ENGINEERING CORP.

GEOTECHNICAL INVESTIGATION

SURFACE WATER TRANSMISSION PROGRAM CONTRACT 70B
60-INCH WATERLINE ALONG MONROE AND ROCKHILL
FROM AIRPORT TO GLEN VALLEY
WBS NO. S-000900-0129-4
HOUSTON, TEXAS

Reported to:
Kuo & Associates, Inc.
Houston, Texas

by

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REPORT NO. G149-14

September 2015

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Reference: **Geotechnical Investigation**
Surface Water Transmission Program Contract 70B
60 Inch Waterline along Monroe and Rockhill
from Airport to Glen Valley
Houston, Texas
WBS No.: S-000900-0129-4
AEC Report No. G149-14

Dear Mr. Chowdhury,

Aviles Engineering Corporation (AEC) is pleased to present this report of the results of our draft geotechnical investigation for the above referenced project. Notice to proceed for the geotechnical investigation was provided via email on August 20, 2014 by Mr. Shaheen Chowdhury, P.E., of Kuo & Associates, Inc., based on AECs proposal G2011-09-18R9, dated August 7, 2014. Additional borings were authorized via email on April 16, 2015, based on AEC proposal G2011-09-18S2, dated November 14, 2014, and AEC proposal G2015-01-12, dated January 16, 2015.

AEC appreciates the opportunity to be of service to you. Please call us if you have any questions or comments concerning this report or when we can be of further assistance.

Respectfully submitted,
Aviles Engineering Corporation
(TBPE Firm Registration No. F-42)

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EXECUTIVE SUMMARY

The report submitted herein presents the results of Aviles Engineering Corporation's (AEC) geotechnical investigation for the City of Houston's (COH) Surface Water Transmission Program (SWTP) Contract 70B Waterline along Monroe Road and Rockhill Street in Houston, Texas (Houston/Harris County Key Map Nos.: 535X, Y, and 575C).

The project alignment is located along Monroe Road and Rockhill Street, starting at the intersection of Monroe Road and Airport Boulevard and ending at the intersection of Rockhill Street and Glen Valley Drive. Based on 90 percent complete drawings (dated June 2015) provided by Kuo & Associates, Inc. (KAI), the proposed improvements include: (i) installation of a 60-inch diameter SWTP water line along Monroe Road and Rockhill Street; (ii) installation of a 16 inch diameter waterline along Monroe Road and a 12 inch diameter waterline along Rockhill Street from Monroe Road to Ruthby Street; (iii) installation of 24 to 42 inch diameter RCP storm sewers along portions of Monroe Road and Rockhill Street, including manholes and inlets; and (iv) the addition of new left turn lanes along southbound Monroe Road, at the intersections of Wynlea Street, Monroe PR 1 Drive, and Byran Street. The proposed 16 inch (and smaller) diameter waterlines will be installed by trenchless methods, and the 60 inch diameter waterline and storm sewer will be installed by open cut method; however, there will be three tunnel crossings for the 60 inch diameter SWTP waterline: (i) a 190 foot long tunnel along Monroe Road at the intersection with Airport Boulevard; (ii) a 45 foot long tunnel along Rockhill Street to the east of Hinman Street crossing under a 6 inch diameter Kinder Morgan Pipeline; and (iii) a 210 foot long tunnel along Rockhill Street crossing under COH Drainage Easement Unit C165-00-00.

1. Subsurface Soil Conditions: Based on the borings, subsurface soil conditions along Monroe Road and Rockhill Street generally consist of approximately 8 to 18 feet of firm to hard lean/fat clay (CL/CH) fill at the ground surface, underlain by interlayered soft to hard lean/fat clay (CL/CH), loose to medium dense silt (ML), and loose to medium dense silty sand (SM) to the boring termination depths.

2. Subsurface Soil Properties: The subsurface clayey soils encountered in the borings have none to very high plasticity, with liquid limits (LL) ranging from 24 to 84, and plasticity indices (PI) ranging from 5 to 60. The cohesive soils encountered are classified as "CL-ML", "CL", and "CH" type soils and granular soils were classified as "ML", "SM", and "SC" type soils in accordance with ASTM D 2487.

3. Groundwater Conditions: Groundwater was encountered at a depth of 10 to 23 feet below grade during drilling and was subsequently observed at a depth of 7.6 to 17.1 feet after the initial encounter in Borings B-1, B-2, B-4 through B-12, B-14 through B-16, and B-18. Groundwater at the site may be pressurized. Groundwater was not encountered in Borings B-3, B-13, and B-17. A detailed description of ground water readings is presented on Table 5 in Section 4.1 of this report.

4. Hazardous Materials: No signs of visual staining or odors were encountered during field drilling or during processing of the soil samples in the laboratory.

5. Geologic Hazards: AEC performed a desktop fault study of the project alignment. Available literature indicates that several faults cross the Monroe Road alignment. Potential fault locations are presented in Section 4.3 of this report. AEC understands that a Phase I fault study will be performed by others.

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EXECUTIVE SUMMARY (cont.)

6. Design parameters and recommendations for installation of 60 inch diameter waterlines and storm sewers by open cut method are presented in Section 5.2 of this report.

7. Design parameters and recommendations for installation of 16 inch (and smaller) diameter waterlines by trenchless method are presented in Section 5.3 of this report.

8. Design parameters and recommendations for installation of 60 inch diameter waterline by tunnel method are presented in Section 5.4 of this report

9. Design parameters and recommendations for reconstruction of concrete pavement are presented in Section 5.5 of this report.

10. Evaluation of the impact of new left turn lanes on the slope stability of Berry Creek and COH drainage channel are presented in Section 5.6 of this report.

This Executive Summary is intended as a summary of the investigation and should not be used without the full text of this report.

GEOTECHNICAL INVESTIGATION

SURFACE WATER TRANSMISSION PROGRAM CONTRACT 70B
60-INCH WATERLINE ALONG MONROE AND ROCKHILL
FROM AIRPORT TO GLEN VALLEY
WBS NO. S-000900-0129-4
HOUSTON, TEXAS

1.0 INTRODUCTION

1.1 General

The report submitted herein presents the results of Aviles Engineering Corporation's (AEC) geotechnical investigation for the City of Houston's (COH) Surface Water Transmission Program (SWTP) Contract 70B Waterline along Monroe Road and Rockhill Street in Houston, Texas (Houston/Harris County Key Map Nos.: 535X, Y, and 575C). A vicinity map is presented on Plate A-1, in Appendix A.

The project alignment is located along Monroe Road and Rockhill Street, starting at the intersection of Monroe Road and Airport Boulevard and ending at the intersection of Rockhill Street and Glen Valley Drive. Based on 90 percent complete drawings (dated June 2015) provided by Kuo & Associates, Inc. (KAI), the proposed improvements include: (i) installation of a 60-inch diameter SWTP water line along Monroe Road and Rockhill Street; (ii) installation of a 16 inch diameter waterline along Monroe Road and a 12 inch diameter waterline along Rockhill Street from Monroe Road to Ruthby Street; (iii) installation of 24 to 42 inch diameter RCP storm sewers along portions of Monroe Road and Rockhill Street, including manholes and inlets; and (iv) the addition of new left turn lanes along southbound Monroe Road, at the intersections of Wynlea Street, Monroe PR 1 Drive, and Byran Street.

The proposed 16 inch (and smaller) diameter waterlines will be installed by trenchless methods, and the 60 inch diameter waterline and storm sewer will be installed by open cut method; however, there will be three tunnel crossings for the 60 inch diameter SWTP waterline: (i) a 190 foot long tunnel along Monroe Road at the intersection with Airport Boulevard; (ii) a 45 foot long tunnel along Rockhill Street to the east of Hinman Street crossing under a 6 inch diameter Kinder Morgan Pipeline; and (iii) a 210 foot long tunnel along Rockhill Street crossing under COH Drainage Easement Unit C165-00-00.

1.2 Purpose and Scope

The purpose of this geotechnical investigation is to evaluate the subsurface soil conditions along the alignment and develop geotechnical engineering recommendations for the design and construction of underground utilities by open cut, trenchless, and tunnel methods. The scope of this geotechnical investigation is summarized below:

1. Drilling and sampling twenty-two geotechnical borings ranging from 15 to 40 feet below existing grade;
2. Soil laboratory testing on selected soil samples;
3. Engineering analyses and recommendations for the installation of large diameter waterlines and storm sewers by open cut method, including loadings on pipes, bedding, lateral earth pressure parameters, trench stability, and backfill requirements;
4. Engineering analyses and recommendations for the installation of waterlines by trenchless method, including loadings on pipes, auger face stability, as well as bedding, lateral earth pressure parameters, trench stability, and backfill requirements for auger pits;
5. Engineering analyses and recommendations for the installation of waterlines by tunnel method, including tunnel access shafts, reaction walls, and tunnel stability;
6. Engineering analyses and recommendations to determine the impact of new left turn lanes on the slope stability of the existing channel within the median of Monroe Road;
7. Construction recommendations for installation of waterlines and storm sewers by open cut, trenchless, and tunnel methods.

2.0 SUBSURFACE EXPLORATION

2.1 Soil Borings

As requested by KAI, the boring layout (boring spacing of 1,000 feet) and depths for the 60 inch diameter SWTP waterline were performed in general accordance with Chapter 7 of the May 2001 COH SWTP Design Manual; however, the boring layout (boring spacing of 500 feet) and depths for the 12 and 16 inch diameter waterline and storm sewers were performed in general accordance the COH Infrastructure Design Manual. As requested by the SWTP Program Manager, Lockwood, Andrews, and Newnam, Inc. (LAN), the minimum boring depth for the 60 inch diameter SWTP waterline is 25 feet below grade. The original subsurface exploration consisted of drilling and sampling a total of eighteen borings ranging from 15 to 40 feet below existing grade. After Borings B-1 through B-18 were completed in September 2014, four additional borings (Borings B-5A, B-7A, B-15A, and B-16A) were drilled in April 2015 due to an

expansion of the project scope (moving the waterline tunnel crossing beneath COH Drainage Unit C165-00-00 from the north side of Rockhill Street to the south side, and adding turning lanes along Monroe Road). The boring locations are shown on the Boring Location Plan on Plate A-2, in Appendix A. Total drilling footage is 600 feet. Boring locations were surveyed after completion of drilling. Boring survey data is presented in the boring logs. The boring designations and depths and corresponding utility invert depths are presented in Table 1 below.

Table 1. Boring Number, Station, and Depth

Boring/PZ No.	Boring/PZ Depth (ft)	Station (Baseline)	Boring Surface Elevation (ft)	Invert Elevation at Boring (ft)	Maximum Invert Depth in Boring (ft)
B-1	30	2+53.52 (Monroe)	32.06	13.0 (60 in WL tunnel)	19.1
B-2/PZ-1	30/25	3+83.36 (Monroe)	32.96	20.6 (16 in WL) 13.0 (60 in WL tunnel)	20.0
B-3	15[(a)]	8+40.55 (Monroe)	33.00	26.0 (16 in WL) 19.0 (60 in WL)	14.0
B-4	25	13+00.27 (Monroe)	31.67	24.4 (16 in WL) 18.5 (60 in WL)	13.2
B-5	25	18+41.99 (Monroe)	31.24	24.0 (16 in WL) 17.0 (60 in WL)	14.3
B-5A	25	18+84.64 (Monroe)	31.83	24.0 (16 in WL) 17.0 (60 in WL)	14.8
B-6	25	23+44.72 (Monroe)	31.49	24.8 (16 in WL) 18.5 (60 in WL)	13.0
B-7	15[(a)]	28+46.82 (Monroe)	31.98	24.8 (16 in WL) 18.0 (60 in WL)	14.0
B-7A	25	31+11.82 (Monroe)	32.13	24.7 (16 in WL) 17.0 (60 in WL)	15.1
B-8	25	33+52.67 (Monroe)	31.79	22.7 (16 in WL) 18.0 (60 in WL)	13.8
B-9	25	38+25.13 (Monroe)	32.22	25.9 (16 in WL) 16.5 (60 in WL)	15.7
B-10	25	35+78.95 (Rockhill)	32.10	27.3 (24 in Storm) 26.2 (12 in WL) 19.0 (60 in WL)	13.1
B-11/PZ-2	35/30	30+69.11 (Rockhill)	33.50	27.2 (12 in WL) 20.0 (60 in WL)	13.5
B-12	35	27+74.54 (Rockhill)	33.88	28.4 (24 in Storm) 25.1 (12 in WL) 13.0 (60 in WL tunnel)	20.9
B-13	15[(a)]	24+11.49 (Rockhill)	32.77	27.3 (24 in Storm) 27.2 (12 in WL) 20.0 (60 in WL)	12.8

Boring/PZ No.	Boring/PZ Depth (ft)	Station (Baseline)	Boring Surface Elevation (ft)	Invert Elevation at Boring (ft)	Maximum Invert Depth in Boring (ft)
B-14	25	20+60.38 (Rockhill)	33.89	28.2 (12 in WL) 26.3 (24 in Storm) 20.0 (60 in WL)	13.9
B-15	40	16+03.23 (Rockhill)	33.78	7.0 (60 in WL tunnel)	26.8
B-15A	40	15+89.34 (Rockhill)	36.31	7.0 (60 in WL tunnel)	29.3
B-16/PZ-3	40/30	13+20.90 (Rockhill)	34.62	24.2 (42 in Storm) 7.0 (60 in WL tunnel)	27.6
B-16A	40	13+41.38 (Rockhill)	36.29	24.1 (42 in Storm) 7.0 (60 in WL tunnel)	29.3
B-17	15[(a)]	9+50.56 (Rockhill)	34.41	24.2 (42 in Storm) 21.0 (60 in WL)	13.4
B-18	25	4+87.23 (Rockhill)	33.19	25.1 (36 in Storm) 21.0 (60 in WL)	12.2

Note: (a) as directed by KAI, 15 foot borings are to cover small diameter waterline alignment only.

Existing pavement at Borings B-5 through B-18 was first cut with a core barrel prior to field drilling. Borings B-1 through B-4 were located either on the grass shoulder or grass median of Monroe Road. The field drilling was performed with a truck-mounted drilling rig primarily using dry auger method, and then using wet rotary method once water-bearing granular soils were encountered or the borings began to cave in. Undisturbed samples of cohesive soils were obtained from the borings by pushing 3-inch diameter thin-wall, seamless steel Shelby tube samplers in general accordance with ASTM D 1587. Granular soils were sampled with a 2-inch split-barrel sampler in accordance with ASTM D 1586. Standard Penetration Test resistance (N) values were recorded for the granular soils as "Blows per Foot" and are shown on the boring logs. Strength of the cohesive soils was estimated in the field using a hand penetrometer. The undisturbed samples of cohesive soils were extruded mechanically from the core barrels in the field and wrapped in aluminum foil; all samples were sealed in plastic bags to reduce moisture loss and disturbance. The samples were then placed in core boxes and transported to the AEC laboratory for testing and further study. Borings B-2, B-11, and B-16 were converted to piezometers upon completion of drilling. The remaining borings were grouted with cement-bentonite. Existing pavement was patched with non-shrink grout.

3.0 LABORATORY TESTING PROGRAM

Soil laboratory testing was performed by AEC personnel. Samples from the borings were examined and classified in the laboratory by a technician under the supervision of a geotechnical engineer. Laboratory

tests were performed on selected soil samples in order to evaluate the engineering properties of the foundation soils in accordance with applicable ASTM Standards. Atterberg limits, moisture contents, percent passing a No. 200 sieve, and dry unit weight tests were performed on typical samples to establish the index properties and confirm field classification of the subsurface soils. Strength properties of cohesive soils were determined by means of torvane (TV), unconfined compression (UC), and undrained-unconsolidated (UU) triaxial tests performed on undisturbed samples. The test results are presented on the boring logs.

Details of the soils encountered in the borings are presented on the representative boring logs. Boring logs B-1 through B-18 are presented in COH format on Plates A-3 through A-24, in Appendix A. For slope stability analysis, Borings B-5 through B-8 were also prepared in Harris County Flood Control District (HCFCD) format, as presented on Plates H-1 through H-6, in Appendix H. A key to the boring logs, classification of soils for engineering purposes, terms used on boring logs, and reference ASTM Standards for laboratory testing are presented on Plates A-25 through A-28, in Appendix A. Sieve analysis results are presented on Plate A-29, in Appendix A. A summary of the laboratory test results is presented on Plates A-37 through A-44, in Appendix A.

Pinhole Tests: To evaluate the dispersibility of clayey soils along Berry Creek, two pinhole tests were performed on selected soil samples in accordance with ASTM D 4647, Method A. According to the pinhole tests, cohesive soils at the channel can be classified as nondispersive (ND1). The results of the pinhole test are presented on Plates A-30 to A-31, in Appendix A.

Crumb Tests: To evaluate the colloidal erodibility of clayey soils along Berry Creek, four crumb tests were performed on selected soil samples in accordance with ASTM D 6572, Method A. According to the crumb tests, cohesive soils at the channel can be classified as Grade 1 nondispersive (Boring B-5A, 2 to 4 feet and 10 to 12 feet; Boring B-7A, 2 to 4 feet) to Grade 4 highly dispersive (Boring B-7A, 8 to 10 feet). The results of the crumb tests are presented on Plate A-32, in Appendix A.

Consolidated-Undrained Triaxial Tests: Two consolidated-undrained (CU) triaxial shear tests were performed in accordance with ASTM D 4767 to determine shear strength parameters for slope stability analyses along Berry Creek. The CU triaxial tests Mohr Circles are included on Plates A-33 through A-36,

in Appendix A; CU test results are presented in Appendix J-1 and J-2 of this report. The shear strength parameters obtained from the CU triaxial tests are summarized below in Table 2.

Table 2. Summary of Shear Strength Parameters from CU Triaxial Tests

Sample ID and Description	C_u (psf)	Effective Stress		Total Stress	
		c′ (psf)	φ′ (deg)	c_{cu} (psf)	φ_{cu} (deg)
B-5A, 14'-16', Lean Clay (CL)	1,200	190	31.3	80	23.1
B-7A, 6'-8', Fat Clay (CH)	1,800	510	15.9	470	12.8

Notes: (1) C_u = cohesion, obtained from UC and UU tests;
(2) c' = effective cohesion, φ' =effective friction angle, obtained from CU tests with pore pressure measurements;
(3) c_{cu} = cohesion in total stress, φ_{cu} = friction angle in total stress, obtained from CU tests.

4.0 SITE CONDITIONS

Based on AEC's site visit, Monroe Road in between Airport Boulevard and Rockhill Street is currently a four lane (2 lanes in each direction) concrete roadway, with a drainage channel in the median. The southbound lanes of Monroe Road appear to be in poor to average condition; several sections of the roadway have been reconstructed with new concrete panels (possibly due to faulting, see Section 4.3 of this report); older pavement has longitudinal and transverse cracks as well. Rockhill Street is a two lane (1 lane in each direction) concrete roadway. The pavement on Rockhill Street appears to be in average condition, with longitudinal and transverse pavement cracks.

A summary of pavement types encountered in our borings is presented on Table 3.

Table 3. Existing Pavement Encountered at Pavement Borings

Boring No.	Pavement Section
B-5	5.75" concrete
B-6	6" concrete
B-7	6.4" concrete, 2" silty sand
B-8	7" concrete, 6" silty sand
B-9	6.25" concrete
B-10	6" concrete
B-11	6.125" concrete
B-12	5.375" concrete, 1" crushed shell

Boring No.	Pavement Section
B-13	5.75” concrete, 0.25” shell and sand
B-14	5.75” concrete
B-15	5.5” concrete, 0.25 sand, gravel, and shell
B-16	5.75” concrete, 0.25 sand, gravel, and shell
B-17	5.875” concrete, 0.25” sand and shell
B-18	5.5” concrete, 0.5” crushed shell

4.1 Subsurface Conditions

Details of the soils encountered during drilling are presented in the boring logs. Soil strata encountered in our borings are summarized below. A generalized subsurface profile along the Monroe Road and Rockhill alignments is presented on Plates B-1a and B-1b and B-2a and B-2b, respectively, in Appendix B.

