encountered in the cut, the average undrained cohesion becomes

$$c_{av} = \frac{1}{H}(c_1 H_1 + c_2 H_2 + \ldots + c_n H_n)$$

The average unit weight, γ_a, is

$$\gamma_a = \frac{1}{H}(\gamma_1 H_1 + \gamma_2 H_2 + \ldots + g_n H_n)$$

Reference: Pages 524 and 525, Principles of Foundation Engineering, 4th Edition, Braja Das

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Pressure Envelope for Braced-Cut Design (Cuts in Layered Soils)	
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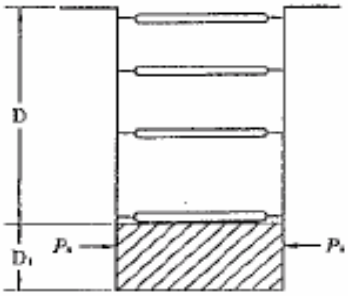
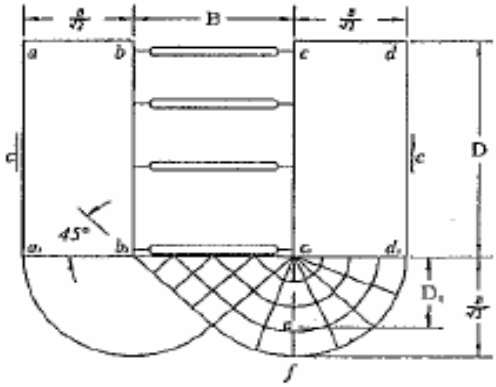




Factor of Safety against bottom of heave,

$$F.S = \frac{NcC}{(\gamma D+q)}$$

where, Nc = Coefficient depending on the dimension of the excavation (see Figure at the bottom)
C = Undrained shear strength of soil in zone immediately around the bottom of the excavation,
γ = Unit weight of soil,
D = Depth of excavation,
q = Surface surcharge.

If F.S < 1.5, sheeting should be extended further down to achieve stability

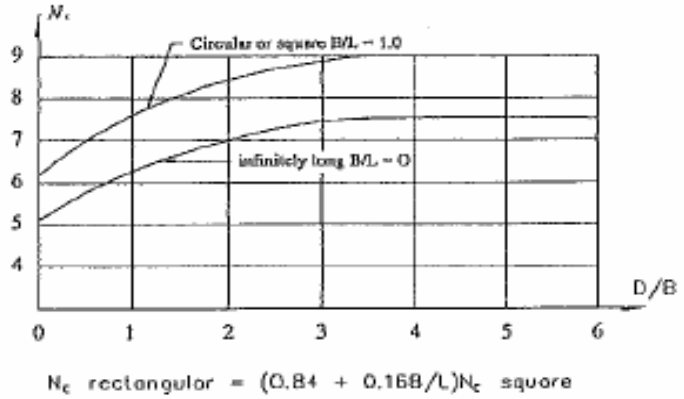
$$\text{Depth of Buried Length, } (D_1) = \frac{1.5(\gamma D+q)-NcC}{(C/B)-0.5\gamma} \; ; D_1 \geq 5 \text{ ft.}$$

Pressure on buried length, P_a

For $D_1 < 0.47B$; $P_a = 1.5\, D_1(\gamma D - 1.4\, CD/B - 3.14C)$

For $D_1 > 0.47B$; $P_a = 0.7\, (\gamma DB - 1.4\, CD - 3.14CB)$

where; B = width of excavation



N_c rectangular = $(0.84 + 0.16B/L)N_c$ square

Bottom Stability of Braced Excavations in Clays	
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