Boring	Depth (ft)	Description of Stratum
B-1	0 - 18	Soft to very stiff, Fat Clay (CH), with slickensides
	18 - 22	Firm to stiff, Silty Clay (CL-ML)
	22 - 24	Stiff to very stiff, Fat Clay (CH), with slickensides and silty clay pockets
	24 - 28	Sandy Silt (ML)
	28 - 30	Hard, Fat Clay (CH)
B-2	0 - 12	Stiff to hard, Fat Clay (CH), with slickensides
	12 - 14	Silt (ML), with clay pockets
	14 - 18	Stiff to very stiff, Lean Clay (CL), with silt seams
	18 - 22	Medium dense, Silt (ML), with clay pockets
	22 - 30	Stiff to very stiff, Lean Clay (CL), with slickensides and fat clay partings
B-3	0 - 10	Very stiff to hard, Fat Clay (CH), with slickensides
	10 - 15	Soft to very stiff, Lean Clay (CL)
B-4	0 - 2	Fill: hard, Fat Clay (CH)
	2 - 10	Very stiff to hard, Fat Clay (CH), with slickensides
	10 - 16	Soft to stiff, Lean Clay (CL)
	16 - 18	Stiff to very stiff, Fat Clay (CH), with silt pockets
	18 - 25	Dense to very dense, Sandy Silt (ML)
B-5	0 - 0.5	Pavement: 5.75” concrete
	0.5 - 12	Stiff to very stiff, Fat Clay (CH), with slickensides and sand partings
	12 - 18	Firm to hard, Lean Clay w/Sand (CL), with silt partings
	18 - 23	Medium dense, Sandy Silt (ML)
	23 - 25	Very stiff, Fat Clay (CH), with slickensides and sand pockets

Boring	Depth (ft)	Description of Stratum
B-5A	0 - 2	Fill: very stiff, Fat Clay (CH), with roots
	2 - 14	Stiff to hard, Fat Clay (CH), with slickensides
	14 - 16	Stiff, Lean Clay (CL), with abundant silt seams and partings
	16 - 22	Very stiff to hard, Fat Clay (CH), with slickensides and siltstone fragments
	22 - 25	Stiff, Lean Clay (CL), with silt seams
B-6	0 - 0.5	Pavement: 6” concrete
	0.5 - 8	Stiff to very stiff, Fat Clay (CH), with slickensides
	8 - 12	Firm to very stiff, Silty Clay (CL-ML)
	12 - 16	Stiff to very stiff, Lean Clay (CL), with slickensides
	16 - 25	Medium dense, Silt (ML)
B-7	0 - 0.5	Pavement: 6.4” concrete
	0.5 - 0.7	Base: 2” silty sand, with clay pockets
	0.7 - 8	Stiff to very stiff, Fat Clay (CH), with slickensides
	8 - 15	Firm to stiff, Lean Clay (CL), with silt pockets
B-7A	0 - 6	Stiff to hard, Fat Clay (CH)
	6 - 10	Stiff to very stiff, Fat Clay w/Sand (CH)
	10 - 14	Firm to stiff, Silty Clay w/Sand (CL-ML), with siltstone fragments
	14 - 25	Loose to medium dense, Silt (ML), with abundant clay and sand seams
B-8	0 - 0.6	Pavement: 7” concrete
	0.6 - 1	Base: 6” Silty Sand (SM), with clay pockets
	1 - 6	Stiff to very stiff, Fat Clay (CH)
	6 - 10	Firm to very stiff, Sandy Fat Clay (CH), with abundant sand and silt pockets
	10 - 18	Loose to medium dense, Silty Sand (SM)
	18 - 25	Very stiff to hard, Sandy Lean Clay (CL)
B-9	0 - 0.5	Pavement: 6.25” concrete
	0.5 - 6	Stiff to very stiff, Fat Clay (CH), with slickensides
	6 - 8	Very stiff, Lean Clay (CL)
	8 - 14	Firm, Silty Clay (CL-ML)
	14 - 16	Firm to stiff, Lean Clay (CL), with silt pockets
	16 - 22	Loose to medium dense, Silt w/Sand (ML)
	22 - 25	Hard, Fat Clay (CH), with slickensides
B-10	0- 0.5	Pavement: 6” concrete
	0.5 - 12	Stiff to hard, Fat Clay (CH), with slickensides
	12 - 16	Loose, Silt w/Sand (ML)
	16 - 22	Medium dense, Silt (ML)
	22 - 25	Medium dense, Sandy Silt (ML), with gravel
B-11	0 - 0.5	Pavement: 6.125” concrete
	0.5 - 12	Stiff to very stiff, Fat Clay (CH)
	12 - 14	Soft to firm, Lean Clay (CL), with abundant silt seams

Boring	Depth (ft)	Description of Stratum
B-11 (cont.)	14 - 20	Very stiff to hard, Fat Clay (CH), with slickensides
	20 - 24	Soft to stiff, Lean Clay (CL), with fat clay pockets
	24 - 26	Clayey Sand (SC), with fat clay seams
	26 - 32	Very stiff to hard, Fat Clay (CH), with slickensides
	32 - 35	Silt w/Sand (ML)
B-12	0 - 0.4	Pavement: 5.375” concrete
	0.4 - 0.5	Base: 1” crushed shell
	0.5 - 8	Stiff to very stiff, Fat Clay (CH), with slickensides
	8 - 14	Firm to very stiff, Lean Clay (CL)
	14 - 22	Stiff to hard, Fat Clay (CH), with slickensides
	22 - 24	Sandy Silt (ML)
	24 - 35	Very stiff to hard, Fat Clay (CH), with slickensides
B-13	0 - 0.5	Pavement: 5.75” concrete
	0.5 - 0.5	Base: 0.25” shell and sand
	0.5 - 6	Firm to stiff, Fat Clay (CH), with slickensides
	6 - 15	Firm to very stiff, Lean Clay (CL), with silty clay seams and pockets
B-14	0 - 0.5	Pavement: 5.75” concrete
	0.5 - 10	Stiff to very stiff, Fat Clay (CH), with slickensides
	10 - 22	Firm to very stiff, Lean Clay (CL)
	22 - 25	Very stiff, Fat Clay (CH), with slickensides and silt seams
B-15	0 - 0.5	Pavement: 5.5” concrete
	0.5 - 0.5	Base: 0.25” sand, gravel, and crushed shell
	0.5 - 8	Stiff to very stiff, Fat Clay (CH), with slickensides
	8 - 16	Stiff to very stiff, Lean Clay (CL), with silt pockets
	16 - 20	Stiff to very stiff, Fat Clay (CH), with slickensides
	20 - 24	Firm to very stiff, Lean Clay (CL)
	24 - 40	Stiff to hard, Fat Clay (CH), with slickensides
B-15A	0 - 15	<No samples>
	15 - 21	Loose to medium dense, Silt (ML), with clay partings
	21 - 23	Stiff to very stiff, Fat Clay (CH), with slickensides and siltstone fragments
	23 - 25	Very soft, Sandy Silty Clay (CL-ML)
	25 - 33	Stiff to hard, Fat Clay (CH), with slickensides
	33 - 37	Silt (ML)
	37 - 40	Medium dense, Sandy Silt (ML)
B-16	0 - 0.5	Pavement: 5.75” concrete
	0.5 - 0.5	Base: 0.25” sand, gravel, and crushed shell
	0.5 - 10	Stiff to hard, Fat Clay (CH), with slickensides
	10 - 16	Firm to very stiff, Lean Clay (CL)
	16 - 22	Stiff to very stiff, Fat Clay (CH), with slickensides
	22 - 26	Medium dense, Silt w/Sand (ML), with clay partings
	26 - 40	Stiff to hard, Fat Clay (CH), with slickensides

Boring	Depth (ft)	Description of Stratum
B-16A	0 - 15	<No samples>
	15 - 17	Firm, Lean Clay (CL), with abundant silt seams
	17 - 23	Firm to hard, Fat Clay (CH), with slickensides
	23 - 26	Medium dense, Silt (ML), with clay partings
	26 - 38	Stiff to hard, Fat Clay (CH), with slickensides
	38 - 40	Medium dense, Sandy Silt (ML)
B-17	0 - 0.5	Pavement: 5.875” concrete
	0.5 - 0.5	Base: 0.25” sand and shell
	0.5 - 10	Stiff to very stiff, Fat Clay (CH), with slickensides
	10 - 15	Firm to very stiff, Lean Clay (CL)
B-18	0 - 0.4	Pavement: 5.5” concrete
	0.4 - 0.5	Base: 0.5” crushed shell
	0.5 - 8	Stiff to very stiff, Fat Clay (CH), with slickensides
	8 - 18	Firm to hard, Lean Clay (CL)
	18 - 25	Stiff to hard, Fat Clay (CH), with slickensides

A summary of granular and soft/weak soils encountered in the borings is presented in Table 4.

Table 4. Granular/Cohesionless and Weak/Soft Soils Encountered in Borings

Boring	Depth to Granular and Weak/Soft Soil (ft)	Soil Type
B-1	12 to 14 24 to 28	Soft, Fat Clay (CH), with silt Sandy Silt (ML)
B-2	12 to 14 18 to 22	Silt (ML) Medium dense, Silt (ML)
B-3	14 to 15	Soft, Lean Clay (CL)
B-4	10 to 14 18 to 25	Soft to firm, Lean Clay (CL), with silt Dense to very dense, Sandy Silt (ML)
B-5	18 to 23	Medium dense, Sandy Silt (ML)
B-6	16 to 25	Medium dense, Silt (ML)
B-7A	14 to 25	Loose to medium dense, Silt (ML)
B-8	10 to 18	Loose to medium dense, Silty Sand (SM)
B-9	10 to 14 16 to 22	Firm, Silty Clay (CL-ML) Loose to medium dense, Silt w/Sand (ML)
B-10	12 to 25	Loose to medium dense, Sandy Silt (ML)
B-11	12 to 14 22 to 24 32 to 35	Soft to firm, Lean Clay (CL), with silt Soft to firm, Lean Clay (CL) Silt w/Sand (ML)

Boring	Depth to Granular and Weak/Soft Soil (ft)	Soil Type
B-12	22 to 24	Sandy Silt (ML)
B-15A	15 to 21 23 to 25 33 to 40	Loose to medium dense, Silt (ML) Very soft, Sandy Silty Clay (CL-ML) Medium dense, Sandy Silt (ML)
B-16	22 to 26	Medium dense, Silt w/Sand (ML)
B-16A	23 to 26 38 to 40	Medium dense, Silt (ML) Medium dense, Sandy Silt (ML)

Subsurface Soil Properties: The subsurface clayey soils encountered in the borings have slight to very high plasticity, with liquid limits (LL) ranging from 24 to 84, and plasticity indices (PI) ranging from 5 to 60. The cohesive soils encountered are classified as "CL-ML", "CL", and "CH" type soils and granular soils were classified as "ML", "SM", and "SC" type soils in accordance with ASTM D 2487. High plasticity clays can undergo significant volume changes due to seasonal changes in moisture contents. "CH" soils undergo significant volume changes due to seasonal changes in soil moisture contents. "CL" type soils with lower LL (less than 40) and PI (less than 20) generally do not undergo significant volume changes with changes in moisture content. However, "CL" soils with LL approaching 50 and PI greater than 20 essentially behave as "CH" soils and could undergo significant volume changes. Slickensides were encountered in the lean and fat clays.

Groundwater Conditions: Groundwater was encountered at a depth of 10 to 23 feet below grade during drilling and was subsequently observed at a depth of 6.8 to 17.1 feet after the initial encounter in Borings B-1, B-2, B-4 through B-12, B-14 through B-16A, and B-18. Groundwater at the site may be pressurized. Groundwater was not encountered in Borings B-3, B-13, and B-17. After completion of drilling, Borings B-2, B-11, and B-16 were converted to piezometers. Piezometer installation details are presented on Plates B-3 through B-5, in Appendix B. Detailed groundwater levels are summarized in Table 5. Piezometers were plugged and abandoned after a second water reading was obtained. Piezometer installation and plugging reports are presented on Plates G-1 to G-3 in Appendix G of this report.

Table 5. Groundwater Depths below Existing Ground Surface

Boring/PZ No.	Date Drilled	Boring/PZ Depth (ft)	Groundwater Depth (ft)	Cave in Depth (ft)	Groundwater Depth in Piezometer (ft)
B-1	9/16/14	30	18 (Drilling) 9.9 (15 min.)	-	-

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Boring/PZ No.	Date Drilled	Boring/PZ Depth (ft)	Groundwater Depth (ft)	Cave in Depth (ft)	Groundwater Depth in Piezometer (ft)
B-2/PZ-1	9/11/14	30/25	18 (Drilling) 11.8 (15 min.)	14.5 (Drilling)	9.4 (9/16/14) 7.5 (3/20/15)
B-3	9/11/14	15	Dry (Drilling)	-	-
B-4	9/11/14	25	18 (Drilling) 12.1 (15 min.)	16 (Drilling)	-
B-5	9/11/14	25	16 (Drilling) 14.8 (15 min.)	-	-
B-5A	4/27/15	25	18 (Drilling) 10.6 (15 min.) 8 (24 hrs.)	-	-
B-6	9/11/14	25	15 (Drilling) 14.1 (15 min.)	-	-
B-7	9/11/14	15	13 (Drilling)	13 (Drilling)	
B-7A	4/27/15	25	13 (Drilling) 6.8 (15 min.) 6.1 (24 hrs.)	10.8 (Drilling) 13.8 (24 hrs.)	-
B-8	9/11/14	25	12 (Drilling) 12.4 (15 min.)	-	-
B-9	9/10/14	25	10 (Drilling) 9.8 (15 min.)	-	-
B-10	9/11/14	25	14 (Drilling) 7.6 (15 min.)	14 (Drilling)	-
B-11/PZ-2	9/12/14	35/30	23 (Drilling) 16.7 (15 min.)	21.7 (Drilling)	15.3 (9/16/14) 9.2 (3/20/15)
B-12	9/12/14	35	22 (Drilling) 17.1 (15 min.)	21.7 (Drilling)	-
B-13	9/11/14	15	Dry (Drilling)	-	-
B-14	9/11/14	25	19 (Drilling) 16.4 (15 min.)	-	-
B-15	9/12/14	40	18 (Drilling) 11 (15 min.)	16.5 (Drilling)	-
B-15A	4/27/15	40	17 (Drilling) 12.0 (15 min.) 11.7 (24 hrs.)	14.5 (24 hrs.)	-
B-16/PZ-3	9/12/14	40/30	16 (Drilling) 15 (15 min.)	-	14.4 (9/16/14) 9.3 (3/20/15)
B-16A	4/27/15	40	17 (Drilling) 13.1 (15 min.) 12.3 (24 hrs.)	24.7 (24 hrs.)	-
B-17	9/11/14	15	Dry (Drilling)	-	-
B-18	9/15/14	25	18 (Drilling) 12.8 (15 min.)	16.2 (Drilling)	-

The information in this report summarizes conditions found on the dates the borings were drilled. It should be noted that our groundwater observations are short-term; groundwater depths and subsurface soil moisture contents will vary with environmental variations such as frequency and magnitude of rainfall and the time of year when construction is in progress.

4.2 Hazardous Materials

No signs of visual staining or odors were encountered during field drilling or during processing of the soil samples in the laboratory.

4.3 Geologic Conditions

AEC performed a preliminary fault investigation, which included a review of available literature, aerial photographs, and public maps. As requested by the COH Geo-Environmental Department, limited field observations were not conducted since faults are known to exist in this area. According to the published maps "*Principal Active Faults of the Houston Area (after O'Neill and Van Siclen, May 1984)*", and "*Principal Surface Faults in the Central Houston Metropolitan Area (after O' Neill, Van Siclen, with additions by C. Norman, May 13, 2004)"*, an unnamed fault is located at the southern end of the project alignment at the intersection of Airport Boulevard and Monroe Road. According to the maps, the fault trends to the southwest from the intersection. A southwest-northeast trending fault, according to the maps, crosses Airport Boulevard approximately 0.25 miles east of Monroe Road and crosses Monroe Road approximately 0.7 of a mile south of Airport Boulevard. In addition, according to the published map *"Surface Faults in Southeastern Houston Metropolitan Area, Texas" (Verbeek & Clanton, 1978),* faults cross Monroe Road approximately 530 feet north (between Airport Boulevard and Wynlea Street) and 1550 feet north (between Wynlea and Meadville Streets) of Airport Boulevard in the project alignment. A 1944 aerial photograph shows a sharp southwest-northeast trending lineation which could be a fault intersecting Wynlea Street approximately 110 feet west of the Monroe Road project alignment. A 1953 aerial photograph shows a sharp southwest-northeast trending lineation which could be a fault intersecting Monroe Road in the project alignment approximately 1,340 feet north of Airport Boulevard. A 1957 aerial photograph included in a Geotechnical Investigation report (AEC Report G243-03, April 19, 2004) shows several lineations interpreted by consulting geologist Dr. Carl Norman, P.G., as faults which cross or come near to Monroe Road in the project alignment between Airport Boulevard and Wynlea Street. Referenced

fault maps are presented on Plates B-6 through B-8, in Appendix B. AEC understands that a Phase I fault study of the project alignment was performed by HVJ Associates.

Limitations: The preliminary fault investigation provided in this report is limited to a review of literature, aerial photographs and maps and our limited field observations, and distances are scaled from maps. Faults may exist in the project area or surrounding area due to the following reasons: not observed during the reconnaissance due to limitations of the scope of work and cost; the presence of obscuring vegetation and environmental features; modification of the land surface by human activities; and lack of documentation in the literature. Faults may also be present below ground but do not currently have surface expressions. Identification of these faults is beyond the scope of work for this project. The observations made during the fault reconnaissance represent conditions at the time of the reconnaissance.

4.4 Subsurface Variations

It should be emphasized that: (i) at any given time, groundwater depths can vary from location to location, and (ii) at any given location, groundwater depths can change with time. Groundwater depths will vary with seasonal rainfall and other climatic/environmental events. Subsurface conditions may vary away from and in between the boring locations.

Clay soils in the Houston area typically have secondary features such as slickensides, siltstone fragments, and contain sand/silt seams/lenses/layers/pockets. It should be noted that the information in the boring logs is based on 3-inch diameter soil samples. In Borings B-3, B-7, B-13, and B-17, samples were obtained continuously at intervals of 2 feet from the ground surface to a depth of 15 feet. In Borings B-4 through B-6, B-8 through B-10, B-14, and B-18, samples were obtained continuously at intervals of 2 feet from the ground surface to a depth of 20 feet, then at intervals of 5 feet thereafter to the boring termination depth of 25 feet. In Borings B-1 and B-2, the samples were obtained continuously at intervals of 2 feet from the ground surface to a depth of 25 feet, then at intervals of 5 feet thereafter to the boring termination depth of 30 feet. In Borings B-11 and B-12, the samples were obtained continuously at intervals of 2 feet from the ground surface to a depth of 30 feet, then at intervals of 5 feet thereafter to the boring termination depth of 35 feet. In Borings B-15 and B-16, the samples were obtained continuously at intervals of 2 feet from the ground surface to a depth of 35 feet, then at intervals of 5 feet thereafter to the boring termination depth of 40 feet. In Borings B-15A and B-16A, the samples were obtained continuously at intervals of 2 feet from a

depth of 15 feet to a depth of 35 feet, then at intervals of 5 feet thereafter to the boring termination depth of 40 feet. A detailed description of the soil secondary features may not have been obtained due to the small sample size and sampling interval between the samples. Therefore, while a boring log shows some soil secondary features, it should not be assumed that the features are absent where not indicated on the boring logs.

5.0 GEOTECHNICAL ENGINEERING RECOMMENDATIONS

The project alignment is located along Monroe Road and Rockhill Street, starting at the intersection of Monroe Road and Airport Boulevard and ending at the intersection of Rockhill Street and Glen Valley Drive. Based on 90 percent complete drawings (dated June 2015) provided by Kuo & Associates, Inc. (KAI), the proposed improvements include: (i) installation of a 60-inch diameter SWTP water line along Monroe Road and Rockhill Street; (ii) installation of a 16 inch diameter waterline along Monroe Road and a 12 inch diameter waterline along Rockhill Street from Monroe Road to Ruthby Street; (iii) installation of 24 to 42 inch diameter RCP storm sewers along portions of Monroe Road and Rockhill Street, including manholes and inlets; and (iv) the addition of new left turn lanes along southbound Monroe Road, at the intersections of Wynlea Street, Monroe PR 1 Drive, and Byran Street.

The proposed 16 inch (and smaller) diameter waterlines will be installed by trenchless methods, and the 60 inch diameter waterline and storm sewer will be installed by open cut method; however, there will be three tunnel crossings for the 60 inch diameter SWTP waterline: (i) a 190 foot long tunnel along Monroe Road at the intersection with Airport Boulevard; (ii) a 45 foot long tunnel along Rockhill Street to the east of Hinman Street crossing under a 6 inch diameter Kinder Morgan Pipeline; and (iii) a 210 foot long tunnel along Rockhill Street crossing under COH Drainage Easement Unit C165-00-00.

5.1 Geotechnical Parameters for Underground Utilities

Recommended geotechnical parameters for the subsurface soils along the alignment to be used for design of underground utilities are presented on Plates C-1 through C-5, in Appendix C. The design values are based on the results of field and laboratory test data on individual boring logs as well as our experience. It should be noted that because of the variable nature of soil stratigraphy, soil types and properties along the alignment or at locations away from a particular boring may vary substantially.

5.2 Installation of Underground Utilities by Open-Cut Method

Waterlines and storm sewers installed by open-cut methods should be designed and installed in accordance with Sections 02511 and 02631 of the latest edition of the City of Houston Standard Construction Specifications (COHSCS), respectively.

5.2.1 Loadings on Pipes

Underground utilities support the weight of the soil and water above the crown, as well as roadway traffic and any structures that exist above the utilities.

Earth Loads: For underground utilities to be installed using open cut methods, the vertical soil load W_e can be calculated as the larger of the two values from Equations (1) and (3):

$$W_e = C_d \gamma B_d^2 \qquad \text{.....Equation (1)}$$

$$C_d = [1 - e^{-2K\mu'(H/B_d)}]/(2K\mu') \qquad \text{.....Equation (2)}$$

$$W_e = \gamma B_c H \qquad \text{.....Equation (3)}$$

where: W_e = trench fill load, in pounds per linear foot (lb/ft);
C_d = trench load coefficient, see Plate C-6, in Appendix C;
γ = effective unit weight of soil over the conduit, in pounds per cubic foot (pcf);
B_d = trench width at top of the conduit < 1.5 B_c (ft);
B_c = outside diameter of the conduit (ft);
H = variable height of fill (ft);
when the height of fill above the top of the conduit H_c >2 B_d, $H = H_h$ (height of fill above the middle of the conduit). When H_c < 2 B_d, H varies over the height of the conduit; and

$K\mu'$ = 0.1650 maximum for sand and gravel,
0.1500 maximum for saturated top soil,
0.1300 maximum for ordinary clay,
0.1100 maximum for saturated clay.

When underground conduits are located below groundwater, the total vertical dead loads should include the weight of the projected volume of water above the conduits.

Traffic Loads: The vertical stress on top of an underground conduit, p_L (psf), resulting from traffic loads (from a HS-20 truck) can be obtained from Plate C-7, in Appendix C. The live load on top of the

underground conduit can be calculated from Equation (4):

$$W_L = p_L B_c \qquad \text{.....Equation (4)}$$

where: W_L = live load on the top of the conduit (lb/ft);
p_L = vertical stress (on the top of the conduit) resulting from traffic loads (psf);
B_c = outside diameter of the conduit, (ft);

Lateral Loads: The lateral soil pressure p_l can be calculated from Equation (5); hydrostatic pressure should be added, if applicable.

$$P_l = 0.5\,(\gamma H_h + p_s) \qquad \text{.....Equation (5)}$$

where: H_h = height of fill above the center of the conduit (ft);
γ = effective unit weight of soil over the conduit (pcf);
p_s = vertical pressure on conduit resulting from traffic and/or construction equipment (psf).

5.2.2 Trench Stability

Cohesive soils in the Houston area contain many secondary features which affect trench stability, including sand seams and slickensides. Slickensides are shiny weak failure planes which are commonly present in fat clays; such clays often fail along these weak planes when they are not laterally supported, such as in an open excavation. The Contractor should not assume that slickensides and sand seams/layers/pockets are absent where not indicated on the logs.

The Contractor should be responsible for designing, constructing and maintaining safe excavations. The excavations should not cause any distress to existing structures.

Trenches 20 feet and Deeper: The Occupational Safety and Health Administration (OSHA) requires that shoring or bracing for trenches 20 feet and deeper be specifically designed by a licensed professional engineer.

Trenches Less than 20 Feet Deep: Trench excavations that are less than 20 feet deep may be shored, sheeted and braced, or laid back to a stable slope for the safety of workers, the general public, and adjacent structures, except for excavations which are less than 5 feet deep and verified by a competent person to have no cave-in potential. The excavation and trenching should be in accordance with OSHA Safety and Health Regulations, 29 CFR, Part 1926. Recommended OSHA soil types for trench design for existing

soils can be found on Plates C-1 through C-5, in Appendix C. Fill soils are considered OSHA Class 'C'; submerged cohesive soils should also be considered OSHA Class 'C', unless they are dewatered first.

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 based on the soil cohesion. Values for various slopes and cohesion are shown on Plate D-1, in Appendix D. 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 the soil at the surface is dry to the point where tension cracks occur, any water in the crack will increase the lateral pressure considerably. In addition, 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 in accordance with OSHA requirements.

The maximum (steepest) allowable slopes for OSHA Soil Types for excavations less than 20 feet are presented on Plate D-2, in Appendix D.

If limited space is available for the required open trench side slopes, the space required for the slope can be reduced by using a combination of bracing and open cut as illustrated on Plate D-3, in Appendix D. Guidelines for bracing and calculating bracing stress are presented below.

<u>Computation of Bracing Pressures:</u> The following method can be used for calculating earth pressure against bracing for open cuts. Lateral pressure resulting from construction equipment, traffic loads, or other surcharge should be taken into account by adding the equivalent uniformly distributed surcharge to the design lateral pressure. Hydrostatic pressure, if any, should also be considered. The active earth pressure at depth z can be determined by Equation (6). The design soil parameters for trench bracing design are presented on Plates C-1 through C-5, in Appendix C.

$$p_a = (q_s + \gamma h_1 + \gamma' h_2) K_a - 2c\sqrt{K_a} + \gamma_w h_2 \qquad \text{.....Equation (6)}$$

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

Pressure distribution for the practical design of struts in open cuts for clays and sands are illustrated on Plates D-4 through D-6, in Appendix D.

Bottom Stability: In open-cuts, it is necessary to consider the possibility of the bottom failing by heaving, due to the removal of the weight of excavated soil. Heaving typically occurs in soft plastic clays when the excavation depth is sufficiently deep enough to cause the surrounding soil to displace vertically due to bearing capacity failure of the soil beneath the excavation bottom, with a corresponding upward movement of the soils in the bottom of the excavation. In fat and lean clays, heave normally does not occur unless the ratio of Critical Height to Depth of Cut approaches one. In very sandy and silty lean clays and granular soils, heave can occur if an artificially large head of water is created due to installation of impervious sheeting while bracing the cut. This can be mitigated if groundwater is lowered below the excavation by dewatering the area. Guidelines for evaluating bottom stability in clay soils are presented on Plate D-7, in Appendix D.

Based on the invert depths presented on Table 1 in Section 2.1 of this report and the depth to granular soils presented on Table 4 in Section 4.1 of this report, AEC anticipates that open cut excavations will encounter granular/soft/weak soils and groundwater within the trench or pipe bedding zone in the vicinity of Borings B-1 through B-6, B-7A, B-8 through B-12, B-15A, B-16, and B-16A.

If the excavation extends below groundwater and the soils at or near the bottom of the excavation are mainly sands or silts, the bottom can fail by blow-out (boiling) when a sufficient hydraulic head exists. The potential for boiling or in-flow of granular soils increases where the groundwater is pressurized. To reduce

the potential for boiling of excavations terminating in granular soils below pressurized groundwater, the groundwater table should be lowered at least 5 feet below the excavation in accordance with Section 01578 of the latest edition of the City of Houston Standard General Requirement (COHSGR).

Calcareous nodules, silt/sand seams, and fat clays with slickensides were encountered in some of the borings. These secondary structures may become sources of localized instability when they are exposed during excavation, especially when they become saturated. Such soils have a tendency to slough or cave in when not laterally confined, such as in trench excavations. The Contractor should be aware of the potential for cave-in of the soils. Low plasticity soils (silts and clayey silts) will lose strength and may behave like granular soils when saturated.

5.2.3 Thrust Force Design Recommendations

Thrust forces are generated in pressure pipes, typically as a result of changes in pipe diameter, pipe direction or at the termination point of the pipes. The pipes could disengage at the joints if the forces are not balanced and if the pipe restraint is not adequate. Various methods of thrust restraint are used including thrust blocks, restrained joints, encasement, and tie-rods.

Thrust restraint design procedure based on the 2008 American Water Works Association (AWWA) Manuals "Concrete Pressure Pipe (M9)" and "Steel Water Pipe (M11)" is discussed below. Plate D-8, in Appendix D shows the force diagram generated by flow in a bend in a pipe and also gives the equation for computing the thrust force. An example computation of a thrust force for a given surge pressure and a bend angle is presented on Plate D-9, in Appendix D.

Frictional Resistance: The unbalanced force due to changes in grade and alignment can be resisted by frictional force F_R, between the pipe and the surrounding soil. The resisting frictional force per linear foot of pipe against soil can be calculated from Equation (7):

$$F_R = f\,(2W_e + W_w + W_p) \qquad \text{.....Equation (7)}$$

where: f = Coefficient of friction between pipe and soil;
W_e = Weight of soil over pipe (lb/ft);
W_w = Weight of water inside the pipe (lb/ft);
W_p = Weight of pipe (lb/ft).

The value of the frictional resistance depends on the material in contact with the backfill and the soil used in the backfill. For a ductile iron pipe or steel pipe with crushed stone or compacted sand backfill, an allowable coefficient of friction of 0.3 can be used. To account for submerged conditions, a soil unit weight of 60 pcf should be used to compute the weight of compacted backfill on the pipe.

Thrust Blocks: Thrust blocks utilize passive earth pressures to resist forces generated by changes in direction or diameter of pressurized pipes. Passive earth pressure can be calculated using Equation (8); we recommend that a factor safety of 2.0 be used when using passive earth pressure for design of thrust blocks. The design soil parameters for thrust block design are presented on Plates C-1 through C-5, in Appendix C. Design parameters for bearing thrust blocks are presented on Plate D-10, in Appendix D.

$$p_p = \gamma K_p + 2c(K_p)^{1/2} \qquad \text{.....Equation (8)}$$

where, p_p = passive earth pressure (psf);
γ = wet unit weight of soil (pcf);
z = depth below ground surface for the point under consideration (ft);
K_p = coefficient of passive earth pressure;
c = cohesion of clayey soils (psf).

5.2.4 Bedding and Backfill

Trench excavation, pipe embedment material, and backfill for the proposed waterlines and storm sewers should be in general accordance with Section 02317 of the latest edition of the COHSCS.

5.2.5 Waterline Trench along Berry Creek

Based on the 90 percent complete drawings provided by KAI, a majority of the 60 inch diameter waterline alignment along Monroe Road from approximately Station 14+50 to Morley Street is located along Berry Creek, Harris Country Flood Control District (HCFCD) Unit C106-01-00, and a portion of the alignment from approximately Morley Street to Rockhill Street is located along a COH 35 foot wide drainage channel. Both Berry Creek and the COH drainage channel are located in the median of Monroe Road.

According to Section 02317, Item 3.05.C of the latest edition of the COHSCS, the minimum trench width of a 60 inch pipe is the outer diameter of the pipe plus 48 inches. Based on the provided drawings and the required minimum trench width, the east edge of the waterline trench is approximately 12 to 16 feet from the edge of the west bank of Berry Creek and the drainage channel. Based on available topographic data, Berry Creek is approximately 10.5 to 11 feet deep and the drainage channel is approximately 7.5 to 9.5 feet deep. Berry Creek is a concrete-lined U-shaped channel, while the drainage channel is grass-lined and has a slope inclination that varies from approximately H:V = 1.75:1 to H:V = 2:1.

According to the drawings, Berry Creek along Monroe Road from Station 14+50 to 23+50 is maintained by HCFCD, while the drainage channel (from Morley Street to Rockhill Street) is maintained by COH. Based on AEC's discussion with the COH Geo-Environmental Branch, slope stability analysis of the trench alongside the COH maintained drainage channel is not required as long as the channel side slopes are not disturbed.

5.2.5.1 Design Soil Parameters and Cross Section for Slope Stability Analysis

AEC performed the stability analyses in general accordance with the December 2010 HCFCD Geotechnical Guidelines. AEC performed a short-term (i.e., construction period only) slope stability analysis to determine if the waterline trench excavation will impact the slope stability of the Berry Creek channel (i.e. Monroe Road from Station 14+50 to 23+50). Slope stability of the long-term and rapid drawdown conditions is not required.

Based on our borings and KAI's waterline plan and profile drawings, AEC selected a most-critical cross sections at Stations 19+00 (based on Boring B-5) to perform slope stability analyses. The slope stability analysis are based on a waterline trench that is approximately 15 feet deep, approximately 16 feet from the edge of a 10.5 to 11 feet deep concrete lined U-shaped channel.

Based on Boring B-5, the subsurface conditions at Station 19+00 along the southbound lanes of Monroe Road generally consist of stiff to very stiff fat clay (CH) from the ground surface to a depth of 12 feet below grade, underlain by approximately 6 feet of firm to hard lean clay (CL), followed by approximately 5 feet of medium dense sandy silt (ML), then approximately 2 feet of very stiff fat clay (CH) to the boring termination depths of 25 feet below grade. Soil parameters used in the slope stability analyses include wet

unit weights and unconsolidated-undrained (UU) shear strengths. The design soil parameters used by AEC for slope stability analysis on the cross-section at Station 19+00 are presented on Plate F-1, in Appendix F.

5.2.5.2 Conditions Analyzed for Slope Stability

We used the Simplified Bishop Method of Slices option in the SLOPE/W computer program to analyze slope stability for 2-dimensional limiting equilibrium. The program has the capability to compute pore water pressures based on a defined piezometric surface.

For short term condition, AEC considered the groundwater depth to be equal to the groundwater level encountered during drilling in Boring B-5. AEC also considered a worst case scenario where the waterline trench is flooded during excavation, but the existing channel remains empty.

HCFCD requires a minimum safety factor (SF) of 1.3 for short-term condition. Stability analyses for the waterline trench excavation were conducted for short-term (construction period) condition. A brief description of the condition is presented below:

1. Construction Period Condition - This condition models rapid construction loading taking place, so that there is no time for the induced excess pore water pressure to dissipate or for consolidation to occur during the loading period. Unconsolidated-undrained shear strength parameters were used for this analysis.

5.2.5.3 Slope Stability Analyses at Station 19+00, based on Boring B-5

We performed slope stability analyses for the impact of the waterline trench excavation on Berry Creek using soil information encountered in Boring B-5. Design soil parameters used for the slope stability analyses are presented on Plate F-1, in Appendix F. Based on the provided cross section drawing at Station 19+00, the edge of the proposed waterline trench excavation will be approximately 16 feet from the edge of the existing 10.5 foot deep concrete U-shaped channel. For short-term condition, we also considered a 250 psf construction surcharge at the top of bank.

The results of the slope stability analyses for the impact of the waterline trench excavation on Berry Creek at Station 19+00, under short-term (construction) condition are presented on Plate F-3, in Appendix F. The safety factor for the trench excavation under short-term condition is presented in Table 6.

Table 6. Impact of Trench Excavation on Berry Creek at Station 19+00 (Based on Boring B-5)

Condition Analyzed	Minimum Factor of Safety
	Short-Term
15 feet deep Waterline Trench, 10.5 feet deep U-Shaped Channel	4.69 (Plate F-3)

Based on the summary in Table 6, the resulting SF for the impact of the waterline trench on the existing concrete lined channel of Berry Creek at Station 19+00 meets HCFCD requirements for short term (construction period) condition. No additional slope protection measures (aside from adequately shoring the trench excavation) are required along Berry Creek.

5.3 Installation of Underground Utilities by Trenchless Method

Sixteen-inch (and smaller) diameter waterlines installed by trenchless methods should be designed and installed in accordance with Section 02447 of the latest edition of the COHSCS.

The Contractor is responsible for selecting, designing, installing, maintaining and monitoring safe trenchless systems and retaining professionals who are qualified and experienced to perform the tasks and who are capable of modifying the system, as required. The following discussion provides general guidelines to the Contractor for augering methods. The information in this report should be reviewed so that appropriate augering equipment and techniques can be planned and factored into the construction plan and cost estimate.

5.3.1 Loadings on Pipes

Determination of loadings on pipes is presented in Section 5.2.1 of this report.

5.3.2 Auger Pits

Auger pits are required for starting and ending pipes. They should be designed and constructed in accordance with Section 02447, Subsection 3.04 of the latest edition of the COHSCS. Auger pits that are constructed in conjunction with open cut methods should be in accordance with Section 02317 of the latest edition of the COHSCS.

Reaction Walls: For the braced pit walls to be used to provide passive reaction for pipe jacking, passive earth pressure can be calculated using Equation (8) in Section 5.2.3 of this report; we recommend that a factor of safety of 2.0 be used for passive earth pressure. The design soil parameters for reaction wall design are presented on Plates C-1 through C-5, in Appendix C.

5.3.3 Auger Pit Excavation

Based on Table 1 in Section 2.1 of this report, invert depths of the small diameter waterlines typically varies from 5.6 to 12.4 feet at Borings B-2 through B-14. Based on the invert depths and Table 4 in Section 4.1 of this report, AEC does not anticipate that granular soils will be encountered within the proposed auger pit excavations. Based on Table 5 in Section 4.1 of this report, AEC does not anticipate that groundwater will be encountered in the auger pit excavations. However, if groundwater or saturated sands are encountered during auger pit excavation, groundwater control could be required. Groundwater control recommendations are presented in Section 6.2 of this report.

Recommendations for auger pit excavation, shoring, critical height, and bottom stability are presented in Section 5.2.2 of this report.

5.3.4 Auger Face Stability During Construction

A Stability Factor, $N_t = (P_z - P_a)/C_u$ may be used to evaluate the stability of an unsupported bore face in cohesive soils (N_t is not applicable to granular soils), where P_z is the overburden pressure to the bore centerline; P_a is the equivalent uniform interior pressure applied to the face; and C_u is the soil undrained shear strength. For augering operations, no interior pressure is applied. Generally, N_t values of 4 or less are desirable as it represents a practical limit below which augering may be accomplished without significant

difficulty. Higher N_t values usually lead to large deformations of the soil around the bore and problems associated with increased subsidence. It should be noted that the exposure time of the face is most important; with time, creep of the soil will occur, resulting in a reduction of shear strength. The N_t values will therefore increase when construction is slow.

An N_t value of about 0.3 to 0.85 was estimated for the cohesive soils encountered within the auger zone of approximately 5.6 to 12.4 feet below existing grade for Borings B-2 through B-14. Note that the cohesive soils have secondary structures such as fissures, sand seams, and sand lenses which can cause the bore face to become unstable. Where granular or soft cohesive soils are encountered, the Contractor should make provisions for casing to stabilize the auger holes. The Contractor should not base their bid on the above information alone, since granular soils may be encountered between boring locations; the Contractor should verify the subsurface conditions between boring locations or add a contingency.

5.3.5 Backfill for Auger Pits

Backfill for auger pits should be in accordance with Section 02317 of the latest edition of the COHSCS.

5.3.6 Influence of Augering on Adjacent Structures

Ground Subsidence: Augering in soft ground often induces some degree of settlement (ground subsidence) of the overlying ground surface. If such settlement is excessive, it may cause damage to existing structures and services located above and/or near the auger zone.

Predicting the amount of loss of ground (or ground subsidence) due to augering is very difficult, primarily because of the uncertainty involved in the analysis: such as heterogeneous soil properties, subsurface variability, or lack of information about proposed construction equipment and techniques.

Loss of Soil Support for Adjoining Structures: Augering operations, when located close to existing structures, will relieve the vertical and lateral soil support that these structures rely upon for their foundation bearing capacity and lateral soil support. This can result in distress to the existing structures if appropriate precautions are not taken.

Measures to Reduce Distress from Augering: Impact to existing foundations and structures can be mitigated by following proper augering procedures. Some methods to mitigate movement and/or distress to existing structures include:

- Supporting the augering excavation with steel or rigid concrete casing or the pipe material itself, as soon as the excavation is advanced and at short intervals; and
- proper grouting of the annular spaces; the type of equipment and method chosen will require the services of a specialty contractor.

To reduce the potential for the augering to influence the existing foundations or structures, we recommend that the outer edge of the influence zone of the auger tunnel be a minimum of 5 feet from the outer edge of the bearing (stress) zone of existing foundations. The bearing (stress) zone is defined by a line drawn downward from the outer edge of an existing foundation and inclined at an angle of 45 degrees to the vertical.

The auger influence zone is assumed to extend a distance of about 2.5i from the center of the auger tunnel, as shown on Plate D-11, in Appendix D. We estimated the resulting influence zones (extending from the centerline of the auger tunnel) to be approximately 4 to 10 feet (depending on invert depths ranging from 5.5 to 12.4 feet below grade). We emphasize that the size of the influence zone of an auger tunnel is difficult to determine because several factors influence the response of the soil to augering operations including type of soil, ground water level, type of augering equipment, method of augering, experience of operator and other construction in the vicinity. The values of auger tunnel influence zone presented herein are therefore rough estimates.

We recommend that the following situations be evaluated on a case by case basis, where:

- augering cannot be located farther than the minimum distance recommended above;
- augering cannot be located outside the stress zone of the foundations for existing structures;
- unstable soils are encountered near existing structures;
- heavily loaded or critical structures are located close to the influence zone of the auger tunnels;

As an option, existing structure foundations should be protected by adequate shoring or strengthened by underpinning or other techniques, provided that augering cannot be located outside the stress zone of the existing foundations.

Disturbance and loss of ground from the augering operation may create surface soil disturbance and subsidence which in turn may cause distress to existing structures (including pavements) located in the zone of soil disturbance. Any open-cut excavation in the proposed augering areas should be adequately shored.

5.4 Tunneling and Its Influence on Adjacent Structures

The Contractor is responsible for designing, constructing, implementing, and monitoring safe tunneling excavation and protecting existing structures in the vicinity from adverse effects resulting from construction, and retaining professionals who are qualified and experienced to perform the tasks and who are capable of modifying the system, as required. The following discussion provides general guidelines to the Contractor.

Based on the 90 percent complete plan and profile drawings provided by KAI, the proposed 60 inch diameter waterline will be installed by tunneling method where the alignment crosses beneath Airport Boulevard, the 6 inch diameter Kinder Morgan pipeline, and COH Drainage Easement Unit C165-00-00; the alignment stations, approximate tunnel invert depths, and possible subsurface conditions are summarized in Table 7 below.

Table 7. Subsurface Conditions in Borings within Tunnel Zones

Soil Boring	Station	Tunnel Segment	Tunnel Invert Depth (ft)	Soil Types Encountered within Tunnel Zone	Ground Water Depth below Existing Ground Surface (ft)	
					Boring	In Piezometer
B-1	2+53	Airport Boulevard	19.1	8' - 18': Soft to very stiff, Fat Clay (CH), with silt 18' - 22': Firm to stiff, Silty Clay (CL-ML) 22' - 24': Stiff to very stiff, Fat Clay (CH), with silt 24' - 25': Sandy Silt (ML)	18 (Drilling) 9.9 (15 min.)	-
B-2	3+83		20.0	9' - 12': Stiff to very stiff, Fat Clay (CH) 12' - 14': Silt (ML) 14' - 18': Stiff to very stiff, Lean Clay (CL), with silt 18' - 22': Medium dense, Silt (ML) 22' - 26': Stiff to very stiff, Lean Clay (CL), with slickensides	18 (Drilling) 11.8 (15 min.)	9.4 (9/16/14) 7.5 (3/20/15)

Soil Boring	Station	Tunnel Segment	Tunnel Invert Depth (ft)	Soil Types Encountered within Tunnel Zone	Ground Water Depth below Existing Ground Surface (ft)	
					Boring	In Piezometer
B-12	27+74	Kinder Morgan Pipeline	20.9	10' - 14': Firm to very stiff, Lean Clay (CL), with silt 14' - 22': Stiff to hard, Fat Clay (CH), with slickensides 22' - 24': Silt (ML) 24' - 27': Hard, Fat Clay (CH), with slickensides	21.7 (Drilling)	In B-11: 15.3 (9/16/14) 9.2 (3/20/15)
B-15A	15+89	COH Unit C165-00-00	29.3	19'-21': Medium dense Silt (ML) 21'-23':Stiff to very stiff, Fat Clay (CH) 23'-25': Very soft, Sandy Silty Clay (CL-ML) 25'-33': Stiff to hard Fat Clay (CH), with slickensides 33'-34': Silt (ML)	17 (Drilling) 12.0 (15 min.) 11.7 (24 hrs.)	-
B-16A	13+41	COH Unit C165-00-00	29.3	19'-23': Firm to hard Fat Clay (CH), with slickensides 23'-26': Medium dense, Silt (ML) 26'-33': Stiff to hard, Fat Clay (CH), with slickensides	17 (Drilling) 13.1 (15 min.) 12.3 (24 hrs.)	In B-16: 14.4 (9/16/14) 9.3 (3/20/15)

Tunneling operations and placement of pipe inside tunnel constructed with primary liner should comply with Sections 02425 (LD) and 02517 of the latest edition of the COHSCS.

Loadings on Pipes: Recommendations for computation of loadings on pipes from HS-20 trucks are presented in Section 5.2.1 of this report.

5.4.1 Tunnel Access Shafts

Tunnel access shafts should be constructed in accordance with Section 02400 of the latest edition of the COHSCS. Based on Table 7, the tunnel access shafts on both ends of the Airport Boulevard (Borings B-1 and B-2), Kinder Morgan Pipeline (Boring B-12), and COH Unit C165-00-00 (Borings B-15A and B-16A) tunnels will encounter clay with silt (CL/CH), silty clay (CL-ML), silt (ML), and groundwater. Since the access shafts will most likely extend into water-bearing sand/silt, the access shaft walls can be supported by internally-braced, water-tight steel sheet piles.

AEC anticipates ground water control will be required for the tunnel shafts. Possible ground water control measures includes: (i) deep wells with turbine or submersible pumps; (ii) educators (for silt); (iii) water-tight sheet pile cut-off walls; or (iv) jet-grouting of sandy soils in the immediate surrounding area. Generally, the groundwater depth should be lowered at least 5 feet below the excavation bottom (in accordance with Section 01578 of the latest edition of the COHSGR) to be able to work on a firm surface when water-bearing granular soils are encountered. If deep wells are used to dewater the excavation, extended and/or excessive dewatering can result in settlement of existing structures in the vicinity. One option to reduce the risk of settlement in these cases includes installing a series of reinjection wells around the perimeter of the construction area. General groundwater control recommendations are presented in Section 6.2 of this report. The options for dewatering presented here are for reference purposes only; it is the Contractor's responsibility to take the necessary precautions to minimize the effect on existing structures in the vicinity of the dewatering operation.

Sheet Piling: Design soil parameters for sheet pile design are presented on Plates C-1 through C-5, in Appendix C. AEC recommends that the sheet pile design consider both short-term and long-term parameters; whichever is critical should be used for design. The determination of the pressures exerted on the sheet piles by the retained soils shall consider active earth pressure, hydrostatic pressure, and uniform surcharge (including construction equipment, soil stockpiles, and traffic load, whichever surcharge is more critical).

Sheet pile design should be based on the following considerations:

(1) Ground water elevation at the top of the ground surface on the retained side;
(2) Ground water elevation 5 feet below the bottom of the access shaft excavation (assuming dewatering operations using deep wells);
(3) Neglect cohesion for active pressure determination, Equation (6) in Section 5.2.2 of this report;
(4) The design retained height should extend from the ground surface to the water line tunnel invert depth;
(5) A 300 psf uniform surcharge pressure from construction equipment or soil stockpiles should be considered at the top of the sheet piles; loose soil stockpiles during access shaft construction should be limited to 3 foot high or less;
(6) Use a Factor of Safety of 2.0 for passive earth pressure in front of (i.e. the shaft side) the sheet piles.

Design, construction, and monitoring of sheet piles should be performed by qualified personnel who are experienced in this operation. Sheet piles should be driven in pairs, and proper construction controls

provided to maintain alignment along the wall and prevent outward leaning of the sheet piles.

Bottom Stability: Recommendations for evaluating tunnel access shaft bottom stability are presented in Section 5.2.2 of this report.

Reaction Walls: Reaction walls (if used) will be part of the tunnel shaft walls; they will be rigid structures and support tunneling operations by mobilizing passive pressures of the soils behind the walls. The passive earth pressure can be calculated using Equation (8) in Section 5.2.3 of this report; we recommend that a factor of safety of 2.0 be used for passive earth pressure. The design soil parameters are presented on Plates C-1 through C-5 in Appendix C.

Due to subsurface variations, soils with different strengths and characteristics will likely be encountered at a given location. The soil resulting in the lowest passive pressure should be used for design of the walls. The soil conditions should be checked by geotechnical personnel to confirm the recommended soil parameters.

5.4.2 Tunnel Face Stability during Construction

5.4.2.1 General

The stability of a tunnel face is governed primarily by ground water and subsurface soil conditions, type of tunnel machine used, and workmanship. Based on the subsurface conditions encountered in our borings and the proposed invert depths (see Table 7 in Section 5.4 of this report), we anticipate that: (i) for the Airport Boulevard tunnel, firm to stiff fat clay (CH) with silt and firm to stiff silty clay (CL-ML) will generally be encountered at the tunneling zone near Boring B-1 and stiff to very stiff lean clay (CL) with silt and water-bearing medium dense silt (ML) will generally be encountered at the tunneling zone near Boring B-2; (ii) for the Kinder Morgan pipeline tunnel, stiff to hard fat clay (CH) with silt will generally be encountered at the tunneling zone near Boring B-12; and (iii) for the COH Unit C165-00-00 tunnel, stiff to hard fat clay (CH) with slickensides, *very soft* silty clay (CL-ML), and silt (ML) will be encountered at the tunneling zone near Boring B-15A, and medium dense silt (ML) and firm to hard fat clay (CH), with slickensides will generally be encountered at the tunneling zone near Boring B-16A.

Secondary features such as sand or silt partings/seams/pockets/layers were also encountered within the cohesive soils, and could be significant at some locations. In addition, the type and property of subsurface soils are subject to change between borings, and may be different at locations away from our borings.

When granular soils are encountered during construction the tunnel face can become unstable. Granular soils below ground water will tend to flow into the excavation hole; granular soils above the ground water level will generally not stand unsupported but will tend to ravel until a stable slope is formed at the face with a slope equal to the angle of repose of the material in a loose state. Thus, granular soils are generally considered unstable in an unsupported excavation face; uncontrolled flowing soil can result in large loss of ground.

5.4.2.2 Anticipated Ground Behavior

Tunnel face stability is described in Section 5.4.2 of this report. The N_t values estimated for the cohesive soils encountered above the tunnel is presented in Table 8. N_t was not able to be determined for Borings B-2, B-15A, and B-16A due to the presence of granular soils. We also estimated the maximum settlements [caused by volume loss if a Tunnel Boring Machine (TBM) is NOT used] at the proposed tunnel locations and the results are included in Table 8.

Table 8. Tunnel Face Stability Factor and Estimated Settlements along Tunnel Alignment

Soil Boring/ Station	Tunnel Segment	Tunnel Invert Depth (ft)	Anticipated Soil Types in Tunnel Zone	Stability Factor N_t	S_{max} (in)	Note/Suggestion
B-1	Airport Boulevard	19.1	Firm to stiff, Fat Clay (CH), with silt Firm to stiff, Silty Clay (CL-ML)	2.4	0.06	Mixed ground conditions under water, suggest using TBM
B-2		20.0	Stiff to very stiff, Lean Clay (CL), with silt Medium dense, Silt (ML)	n/a	0.34	Mixed ground conditions under water, suggest using TBM
B-12	Kinder Morgan Pipeline	20.9	Stiff to hard, Fat Clay (CH), with slickensides	1.9	0.05	Potential swelling ground due to very high plasticity CH

Soil Boring/ Station	Tunnel Segment	Tunnel Invert Depth (ft)	Anticipated Soil Types in Tunnel Zone	Stability Factor N_t	S_{max} (in)	Note/Suggestion
B-15A	COH Unit C165-00-00	29.3	Very soft, Sandy Silty Clay (CL-ML) Stiff to hard, Fat Clay (CH), with slickensides	1.5	0.20	Mixed ground conditions under water, potential swelling ground due to very high plasticity CH. Suggest using TBM
B-16A		29.3	Medium dense, Silt (ML) Stiff to hard, Fat Clay (CH)	1.6	0.20	Mixed ground conditions under water, potential swelling ground due to very high plasticity CH. Suggest using TBM

Note: S_{max} = Estimated settlement along the tunnel alignment due to volume loss if TBM is not used; not including consolidation settlement.

Based on Table 8, it should be noted that the estimated settlement at Airport Boulevard (Boring B-2) is approximately 0.34 inches and COH Unit C165-00-00 (Borings B-15A and B-16A) is approximately 0.20 inches (which does not include consolidation settlement) or more; dewatering at these locations will also cause additional settlement due to increases in effective stress of the soil strata. The information in this report should be reviewed so that appropriate tunneling equipment and operation can be planned and factored into the construction plan and cost estimate. If the estimated settlement is too high, we suggest that the tunnel construction consider the use of: (i) a TBM; (ii) jet grout to stabilize the saturated granular soils; or (iii) micro-tunneling. The choice of tunneling machine should be selected by the Contractor. Plate D-12 in Appendix D provides a general guideline for TBM selection. Tunnel construction should be in accordance with Section 02425 (LD) of the latest edition of the COHSCS.

5.4.2.3 Influence of Tunneling on Existing Structures

We estimated the resulting influence zones (extending from the centerline of the tunnel) for the tunnels to range from approximately 21 to 28 feet; although the values of tunnel influence zone presented are rough estimates. The estimated maximum settlements [caused by volume loss if a TBM is not used] along the tunnel alignment at the proposed tunnel locations are included in Table 8.

AEC emphasizes that the size of the influence zone of a tunnel is difficult to determine because several factors influence the response of the soil to tunneling operations including type of soil, ground water level and control method, type of tunneling equipment, tunneling operations, experience of operator, and other

construction in the vicinity. Methods to prevent movement and/or distress to existing structures will require the services of a specialty contractor.

5.4.3 Measures to Reduce Distress from Tunneling

To control tunneling face loss and reduce potential impact on existing foundations and structures, AEC recommends the use of a steel casing (or equivalent methods) to support the tunnel excavation during tunnel construction. Considering the ground conditions discussed in Table 8, AEC recommends that the following tunneling operations be considered: (i) use a pressurized slurry TBM and keep the pressure at least equal to if not greater than the combined soil and groundwater pressure in the ground at the tunnel level; (ii) if the contractor selects bore and jack operation, boring and jacking steel casing should be performed simultaneously to minimize the soil loss outside the steel casing; ground movement along the tunnel zone should be monitored during tunneling operation; and (iii) if excessive voids occur during tunneling, the contractor should immediately and completely grout the annular space between the steel casing and the ground at the tail of the machine, in accordance with Section 02431 of the latest edition of the COHSCS. It should be noted that grouting may increase friction resistance while advancing the casing and the contractor will need to address this condition as part of his tunnel work plan. Plate D-13, in Appendix D provides a general guideline for selection of grouting material. The tunneling machine selection, tunneling operation, and grouting (as necessary) will be the full responsibility of the Contractor.

To reduce the potential for the tunneling to influence existing foundations or structures, we recommend that the outer edge of the influence zone of the tunnel be a minimum of 5 feet from the outer edge of the bearing (stress) zone of existing foundations. The bearing (stress) zone is defined by a line drawn downward from the outer edge of an existing foundation and inclined at an angle of 45 degrees to the vertical.

We recommend that the following situations be evaluated on a case by case basis, where:

- tunneling cannot be located farther than the minimum distance recommended above;
- tunneling cannot be located outside the stress zone of the foundations for existing structures;
- unstable soils are encountered near existing structures;
- heavily loaded or critical structures are located close to the influence zone of the tunnels;

As an option, existing structure foundations should be protected by adequate shoring or strengthened by underpinning or other techniques, provided that tunneling cannot be located outside the stress zone of the existing foundations.

Disturbance and loss of ground from the tunneling operation may create surface soil disturbance and subsidence which in turn may cause distress to existing structures (including underground utilities and pavements) located in the zone of soil disturbance. Any open-cut excavation in the proposed tunneling areas should be adequately shored.

5.4.4 Monitoring Existing Structures

The Contractor should be responsible for monitoring existing structures nearby and taking necessary action to mitigate impact to adjacent structures. Existing structures located close to the proposed construction excavations should be surveyed prior to construction and pre-existing conditions of such structures and their vicinity be adequately recorded. This can be accomplished by conducting a pre-construction survey, taking photographs and/or video, and documenting existing elevations, cracks, settlements, and other existing distress in the structures. The monitoring should include establishment of elevation monitor stations, crack gauges, and inclinometers, as required. The monitoring should be performed before, periodically during, and after construction. The data should be reviewed by qualified engineers in a timely manner to evaluate the impact on existing structures and develop plans to mitigate the impact, should it be necessary.

5.5 Pavement Reconstruction

Based on 90 percent drawings provided by KAI, the existing concrete roadway along the southbound lanes of Monroe Road and the entirety of Rockhill Street will be reconstructed. The new pavement will be placed at or near the existing grade. The curb-to-curb distance for the southbound lanes of Monroe Road will be 24 feet, and the curb-to-curb distance of Rockhill Street will be 27 feet from Monroe Road to COH Drainage Unit C165-00-00, and will be 40 feet from COH Drainage Unit C165-00-00 to Glen Valley Drive.

COH Infrastructure Design Manual Requirements: Chapter 10 of the latest edition of the COH Infrastructure Design Manual (IDM) requires that concrete pavement have a 28 day compressive strength of 4,000 psi and a minimum reinforcing steel yield strength of 60,000 psi. The minimum design life span of

the concrete pavement is 50 years. Minimum concrete and subgrade thickness is dependent on the classification of the roadway. A 'collector' requires a minimum concrete slab thickness of 9 inches and a minimum stabilized subgrade thickness of 6 inches for granular soil and a minimum thickness of 8 inches for cohesive soil. A 'thoroughfare' requires a minimum concrete slab thickness of 11 inches and a minimum stabilized subgrade thickness of 8 inches.

5.5.1 Estimation of Traffic Loading

Traffic Counts: According to the Houston Regional Traffic Count Map (published by the Texas Transportation Institute), the Texas Department of Transportation (TxDOT) 24 hour Traffic Volume: (i) on Monroe Road between Cayton Street and Wilmerdean Street was 23,818 vehicles per day (vpd) in 2009 (AEC assumes the traffic count includes north and southbound traffic); and (ii) on Rockhill Street between Monroe Road and Hinman Street was 3,110 vpd in 2006 and between Ruthby Street and Glencrest Street was 3,170 vpd in 2006. For the year 2015, AEC projected a daily traffic count of 28,440 vpd for Monroe and 3,788 vpd for Rockhill. AEC should be notified if different traffic count information should be used for design, so that our recommendations can be updated as necessary.

Estimated Anticipated Traffic Loads: AEC approximated traffic loads by estimating the number of repetitions of an 18-kip Equivalent Single-Axle Load (ESAL) over the project alignment. Pavement design is based on the anticipated design number of 18-kip ESAL the pavement is subjected to during its design life. The equation to calculate the number of 18-kip ESAL repetitions to use for pavement design is presented in Equation (9). Assumptions made by AEC to estimate 18-kip ESAL repetitions are presented on Table 9.

$$\text{18-kip ESAL} = (ADT)(T)(T_f)(D)(L)(G)(Y)(365) \qquad \text{.....Equation (9)}$$

where:
- ESAL = 18-kip Equivalent Single-Axle Load repetitions;
- ADT = Average Daily Traffic, vehicles per day;
- T = Percent of heavy trucks;
- T_f = Truck factor;
- D = Directional factor;
- L = Lane factor;
- G = Growth factor;
- Y = Design life, in years.

Table 9. Parameters for Estimation of Traffic Loads

Parameters	Monroe Road from W. Airport to Rockhill	Rockhill from Monroe to Glen Valley
Average Daily Traffic (ADT)	14,220 vpd (southbound lanes only, projected in 2015)	3,788 vpd (both directions, projected in 2015)
Percent Heavy Trucks (T)	3% (assumed)	2% (assumed)
Truck factor (T_f)	1.1 (assumed)	0.7 (assumed)
Directional factor (D)	1.0 (2 lanes in southbound direction)	0.5 (1 lane each direction)
Lane factor (L)	1.0 (2 southbound lanes)	1.0 (1 lane each direction)
Total Growth Rate Factor (G)	1.85 (2.5% annual growth rate over 50 years, assumed)	1.64 (2.0% annual growth rate over 50 years, assumed)
Design life (Y)	50 years	50 years
Estimated 18-kip ESAL Loading over Design Life	15,843,390	793,624

AEC notes that calculated number of 18-kip ESAL repetitions is highly sensitive to heavy truck parameters such as percent heavy trucks, truck factor, and traffic growth rate in pavement design. Differences between assumed and actual traffic parameters can have significant effects on overall pavement thickness design and ultimate roadway performance. AEC should be notified if different traffic loads or design parameters are required for pavement design at the site, so that our analysis can be updated accordingly.

5.5.2 Rigid Pavement

The pavement design recommendations developed below are in accordance with the "AASHTO Guide for Design of Pavement Structures," 1993 edition. Rigid pavement design is based on the anticipated design number of 18-kip ESALs the pavement is subjected to during its design life. The parameters that were used in computing the rigid pavement section are as follows:

Overall Standard Deviation (S_0)	0.35
Initial Serviceability (P_0)	4.5
Terminal Serviceability (P_t)	2.5
Reliability Level I	95% (Monroe), 95% (Rockhill)
Overall Drainage Coefficient (C_d)	1.2 (curb and gutter)
Load Transfer Coefficient (J)	3.2
Loss of Support Category (LS)	1.2
Roadbed Soil Resilient Modulus (M_R)	4,500 psi
Elastic Modulus (E_{sb}) of Stabilized Soils	30,000 psi

Composite Effective Modulus of Subgrade Reaction (k)	97 pci
Concrete Compressive Strength (f'_c)	4,000 psi (at 28 days)
Mean Concrete Modulus of Rupture (S'_c)	600 psi (at 28 days)
Concrete Elastic Modulus (E_c)	3.6×10^6 psi

Table 10. Recommended Rigid Pavement Sections

Pavement Layer	Southbound Lanes of Monroe Road between W. Airport and Rockhill	Rockhill Street between Monroe and Glen Valley
Portland Cement Concrete	11*	9*
Lime-stabilized Subgrade	8	8
Estimated 18-kip ESAL Load Capacity over Design Life	17,603,163	4,827,520

Note: (*) Minimum pavement thickness required by Chapter 10 of COH IDM.

AEC used the DARWin v3.0 computer program to perform rigid pavement design. The DARWin outputs are presented on Plates E-1 through E-4, in Appendix E. Using the DARWin program: (i) for the southbound lanes of Monroe Road, a 10.82 inch thick concrete pavement with 8 inch thick lime stabilized subgrade is required based on an estimated loading of 15,843,390 18-kip ESALs (see Table 9 in Section 5.5.1 of this report); and (ii) for Rockhill Street, a 6.63 inch thick concrete pavement with 8 inch thick lime stabilized subgrade is required based on an estimated loading of 793,624 18-kip ESALs (see Table 9 in Section 5.5.1 of this report). In accordance with Chapter 10 of the latest edition of the COH IDM, the minimum requirement pavement for a 'thoroughfare' street is 11 inches of concrete and 8 inches of stabilized subgrade, and for a 'collector' street is 9 inches of concrete and 8 inches of stabilized subgrade (for cohesive soils).

Given the above design parameters, the minimum 11 inch thick 'thoroughfare' concrete pavement section should sustain 17,603,163 repetitions of 18-kip ESALs, and the minimum 9 inch thick 'collector' concrete pavement section should sustain 4,827,520 repetitions of 18-kip ESALs. The design engineer should verify whether the proposed pavement section will provide enough ESALs for the anticipated amount of site traffic. AEC should be notified if different standards or constants are required for pavement design at the site, so that our recommendations can be updated accordingly.

Concrete Pavement: Portland Cement Concrete (PCC) pavement should be constructed in accordance with Section 02751 of the latest edition of the COHSCS. AEC notes that there is a discrepancy between the

requirements of the latest edition of the COHSCS and the latest edition of the COH IDM. Chapter 10 of the latest edition of the COH IDM requires a minimum 28-day concrete compressive strength of 4,000 psi to be used for concrete pavement design. However, according to Section 02751, concrete mix design has a required flexural strength of 600 psi at 28 days and field testing shall confirm a minimum concrete compressive strength of 3,500 psi at 28 days. In regards to this discrepancy, AEC recommends that the concrete mix design be performed to achieve a concrete compressive strength of 4,000 psi at 28 days, and also meets a minimum concrete flexural strength of 500 psi at 7 days and 600 psi at 28 days.

5.5.3 Reinforcing Steel

Reinforcing steel should be in accordance with Section 02751 of the latest edition of the COHSCS. Reinforcing steel is required to control pavement cracks, deflections across pavement joints and resist warping stresses in rigid pavements. The cross-sectional area of steel (A_s) required per foot of slab width can be calculated as follows (for both longitudinal and transverse steel).

$$A_s = FLW/(2f_s) \qquad \text{.....Equation (10)}$$

where:
- A_s = Required cross-sectional area of reinforcing steel per foot width of pavement, in^2
- F = Coefficient of resistance between slab and subgrade, F = 1.8 for stabilized soil
- L = Distance between free transverse joints or between free longitudinal edges, ft.
- W = Weight of pavement slab per foot of width, lbs/ft
- f_s = Allowable working stress in steel, 0.75 x (yield strength), psi
  i.e. f_s = 45,000 psi for Grade 60 steel.

5.5.4 Pavement Subgrade Preparation

Roadway grading and fill should be performed in general accordance with Section 02315 of the latest edition of the COHSCS. Existing pavement should be demolished in accordance with Section 02221 of the latest edition of the COHSCS. Subgrade preparation should extend a minimum of 2 feet beyond the paved area perimeters. After demolition of existing pavement, we recommend that a competent soil technician inspect the exposed subgrade to determine if there are any unsuitable soils or other deleterious materials. Excavate and dispose of unsuitable soils and other deleterious materials which will not consolidate; the excavation depth should be increased when inspection indicates the presence of organics and deleterious materials to greater depths. Unsuitable soil is defined in Section 02319 of the latest edition of the COHSCS. The exposed soils should be proof-rolled (see below) to identify and remove any weak,

compressible, or other unsuitable materials; such over-excavations should be backfilled in general accordance with Section 02315 of the latest edition of the COHSCS. Proof rolling should be performed with a pneumatic tire roller (or using equivalent compaction equipment), with a loaded weight between 25 and 50 tons. At least two coverages should be made with the proof-roller, and offset each trip of the roller by at most 1 tire width. Rollers should make passes at a speed between 2 and 6 miles per hour.

Scarify areas to be filled to a depth of 4 inches to bond existing and new materials, and then mix with the first fill layer in accordance with Section 02315 of the latest edition of the COHSCS. Cut and pulverize material to bottom of subgrade, then stabilize the subgrade with at least 7 percent hydrated lime by dry soil weight. Lime stabilization shall be performed in accordance with Section 02336 of the latest edition of the COHSCS. The percentage of lime required for stabilization is a preliminary estimate for planning purposes only; laboratory testing should be performed to determine optimum contents for stabilization prior to construction. The stabilized soils should be compacted to 95 percent of their ASTM D 698 (Standard Proctor) dry density at a moisture content ranging from optimum to 3 percent above optimum.

5.6 Impact of New Left Turn Lanes on Channel Slope Stability

Based on drawings provided by KAI, new left turn lanes will be added along the southbound lanes of Monroe Road at the intersections of Wynlea Street, Monroe PR 1 Drive, and Byran Street. The new turn lanes will be constructed adjacent to the top of slope of Berry Creek (HCFCD Unit C106-01-00) and the COH maintained 35 foot wide drainage channel that are located within the median of Monroe Road.

Based on available topographic data, Berry Creek is approximately 10.5 to 11 feet deep and the drainage channel is approximately 7.5 to 9.5 feet deep. Berry Creek is a concrete-lined U-shaped channel, while the drainage channel is grass-lined and have a slope inclination that is approximately H:V = 1.75:1.

AEC evaluated the impact of the new turn lanes on the slope stability of Berry Creek and COH drainage channel, based on Borings B-5, B-5A, B-7, B-7A, and B-8 (i.e., borings drilled near the proposed left turn lanes). AEC selected two most-critical cross sections for analysis at Station 19+00 and Station 30+00 along Monroe Road, based on our borings along the channels and on the cross section drawings provided by KAI.

5.6.1 Design Soil Parameters and Cross Section for Slope Stability Analysis

Soil parameters used in the analyses include wet unit weights, unconsolidated-undrained (UU) shear strengths, consolidated-drained (CD) shear strengths, and consolidated-undrained (CU) shear strengths. Based on Borings B-5, B-5A, B-7, B-7A, and B-8, the subsurface conditions along the west bank of the channels generally consist of firm to hard lean/fat clay (CL/CH) from the ground surface to a depth of 10 to 25 feet, underlain by firm to very stiff silty clay (CL-ML) and loose to medium dense silt (ML) to the boring termination depths.

High plasticity fat clay was encountered in Borings B-5, B-5A, B-7, B-7A, and B-8. Exposing these fat clays to the atmosphere and cycles of wetting-drying from seasonal moisture changes will result in desiccation, cracking, and progressive movement of these clays, and a reduction in their shear strengths. We considered the desiccation zone for fat clay to be approximately 8 feet below the ground/slope surface. For fat clay within the desiccation zone, we used effective stress residual shear strengths of c'_r = 65 pounds per square foot (psf) and ϕ'_r = 21 degrees to evaluate slope stability for both the long-term condition and rapid drawdown condition. We also reduced the c' and c_{cu} of lean clay soils (with a PI greater than 20) within the non-desiccated zone based on our experience with other HCFCD projects. The design soil parameters for the most-critical cross-sections are presented on Plates F-1 and F-2, in Appendix F.

5.6.2 Conditions Analyzed for Slope Stability

We used the Simplified Bishop Method of Slices option in the SLOPE/W computer program to analyze slope stability for 2-dimensional limiting equilibrium. The program has the capability to compute pore water pressures based on a defined piezometric surface.

For rapid drawdown condition, we considered that the water level drops from the 100 year water surface elevation of approximately +33.5 feet above Mean Sea Level (MSL) to the channel bottom. This models the condition where a 100-year flood event occurs and then the water level drops down quickly. For short term conditions, AEC considered the groundwater depth to be equal to the groundwater levels encountered in the borings. For long term conditions, AEC considered the groundwater depth to be equal to the groundwater levels measured in the closest piezometers.

HCFCD requires a minimum SF of 1.3 for short-term conditions, 1.5 for long-term conditions, and 1.25 for rapid drawdown conditions. Stability analyses for the channel slopes were conducted for the short-term (end-of-construction), long-term, and rapid drawdown conditions. A brief description of these conditions is presented below:

1. End-of-Construction Condition - This condition models rapid construction loading taking place, so that there is no time for the induced excess pore water pressure to dissipate or for consolidation to occur during the loading period. Unconsolidated-undrained shear strength parameters were used for this analysis.

2. Long-Term Condition - This condition models long-term steady seepage through embankments and the long-term stability of slopes in stiff clays. Consolidated-drained effective stress shear strength parameters (obtained from CU triaxial tests with pore water pressure measurements) were used for this analysis.

3. Rapid Drawdown Condition - The majority of slope failures in the Harris County/Houston area occur under rapid drawdown conditions. This condition models when the slope becomes fully saturated and consolidated and is at equilibrium with the existing stress system, then encounters rapid drawdown and simultaneously allows no drainage to occur. Consolidated-undrained total stress shear strength with pore pressures parameters modeling rapid drawdown conditions were used for this analysis.

5.6.3 Slope Stability Analyses at Station 19+00, based on Boring B-5

We performed slope stability analyses for the concrete lined U-shaped channel slopes along Berry Creek using soil information encountered in Boring B-5. Design soil parameters used for the slope stability analyses are presented on Plate F-1, in Appendix F. Based on the provided cross section drawing at Station 19+00, the existing U-shaped channel is approximately 10.5 feet deep. For short-term, long term, and rapid drawdown conditions, we also considered a 240 psf traffic surcharge at the top of bank.

The results of the slope stability analyses for the impact of the new left turn lane on Berry Creek at Station 19+00, under short-term, long-term, and rapid drawdown conditions are presented on Plates F-4 through F-6, in Appendix F. The safety factors for the channel under short-term, long-term, and rapid drawdown conditions are in Table 11.

Table 11. Slope Stability Analysis Results at Station 19+00 (Based on Boring B-5)

Condition Analyzed	Minimum Factor of Safety		
	Short-Term	Long-Term	Rapid Drawdown
New left turn lane adjacent to existing 10.5 feet deep U-shaped Channel	4.43 (Plate F-4)	3.37 (Plate F-5)	2.49 (Plate F-6)

Based on the summary in Table 11, the result SF's for the additional left turn lane on the stability of the west bank of Berry Creek meet HCFCD requirements for short term, long term, and rapid drawdown conditions. No additional slope improvement measures are required for the turn lanes along Berry Creek.

5.6.4 Slope Stability Analyses at Station 30+00, based on Boring B-8

We performed slope stability analyses for the channel slopes along the COH drainage channel using soil information encountered in Boring B-8. Design soil parameters used for the slope stability analyses are presented on Plate F-2, in Appendix F. Based on the provided cross section drawing at Station 30+00, the existing channel is approximately 8.3 feet deep. For short-term, long term, and rapid drawdown conditions, we also considered a 240 psf traffic surcharge at the top of bank.

The results of the slope stability analyses for the impact of the new left turn lane on the COH drainage channel at Station 30+00, under short-term, long-term, and rapid drawdown conditions are presented on Plates F-7 through F-9, in Appendix F. The safety factors for the channel under short-term, long-term, and rapid drawdown conditions are in Table 12.

Table 12. Slope Stability Analysis Results at Station 30+00 (Based on Boring B-8)

Condition Analyzed	Minimum Factor of Safety		
	Short-Term	Long-Term	Rapid Drawdown
New left turn lane adjacent to existing 8.3 feet deep, H:V = 2.6:1 slope channel	4.83 (Plate F-7)	2.77 (Plate F-8)	2.11 (Plate F-9)

Based on the summary in Table 12, the result SF's for the additional left turn lane on the stability of the west bank of the COH drainage channel meet HCFCD requirements for short term, long term, and rapid

drawdown conditions. No additional slope improvement measures are required for the turn lanes along the COH drainage channel.

6.0 CONSTRUCTION CONSIDERATIONS

6.1 Site Preparation

To mitigate site problems that may develop following prolonged periods of rainfall, it is essential to have adequate drainage to maintain a relatively dry and firm surface prior to starting any work at the site. Adequate drainage should be maintained throughout the construction period. Methods for controlling surface runoff and ponding include proper site grading, berm construction around exposed areas, and installation of sump pits with pumps.

6.2 Groundwater Control

The need for groundwater control will depend on the depth of excavation relative to the groundwater depth at the time of construction. 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. In addition, groundwater may be pressurized in certain areas of the alignment, requiring further evaluation and consideration of the excess hydrostatic pressures. Groundwater control should be in general accordance with Section 01578 of the latest edition of the COHSGR.

The Contractor should be responsible for selecting, designing, constructing, maintaining, and monitoring a groundwater control system and adapt his operations to ensure the stability of the excavations. Groundwater information presented in Section 4.1 and elsewhere in this report, along with consideration for potential environmental and site variation between the time of our field exploration and construction, should be incorporated in evaluating groundwater depths. The following recommendations are intended to guide the Contractor during design and construction of the dewatering system.

In cohesive soils seepage rates are lower than in granular soils and groundwater is usually collected in sumps and channeled by gravity flow to storm sewers. If cohesive soils contain significant secondary

features, seepage rates will be higher. This may require larger sumps and drainage channels, or if significant granular layers are interbedded within the cohesive soils, methods used for granular soils may be required. Where it is present, pressurized groundwater will also yield higher seepage rates.

Groundwater for excavations within saturated sands can be controlled by the installation of wellpoints. The practical maximum dewatering depth for well points is about 15 feet. When groundwater control is required below 15 feet, possible ground water control measures include: (i) deep wells with turbine or submersible pumps; (ii) multi-staged well points; or (iii) water-tight sheet pile cut-off walls. Generally, the groundwater depth should be lowered at least 5 feet below the excavation bottom (in accordance with Section 01578 of the latest edition of the COHSGR) to be able to work on a firm surface when water-bearing granular soils are encountered.

Extended and/or excessive dewatering can result in settlement of existing structures in the vicinity; the Contractor should take the necessary precautions to minimize the effect on existing structures in the vicinity of the dewatering operation. We recommend that the Contractor verify the groundwater depths and seepage rates prior to and during construction and retain the services of a dewatering expert (if necessary) to assist him in identifying, implementing, and monitoring the most suitable and cost-effective method of controlling groundwater.

For open cut construction in cohesive soils, the possibility of bottom heave must be considered due to the removal of the weight of excavated soil. In lean and fat clays, heave normally does not occur unless the ratio of Critical Height to Depth of Cut approaches one. In silty clays, heave does not typically occur unless an artificially large head of water is created through the use of impervious sheeting in bracing the cut. Guidelines for evaluating bottom stability are presented in Section 5.2.2 of this report.

6.3 Construction Monitoring

Pavement construction and subgrade preparation, as well as excavation, bedding, and backfilling of underground utilities should be monitored by qualified geotechnical professionals to check for compliance with project documents and changed conditions, if encountered. AEC should be allowed to review the design and construction plans and specifications prior to release to check that the geotechnical recommendations and design criteria presented herein are properly interpreted.

6.4 Monitoring of Existing Structures

Existing structures in the vicinity of the proposed alignment should be closely monitored prior to, during, and for a period after excavation. Several factors (including soil type and stratification, construction methods, weather conditions, other construction in the vicinity, construction personnel experience and supervision) may impact ground movement in the vicinity of the alignment. We therefore recommend that the Contractor be required to survey and adequately document the condition of existing structures in the vicinity of the proposed alignments.

7.0 LIMITATIONS

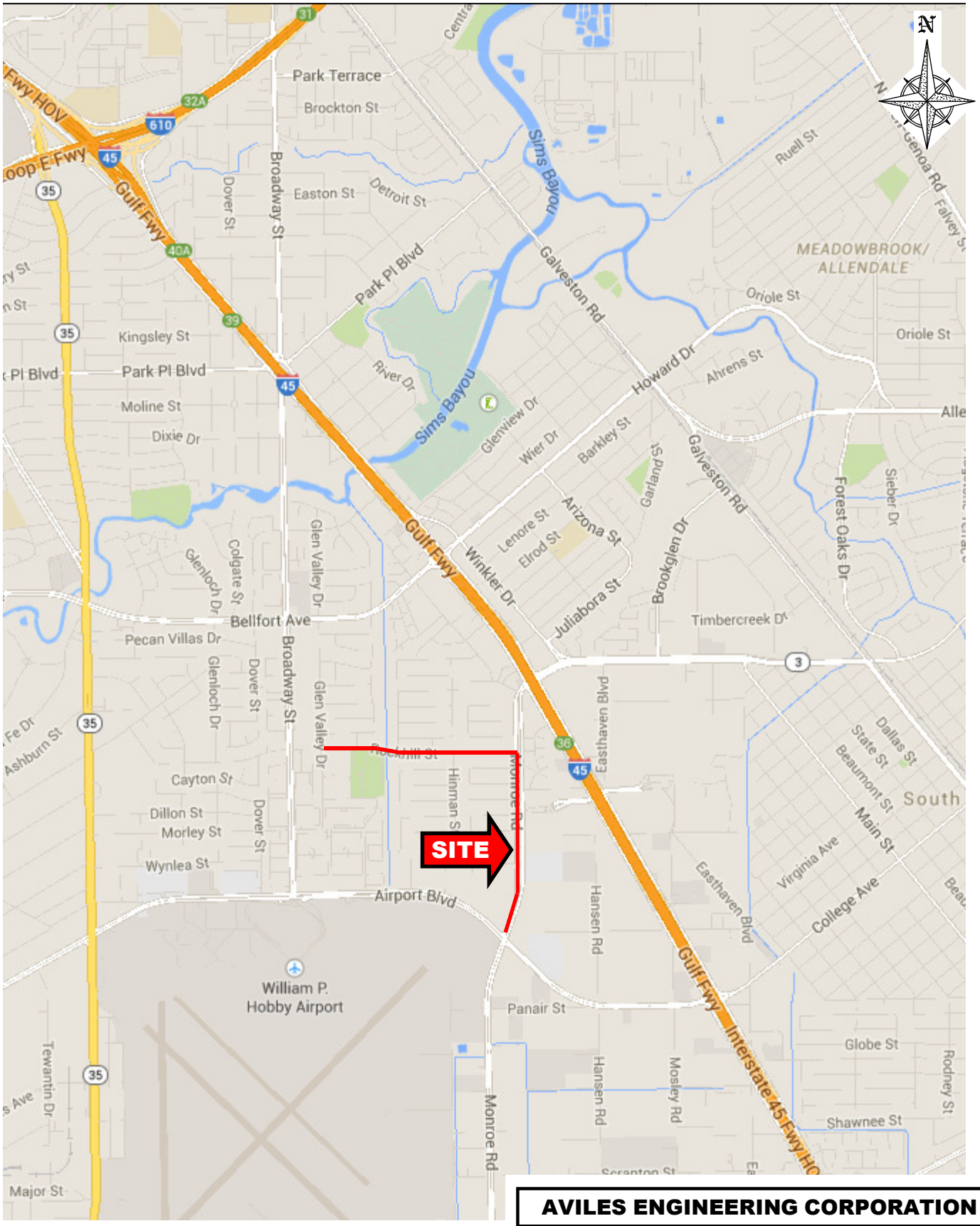
The information contained in this report summarizes conditions found on the dates the borings were drilled. The attached boring logs are true representations of the soils encountered at the specific boring locations on the dates of drilling. Reasonable variations from the subsurface information presented in this report should be anticipated. If conditions encountered during construction are significantly different from those presented in this report; AEC should be notified immediately.

This investigation was performed using the standard level of care and diligence normally practiced by recognized geotechnical engineering firms in this area, presently performing similar services under similar circumstances. This report is intended to be used in its entirety. The report has been prepared exclusively for the project and location described in this report. If pertinent project details change or otherwise differ from those described herein, AEC should be notified immediately and retained to evaluate the effect of the changes on the recommendations presented in this report, and revise the recommendations if necessary. The recommendations presented in this report should not be used for other structures located along these alignments or similar structures located elsewhere, without additional evaluation and/or investigation.

AVILES ENGINEERING CORP.

APPENDIX A

Plate A-1	Vicinity Map
Plate A-2	Boring Location Plan
Plates A-3 to A-24	Boring Logs B-1 to B-18 in COH format
Plate A-25	Key to Symbols
Plate A-26	Classification of Soils for Engineering Purposes
Plate A-27	Terms Used on Boring Logs
Plate A-28	ASTM & TXDOT Designation for Soil Laboratory Tests
Plate A-29	Sieve Analysis Results
Plates A-30 to A-31	Pinhole Test Results
Plate A-32	Crumb Test Results
Plates A-33 to A-36	CU Test Mohr Circles
Plates A-37 to A-44	Summary of Lab Data



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VICINITY MAP

60 INCH WATERLINE ALONG MONROE AND ROCKHILL
WBS NO. S-000900-0129-4
HOUSTON, TEXAS

AEC PROJECT NO.:	DATE:	SOURCE DRAWING:
G149-14	10-27-14	GOOGLE
APPROX. SCALE:	DRAFTED BY:	PLATE NO.:
N.T.S.	WLW	PLATE A-1

AVILES ENGINEERING CORPORATION

BORING LOCATION PLAN

60 INCH WATERLINE ALONG MONROE AND ROCKHILL
WBS NO. S-000900-0129-4
HOUSTON, TEXAS

AEC PROJECT NO.:	DATE:	SOURCE DRAWING PROVIDED BY:
G149-14	10-27-14	GOOGLE
APPROX. SCALE:	DRAFTED BY:	PLATE NO.:
1" = 500'	WLW	PLATE A-2

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-1**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/16/14**

DESCRIPTION

Survey Coordinates (TSPC, Surface):

Easting: 3155199.9584

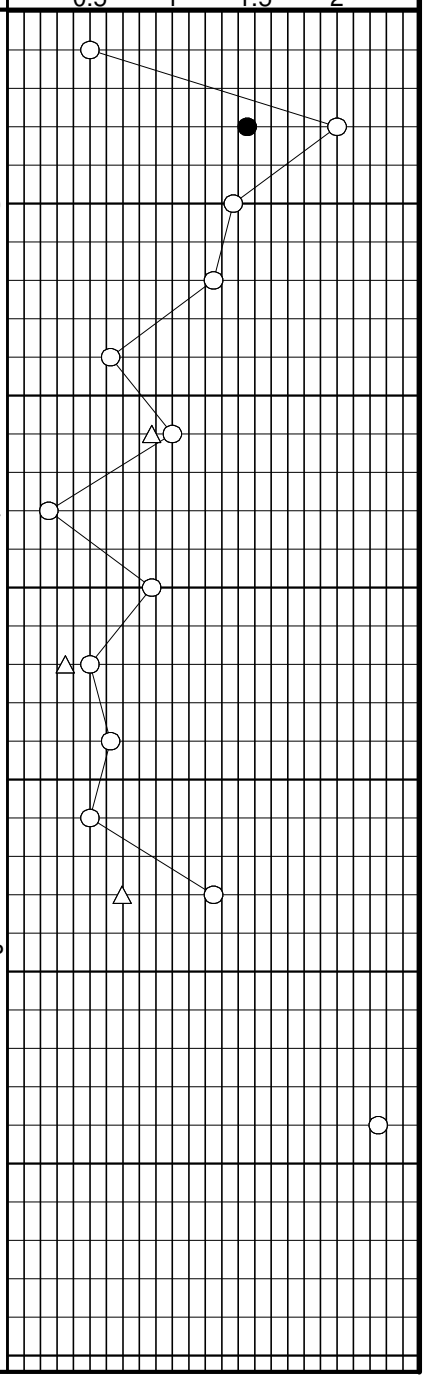
Northing: 13806405.0761

Elevation: 32.064

Depth in Feet	Description	S.P.T. Blows / Ft.	-200 Mesh	Dry Density, PCF	Moisture Content, %	Liquid Limit	Plastic Limit	Plasticity Index
0	Soft to very stiff, olive gray Fat Clay (CH), with slickensides				29			
	-with roots 0'-2'							
	-dark olive gray 2'-4'			106	21			
	-gray, dark gray, and olive gray 4'-8', with ferrous and calcareous nodules 4'-6'		94		29	71	22	49
	-with silty clay pockets and gravel 6'-8'				28			
	-reddish tan, gray, and light gray 8'-12', with ferrous nodules 8'-10'				36			
				101	27			
	-light gray and tan 12'-14', with silty clay pockets 12'-18'		97		29	54	20	34
	-tan and red 14'-18'				24			
				102	25			
	Firm to stiff, tan and gray Silty Clay (CL-ML), wet		86		24	26	20	6
	-with silt pockets and calcareous nodules 18'-20'				24			
	Stiff to very stiff, reddish tan Fat Clay (CH), with slickensides and silty clay pockets			102	23			
	Dark tan Sandy Silt (ML), wet		50		22	NP	NP	NP
	Hard, dark reddish tan Fat Clay (CH)				27			
30	Termination Depth = 30 feet							

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **20** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **18** FEET WHILE DRILLING

WATER LEVEL AT **9.9** FEET AFTER **1/4 HR**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

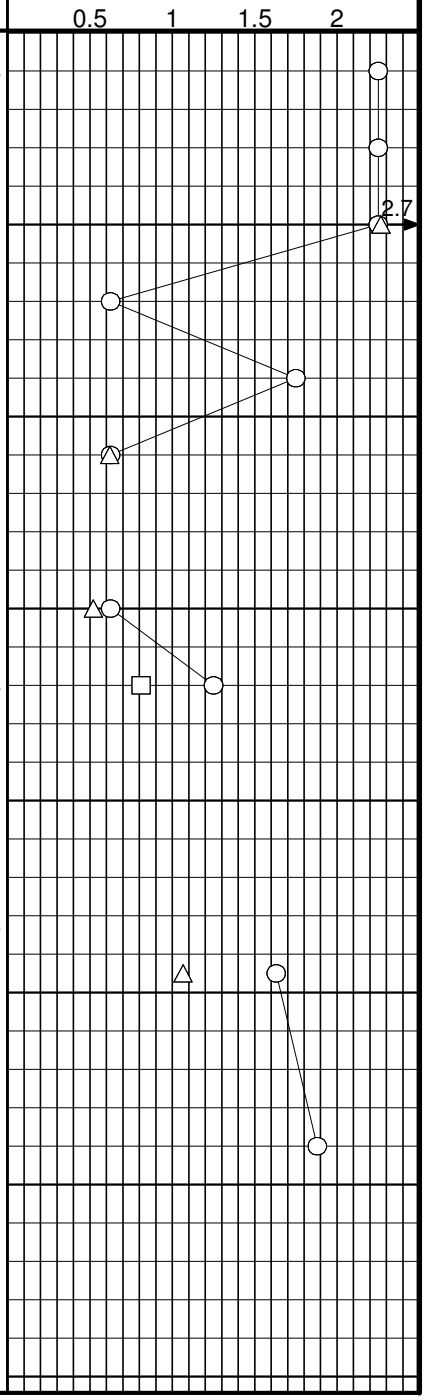
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-2**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3155264.7230* *Northing: 13806520.4507* *Elevation: 32.964*							
	0			Stiff to hard, dark olive brown Fat Clay (CH), with slickensides -with roots 0'-4' -dark olive gray 2'-6'		90		22	67	23	44
30				-with ferrous nodules 4'-6'				21			
	5						104	22			
				-tan and gray 6'-12', with calcareous nodules 6'-10'				34			
25				-with ferrous nodules 8'-10'		94		25	75	22	53
	10						96	28			
20				Gray Silt (ML), with clay pockets		96		27			
	15			Stiff to very stiff, red and tan Lean Clay (CL), with silt seams -with fat clay pockets 14'-18' -boring cave-in at 14.5' during drilling			101	26			
						87		21	40	16	24
15				Medium dense, red and tan Silt (ML), with clay pockets, wet	20	91		23	24	22	2
	20				14	89		25			
10				Stiff to very stiff, dark tan Lean Clay (CL), with slickensides and fat clay partings	15	99		26	45	19	26
				-red 24'-30'			88	37			
5								28			
	30			Termination Depth = 30 feet							
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **18** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **18** FEET WHILE DRILLING
WATER LEVEL AT **11.8** FEET AFTER **1/4 HR**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

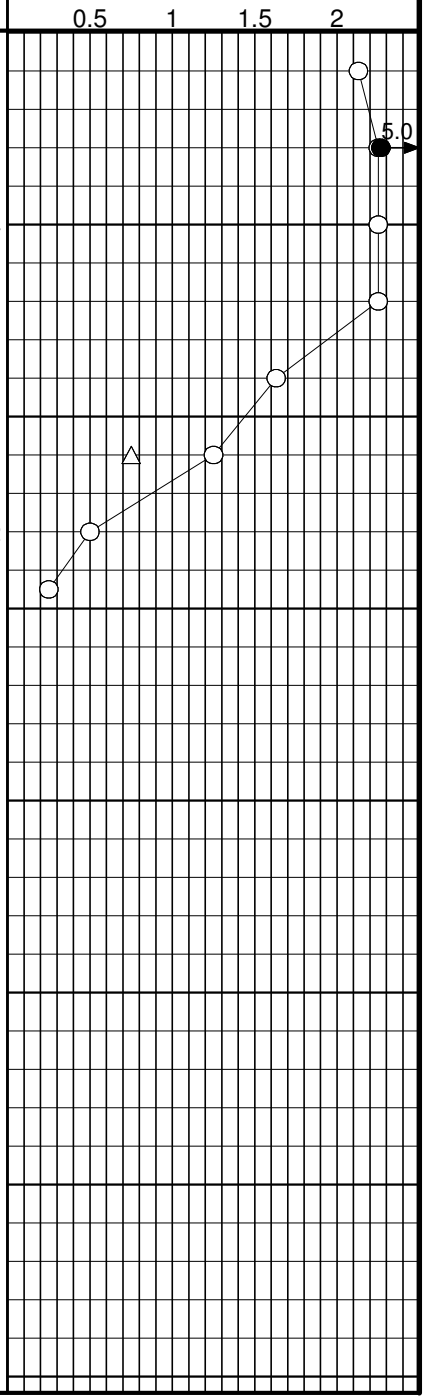
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-3**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION *Survey Coordinates (TSPC, Surface):* *Easting: 3155396.0012* *Northing: 13806958.5528* *Elevation: 33.003*	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Very stiff to hard, dark brown Fat Clay (CH), with slickensides and ferrous nodules				19			
30							111	17			
	5			-dark olive gray 4'-6'		94		22	75	21	54
				-gray and tan, with calcareous nodules 6'-10'				26			
25								24			
	10			Soft to very stiff, red, tan, and gray Lean Clay (CL), with ferrous nodules			106	23			
20						96		23	38	16	22
				-gray and tan 14'-15'				32			
	15			Termination Depth = 15 feet							
15											
	20										
10											
	25										
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **N/A** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **N/A** FEET WHILE DRILLING
WATER LEVEL AT **N/A** FEET AFTER **COMPLETED**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-4**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/11/14**

DESCRIPTION

Survey Coordinates (TSPC, Surface):

Easting: 3155443.6844

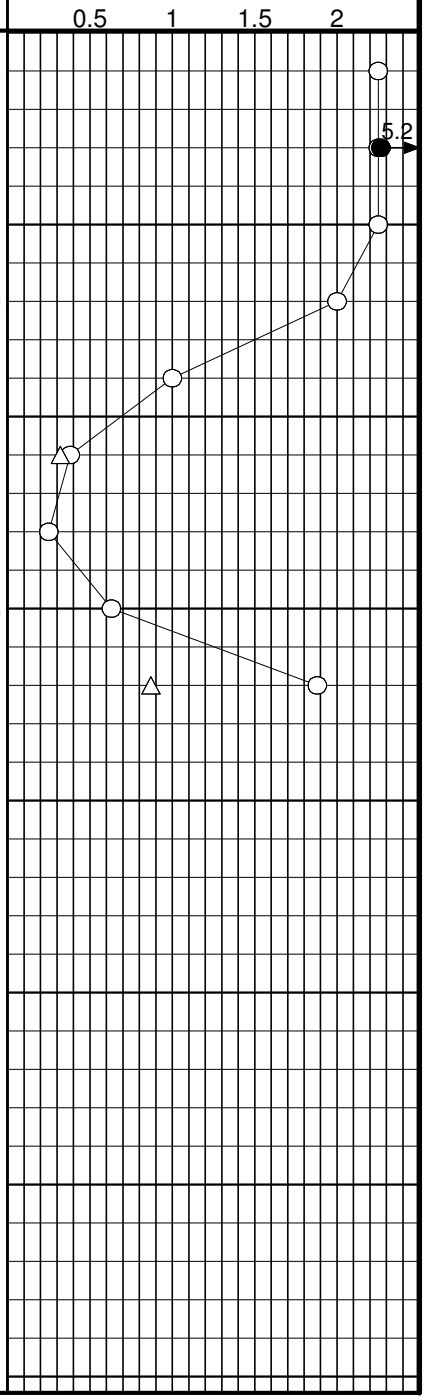
Northing: 13807403.4718

Elevation: 31.669

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Fill: hard, brown and light gray Fat Clay (CH)		95		19	63	20	43
30				Very stiff to hard, brown and olive Fat Clay (CH), with slickensides			110	19			
	5							22			
25				-olive gray and dark gray 6'-8', with calcareous nodules 6'-10'		94		27	84	24	60
				-gray and tan 8'-10'				31			
	10			Soft to stiff, tan and gray Lean Clay (CL)			91	32			
20				-with silt pockets 12'-16', wet at 12'				30			
	15			-with calcareous nodules 14'-16' -boring cave-in at 16' during drilling		95		22	33	17	16
15				Stiff to very stiff, red, tan, and gray Fat Clay (CH), with silt pockets and calcareous nodules			110	21			
	20			Dense to very dense, dark tan Sandy Silt (ML), wet	36	75		25			
10				-tan, with fat clay seams 23'-25'	83/ 10"			20			
	25			Termination Depth = 25 feet							
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **20** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **18** FEET WHILE DRILLING

WATER LEVEL AT **12.1** FEET AFTER **1/4 HR**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

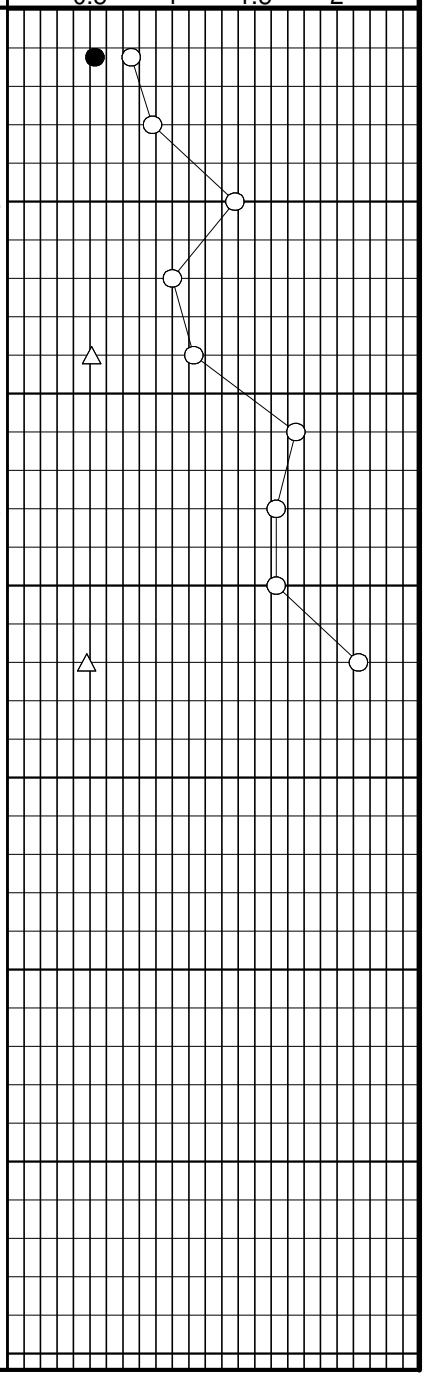
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-5**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3155424.4789* *Northing: 13807944.8737* *Elevation: 31.237*							
	0			Pavement: 5.75" concrete							
30				Stiff to very stiff, olive gray Fat Clay (CH), with slickensides and sand partings			86	37			
				-with ferrous nodules 2'-4'				33			
	5			-gray and tan, with abundant calcareous nodules 4'-6'		79		29	82	24	58
25				-reddish tan 6'-10'				34			
							92	30			
	10			-gray, with ferrous nodules 10'-12'							
20								20			
				Firm to hard, gray Lean Clay w/Sand (CL), with ferrous nodules and silt partings		85		21	33	20	13
	15			-with silt seams 14'-16', and calcareous nodules 14'-18'				22			
15				-gray and reddish tan, with silt pockets and fat clay seams 16'-18'			106	23			
				Medium dense, gray and brown Sandy Silt (ML), wet	24	67		24			
	20										
10											
				Very stiff, reddish brown and gray Fat Clay (CH), with slickensides, calcareous nodules, and sand pockets	25			28			
	25			Termination Depth = 25 feet							
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **16** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **16** FEET WHILE DRILLING
WATER LEVEL AT **14.8** FEET AFTER **1/4 HR**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-5A**

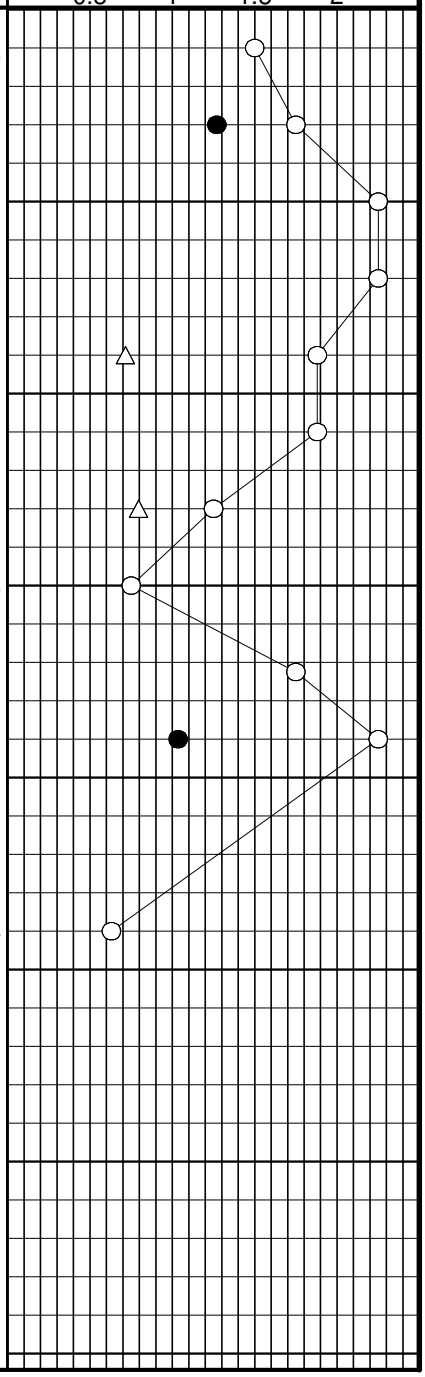
COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger** DATE **4/27/15**

DESCRIPTION
Survey Coordinates (TSPC, Surface):
Easting: 3155438.0757
Northing: 13807987.836
Elevation: 31.8345

ELEVATION IN FEET	DEPTH IN FEET	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0	Fill: very stiff, gray Fat Clay (CH), with roots		93		25	70	20	50
30		Stiff to hard, dark gray Fat Clay (CH), with slickensides			94	28			
		-gray and tan 4'-8'							
	5					24			
25				95		24	76	23	53
		-brown and light gray 8'-12'							
		-borehole cave in at 8' after 24 hours			90	32			
	10								
						24			
20		-with silt and sand partings, siltstone fragments, and ferrous nodules 12'-14'			100	26			
	15	Stiff, tan and gray Lean Clay (CL), with abundant silt seams and partings		97	99	25	46	18	28
15		Very stiff to hard, red, brown, and light gray Fat Clay (CH), with slickensides and siltstone fragments	10			24			
		-with sand seams 18'-20'			98	28			
	20								
10		Stiff, brown Lean Clay (CL), with silt seams							
		-with abundant sand seams 23'-25'		100		33	43	19	24
	25	Termination depth = 25 feet							
5									
	30								
0									
	35								

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **25** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **18** FEET WHILE DRILLING ▽
WATER LEVEL AT **8** FEET AFTER **24 HRS** ▼
DRILLED BY **Van & Sons** DRAFTED BY **CHL** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

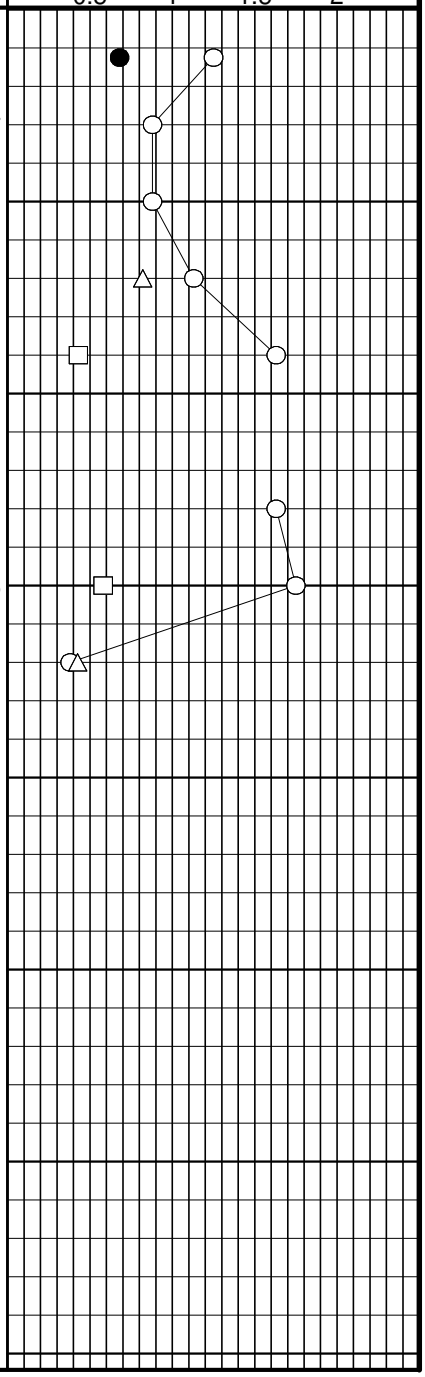
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-6**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
		Survey Coordinates (TSPC, Surface): *Easting: 3155403.6427* *Northing: 13808447.1749* *Elevation: 31.486*							
	0	Pavement: 6" concrete							
30		Stiff to very stiff, olive brown Fat Clay (CH), with slickensides and ferrous nodules			91	32			
		-gray and tan, with calcareous nodules 2'-6'		95		31	79	22	57
	5					36			
25		-tan, with silty clay seams 6'-8'			104	23			
		Firm to very stiff, reddish tan and dark tan Silty Clay (CL-ML)		90		20	26	19	7
	10	-with clayey silt pockets 8'-10'							
20			11	90		24			
		Stiff to very stiff, reddish brown Lean Clay (CL), with slickensides				31			
	15			98		22	43	18	25
15		Medium dense, reddish tan Silt (ML), wet			102	24			
		-with clay partings 16'-18'							
		-dark tan 18'-25'	18			26			
	20								
10									
		-with silty clay pockets 23'-25'	28	97		27			
	25	Termination Depth = 25 feet							
5									
	30								
0									
	35								

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **15** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **15** FEET WHILE DRILLING

WATER LEVEL AT **14.1** FEET AFTER **1/4 HR**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

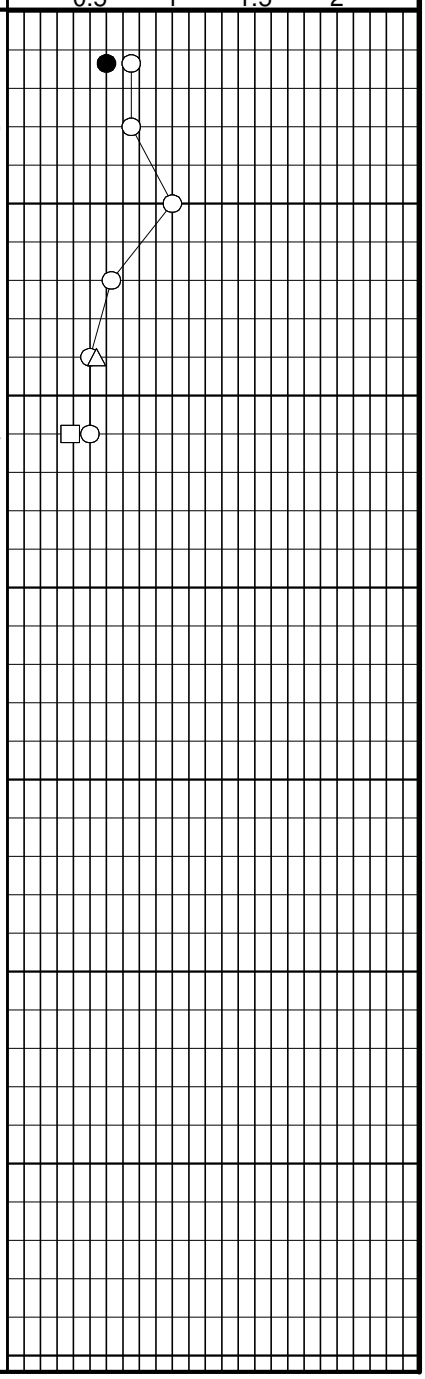
AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-7**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3155382.0260* *Northing: 13808948.8084* *Elevation: 31.979*							
	0			Pavement: 6.4" concrete							
				Base: 2" silty sand, with clay pockets			98	25			
30				Stiff to very stiff, gray and brown Fat Clay (CH), with slickensides		89		30	72	22	50
				-with ferrous nodules 1'-4'							
	5			-light olive gray, with abundant calcareous and ferrous nodules 4'-6'				31			
				-gray and tan 6'-8'							
25								34			
				Firm to stiff, tan Lean Clay (CL), with silt pockets, ferrous and calcareous nodules			97	29			
	10										
						95		24	32	18	14
20				-tan and red, with fat clay seams 12'-14'							
				-boring cave-in at 13' during drilling	11			28			
				-wet at 14'	15	98		24			
	15			Termination Depth = 15 feet							
15											
	20										
10											
	25										
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF



BORING DRILLED TO **N/A** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **13** FEET WHILE DRILLING

WATER LEVEL AT **N/A** FEET AFTER **COMPLETED**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-7A**

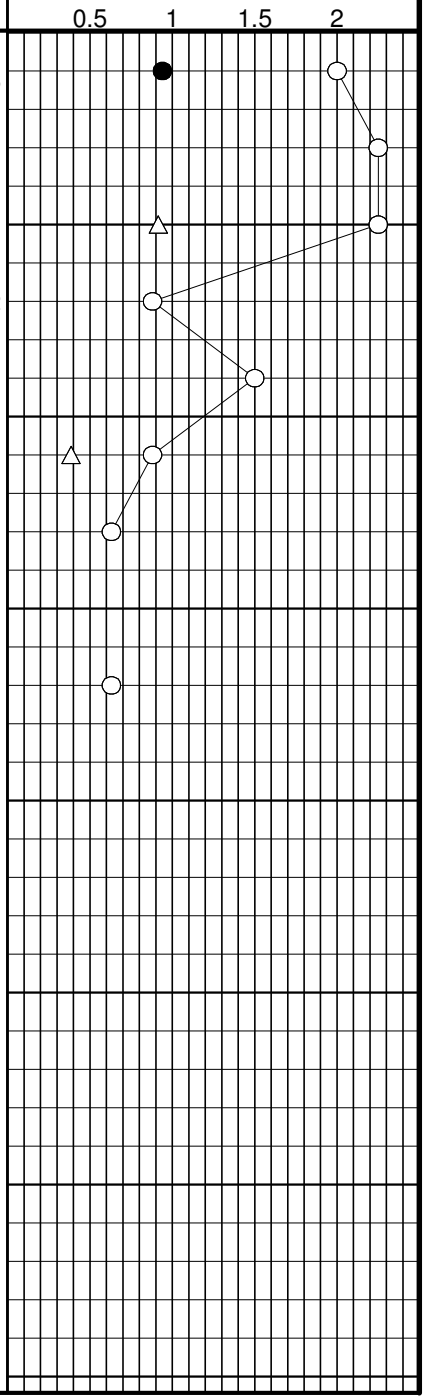
COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/Wet Rotary** DATE **4/27/15**

DESCRIPTION
Survey Coordinates (TSPC, Surface):
Easting: 3155388.9432
Northing: 13809214.3338
Elevation: 32.1266

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Stiff to hard, tan and gray Fat Clay (CH) -with roots 0'-4'		89	97	23	79	23	56
30				-tan and gray, with siltstone fragments, and calcareous and ferrous nodules 2'-6'				20			
	5						101	22			
25				Stiff to very stiff, tan and gray Fat Clay w/ Sand (CH) -with abundant calcareous nodules 6'-8' -red, brown, and light gray, with siltstone fragments 8'-10'		73	97	27	64	22	42
								24			
	10			Firm to stiff, red, brown, and light gray Silty Clay w/Sand (CL-ML), with siltstone fragments and calcareous nodules -boring cave in at 10.8' during drilling			110	24			
20						79		22	26	19	7
				-borehole cave in at 13.8' after 24 hours							
	15			Loose to medium dense, brown, light gray, and tan Silt (ML), with abundant clay and sand seams, wet	5			25			
15				-with calcareous nodules and siltstone fragments 14'-16'				24			
				-brown 16'-18' -tan 18'-25'	11	88		25	25	23	2
	20										
10											
					12			30			
	25			Termination depth = 25 feet							
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **16** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **13** FEET WHILE DRILLING
WATER LEVEL AT **6.1** FEET AFTER **24 HRS**
DRILLED BY **Van & Sons** DRAFTED BY **CHL** LOGGED BY **CHL**

PROJECT: **60 Inch Waterline Along Monroe and Rockhill**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

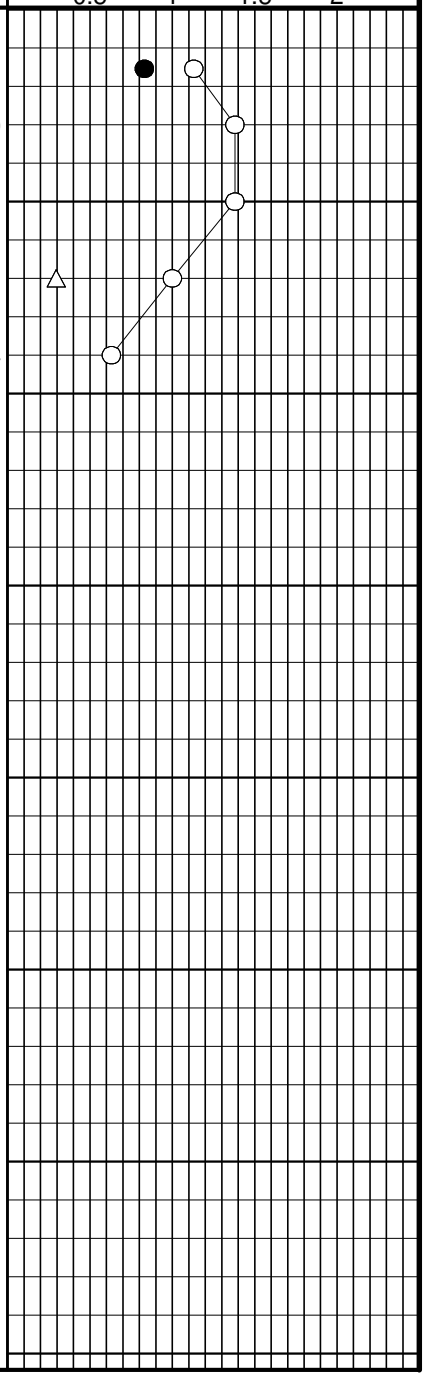
BORING **B-8**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
		Survey Coordinates (TSPC, Surface): *Easting: 3155361.0058* *Northing: 13809454.2279* *Elevation: 31.785*							
	0	Pavement: 7" concrete							
30		Base: 6" dark tan Silty Sand (SM), with clay pockets			103	22			
		Stiff to very stiff, dark gray, brown, and light gray Fat Clay (CH), with ferrous and calcareous nodules		93		24	58	19	39
	5	-gray and tan 2'-4'				22			
		-reddish tan 4'-6'							
25		Firm to very stiff, tan Sandy Fat Clay (CH), with abundant sand and silt pockets, seams, and calcareous nodules			105	22			
		-red, brown, and tan 8'-10'		53		23	54	20	34
	10	Loose to medium dense, tan Silty Sand (SM)	4	34		25			
20		-wet at 12'	7			27			
	15		13			25			
15		-with clay seams and calcareous nodules 16'-18'	14			29			
		Very stiff to hard, tan Sandy Lean Clay (CL), with silty sand seams	41	59		27			
	20	-with fat clay layer 18'-20'							
10		-with clayey and silty sand pockets 23'-25'	29			25			
	25	Termination Depth = 25 feet							
5									
	30								
0									
	35								

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **12** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **12** FEET WHILE DRILLING ▽

WATER LEVEL AT **12.4** FEET AFTER **1/4 HR** ▼

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

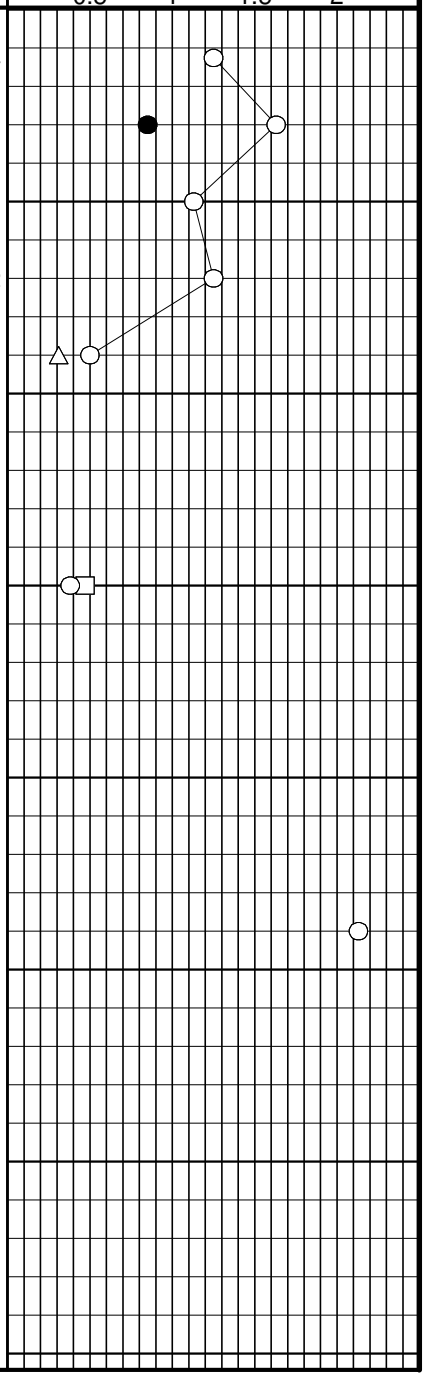
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-9**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/10/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3155341.3908* *Northing: 13809926.2791* *Elevation: 32.221*							
	0			Pavement: 6.25" concrete							
30				Stiff to very stiff, dark brown Fat Clay (CH), with slickensides and ferrous nodules -gray and brown 2'-4'		95		27	63	19	44
							97	24			
				-gray and tan 4'-8'							
	5							25			
25				Very stiff, dark tan, reddish tan, and gray Lean Clay (CL)		96		26	48	16	32
				Firm to stiff, dark tan and gray Silty Clay (CL-ML)			107	23			
	10			-wet at 10'							
					5	89		36			
20											
					6	98		30	28	23	5
				Firm, tan Lean Clay (CL), with silt pockets							
	15					97		25	31	23	8
15				Loose to medium dense, brown Silt w/Sand (ML), wet	5			29			
				-with gray clay pockets 18'-20'							
					15	79		27			
	20										
10				Hard, reddish brown Fat Clay (CH), with slickensides							
								34			
	25			Termination Depth = 25 feet							
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **12** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **10** FEET WHILE DRILLING
WATER LEVEL AT **9.8** FEET AFTER **1/4 HR**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

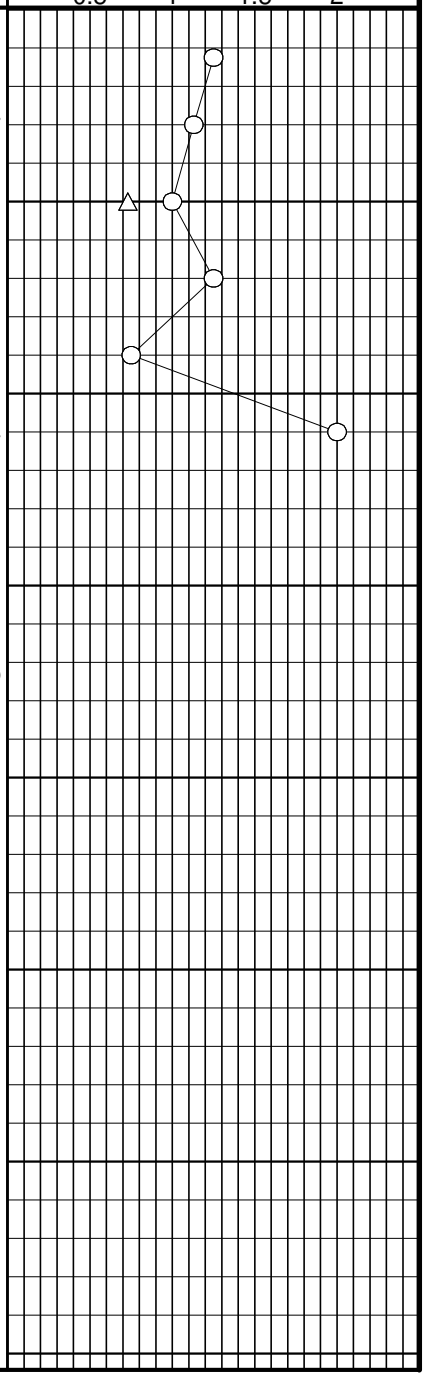
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-10**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3154985.5243* *Northing: 13809999.7325* *Elevation: 32.099*							
	0			Pavement: 6" concrete							
30				Stiff to hard, dark gray and brown Fat Clay (CH), with slickensides and ferrous nodules				27			
				-light brown and dark brown 2'-4'		92		23	67	20	47
	5			-gray and tan 4'-8', with large calcareous nodules 4'-6'			94	29			
				-with silt seams 6'-8'							
25								22			
				-with silt pockets 8'-10'							
								22			
	10			-red and tan, with silty clay pockets and calcareous nodules 10'-12'		99		21	59	25	34
20				Loose, dark tan Silt w/Sand (ML), wet							
				-with silty clay pockets 12'-16'			107	24			
	15			-boring cave-in at 14' during drilling	8	81		23			
15				Medium dense, dark tan Silt (ML), wet	20	86		24	np	np	np
					12			25			
	20										
10				Medium dense, dark tan Sandy Silt (ML), with gravel, wet							
					23	55		25			
	25			Termination Depth = 25 feet							
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **14** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **14** FEET WHILE DRILLING ▽

WATER LEVEL AT **7.6** FEET AFTER **1/4 HR** ▼

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

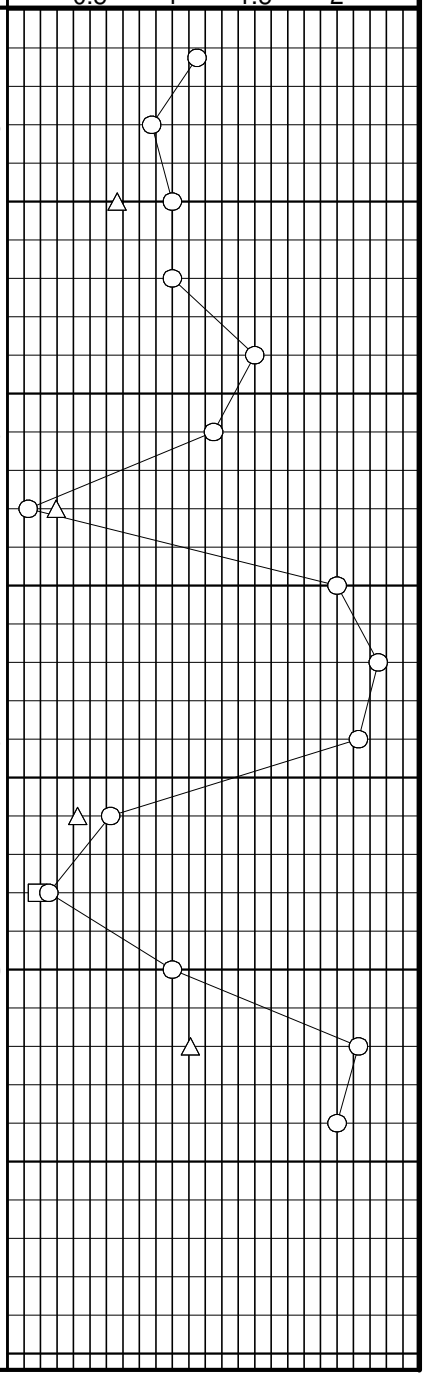
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-11**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/12/14**

DESCRIPTION
Survey Coordinates (TSPC, Surface):
Easting: 3154476.4650
Northing: 13809971.5842
Elevation: 33.499

SHEAR STRENGTH, TSF: △ Confined Compression; ● Unconfined Compression; ○ Pocket Penetrometer; □ Torvane (0.5, 1, 1.5, 2)

ELEVATION IN FEET	DEPTH IN FEET	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0	Pavement: 6.125" concrete							
		Stiff to very stiff, dark gray Fat Clay (CH) -with ferrous nodules 0'-2'				29			
30				93		27	64	19	45
		-tan and gray 4'-12'							
	5				95	29			
		-with calcareous 6'-8' and ferrous nodules 6'- 10'				30			
25						22			
	10	-with calcareous nodules 10'-12'		95		24	52	19	33
		Soft to firm, tan and gray Lean Clay (CL), with abundant silt seams			107	23			
20									
	15	Very stiff to hard, reddish tan Fat Clay (CH), with slickensides				27			
		-with silt seams 16'-18'	▼			26			
15		-with calcareous nodules 18'-20'		99		30	66	23	43
	20	Soft to stiff, reddish tan and dark tan Lean Clay (CL), with fat clay pockets -boring cave-in at 21.7 feet during drilling -with abundant silt seams 22'-24'			104	25			
10			▽	99		23			
	25	Red and tan Clayey Sand (SC), with calcareous nodules and fat clay seams		41		22	39	20	19
		Very stiff to hard, reddish tan Fat Clay (CH), with slickensides			93	30			
5		-brown 28'-30'				29			
	30								
		Dark tan Silt w/Sand (ML), wet							
0		Termination Depth = 35 feet		73		23			
	35								



BORING DRILLED TO **24** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **23** FEET WHILE DRILLING ▽
WATER LEVEL AT **16.7** FEET AFTER **1/4 HR** ▼
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

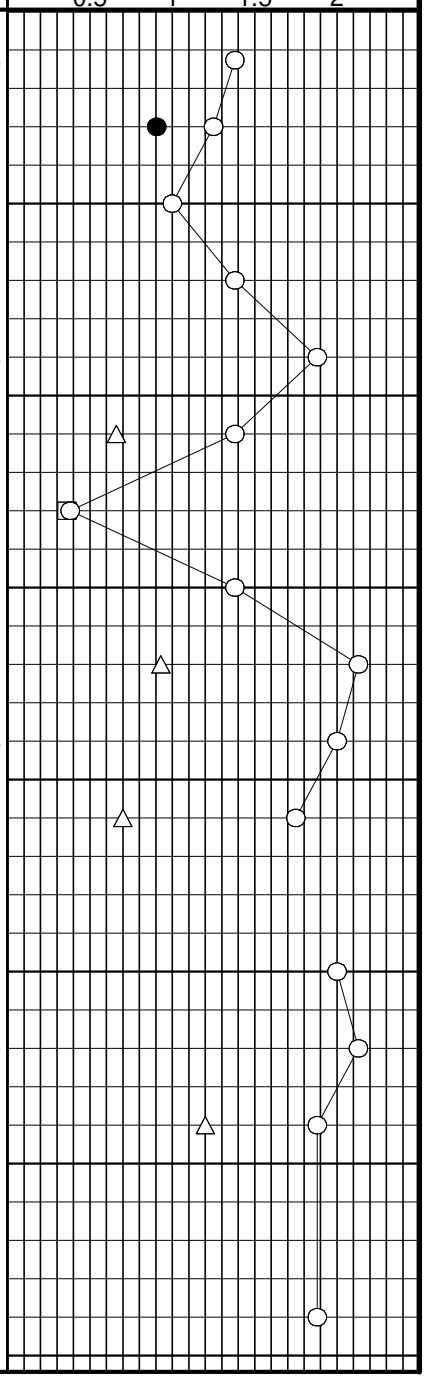
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-12**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/12/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3154182.3370* *Northing: 13809955.5142* *Elevation: 33.880*							
	0			Pavement: 5.375" concrete							
				Base: 1" crushed shell		91		24	63	18	45
				Stiff to very stiff, dark gray and brown Fat Clay (CH), with slickensides and ferrous nodules			101	24			
30				-olive gray 2'-4'							
	5			-light gray, with abundant calcareous nodules 4'-6'				27			
				-gray and reddish tan 6'-8'				30			
25				Firm to very stiff, reddish tan and brown Lean Clay (CL)		99		20	42	17	25
	10			-with silty clay pockets and ferrous nodules 8'-12'			104	21			
				-with fat clay pockets and calcareous nodules 12'-14'		88		22			
20				Stiff to hard, dark tan Fat Clay (CH), with slickensides and fat clay pockets				27			
	15			-with calcareous nodules 14'-18'							
				-reddish brown 16'-20'			101	26			
				-with silt seams 18'-20'							
15						99		26	56	22	34
	20			-boring cave-in at 21.7 feet during drilling							
							94	30			
				Dark tan Sandy Silt (ML), wet		68		23			
10											
	25			Very stiff to hard, reddish brown Fat Clay (CH), with slickensides				34			
						100		31	68	28	40
5							93	32			
	30										
0				Termination Depth = 35 feet				28			
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **24** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **22** FEET WHILE DRILLING

WATER LEVEL AT **17.1** FEET AFTER **1/4 HR**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

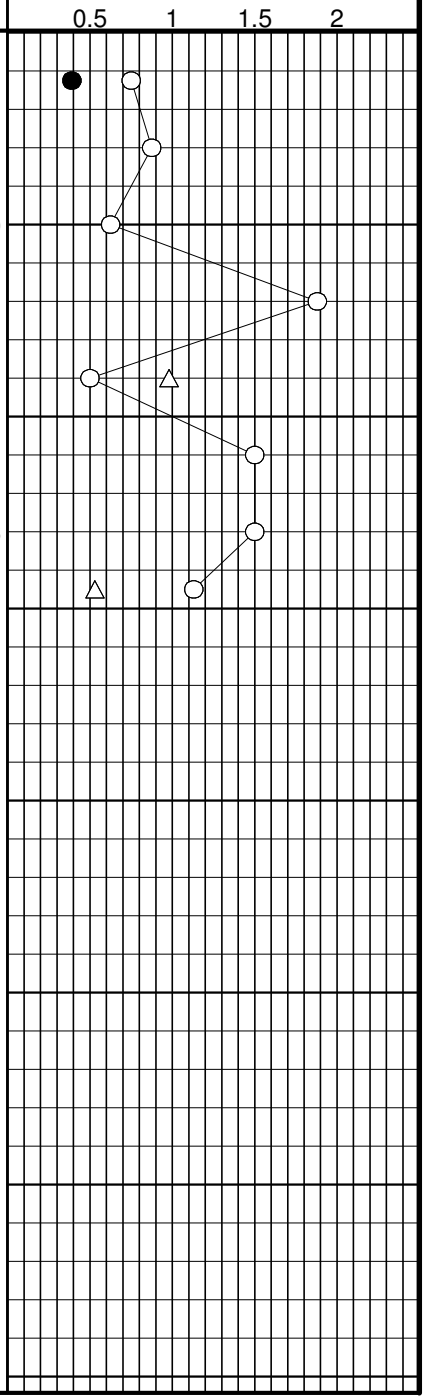
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-13**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION *Survey Coordinates (TSPC, Surface):* *Easting: 3153819.8337* *Northing: 13809935.4681* *Elevation: 32.773*	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Pavement: 5.75" concrete							
				Base:0.25" shell and sand			89	32			
30				Firm to stiff, dark gray Fat Clay (CH), with slickensides -with ferrous nodules 0'-4'				30			
	5			-gray and tan, with abundant calcareous nodules 4'-6'		87		31	72	23	49
25				Firm to very stiff, dark tan and gray Lean Clay (CL), with silty clay seams and pockets -with ferrous nodules, fat clay seams, and fat clay pockets 6'-14'			107	20 20			
	10			-reddish tan, with calcareous nodules 10'-14'				25			
20						98		21	44	18	26
	15			-dark tan 14'-15' Termination Depth = 15 feet			105	23			
15											
	20										
10											
	25										
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **N/A** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **N/A** FEET WHILE DRILLING
WATER LEVEL AT **N/A** FEET AFTER **COMPLETED**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-14**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/11/14**

DESCRIPTION

Survey Coordinates (TSPC, Surface):

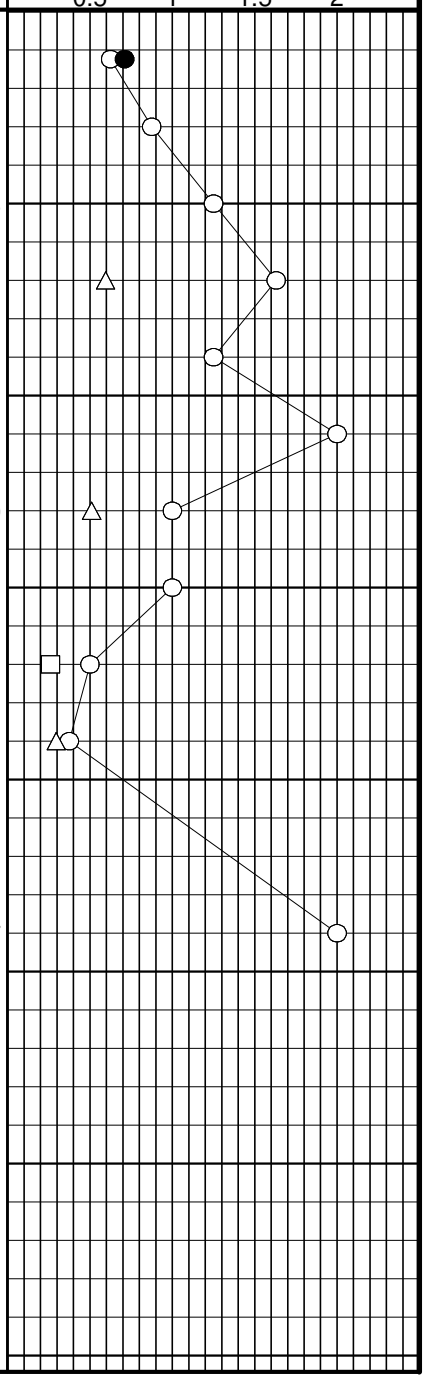
Easting: 3153469.2658

Northing: 13809916.0284

Elevation: 33.886

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Pavement: 5.75" concrete							
				Stiff to very stiff, dark gray and brown Fat Clay (CH), with slickensides and ferrous nodules			99	25			
				-with calcareous nodules 2'-6'				27			
30	5					87		27	63	20	43
				-red, tan, and gray 6'-8'			96	29			
				-with calcareous nodules 8'-10'				32			
25	10			Firm to very stiff, gray, tan, and reddish tan Lean Clay (CL)				18			
				-with ferrous nodules 10'-14'		94	104	21	36	17	19
20				-with silt seams and partings 12'-18'				25			
	15					98		28			
15				-with ferrous nodules 18'-20' -wet at 19'			98	27			
	20										
				Very stiff, reddish brown Fat Clay (CH), with slickensides, silt seams, and calcareous nodules		96		29	73	26	47
10	25			Termination Depth = 25 feet							
5	30										
0	35										

SHEAR STRENGTH, TSF



BORING DRILLED TO **19** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **19** FEET WHILE DRILLING

WATER LEVEL AT **16.4** FEET AFTER **1/4 HR**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

PROJECT: **60 Inch Waterline Along Monroe and Rockhill**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

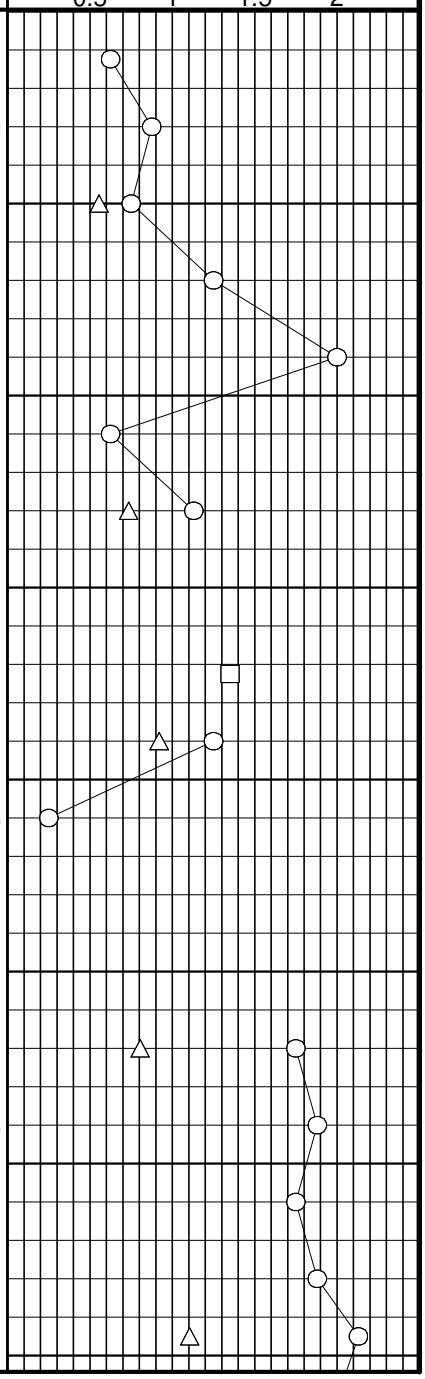
BORING **B-15**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/12/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3153015.3502* *Northing: 13809922.0327* *Elevation: 33.775*							
	0			Pavement: 5.5" concrete							
				Base: 0.25" sand, gravel, and crushed shell				30			
30				Stiff to very stiff, gray Fat Clay (CH), with slickensides		87		28	58	19	39
				-gray and tan 2'-4', with calcareous and ferrous nodules 2-'6'							
	5			-tan and gray 4'-8'			92	32			
								22			
25				Stiff to very stiff, dark tan and gray Lean Clay (CL), with silt pockets				20			
	10			-gray and tan, with calcareous nodules 10'-14'		85		21	36	15	21
							106	24			
20											
	15			-tan,with abundant silt seams 14'-16'	16	99		23			
				Stiff to very stiff, red and tan Fat Clay (CH), with slickensides	39			27			
				-boring cave-in at 16.5' during drilling							
15				-with abundant silt seams 18'-20'			97	25			
	20			Firm to very stiff, reddish tan Lean Clay (CL)		99		26	34	20	14
				-with silty clay seams and pockets 20'-24' and calcareous nodules 20'-22', wet	27	86		28			
10											
	25			Stiff to hard, red Fat Clay (CH), with slickensides	33			27			
				-red and brown, with gravel 26'-28'			93	28			
				-brown 28'-35'							
5						100		30	74	28	46
	30										
								30			
								30			
0				-with silt seams 34'-35'			99	27			
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **18** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **18** FEET WHILE DRILLING

WATER LEVEL AT **11** FEET AFTER **1/4 HR**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

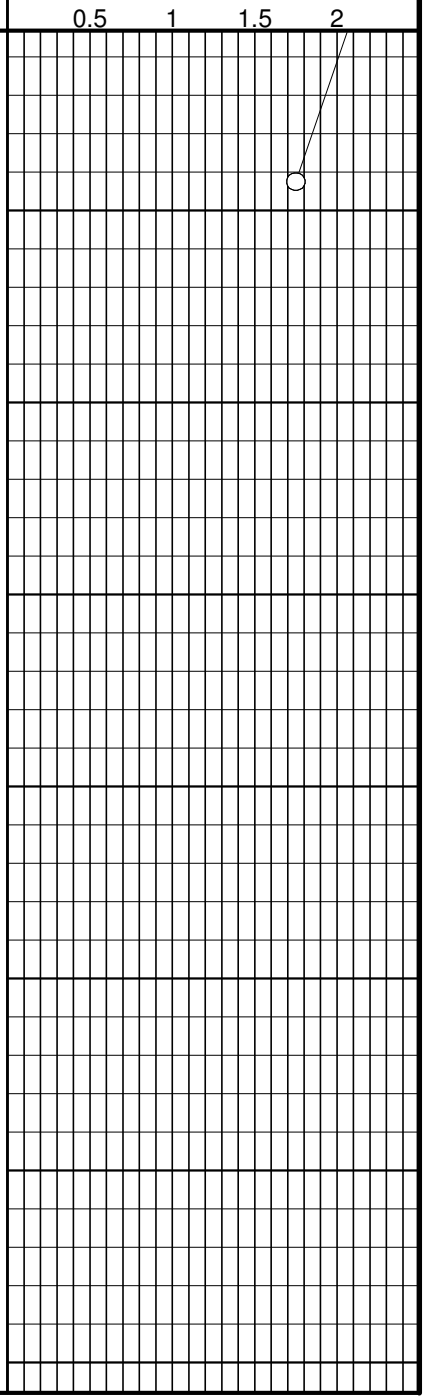
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-15**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/12/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Fat Clay (cont...)							
				-dark tan, with silt seams 38'-40'	28			25			
-5	40			Termination Depth = 40 feet							
-10	45										
-15	50										
-20	55										
-25	60										
-30	65										
-35	70										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **18** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **18** FEET WHILE DRILLING
WATER LEVEL AT **11** FEET AFTER **1/4 HR**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

PROJECT: **60 Inch Waterline Along Monroe and Rockhill**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

BORING **B-15A**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **4/27/15**

DESCRIPTION

Survey Coordinates (TSPC, Surface):

Easting: 3152991.03

Northing: 13809847.422

Elevation: 36.314

SHEAR STRENGTH, TSF

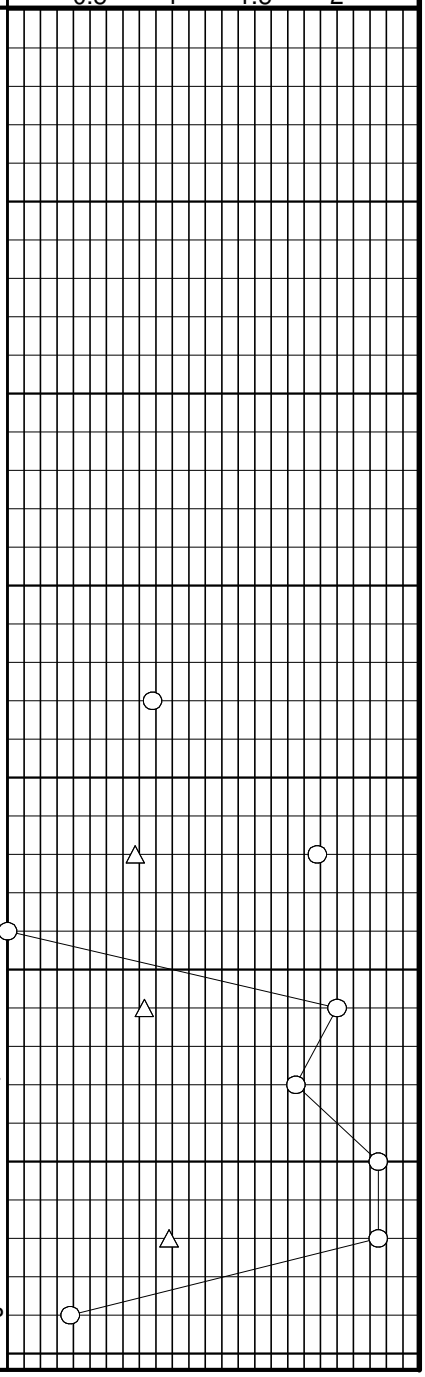
△ Confined Compression

● Unconfined Compression

○ Pocket Penetrometer

□ Torvane

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Auger to 15 feet below grade							
35											
	5										
30											
	10										
25											
	15			-borehole cave in at 14.5' after 24 hours							
20				Loose to medium dense, tan Silt (ML), with clay partings, wet	5			26			
						97		23	26	23	3
	20			-with abundant siltstone fragments and large calcareous nodules 19'-21'	14			25			
15				Stiff to very stiff, red, brown, and light gray Fat Clay (CH), with slickensides, siltstone fragments, and calcareous nodules			97	29			
				Very soft, tan Sandy Silty Clay (CL-ML), wet		69		32	28	24	4
	25			Stiff to hard, red, brown, and light gray Fat Clay (CH), with slickensides			92	31			
10				-with silt seams and pockets 27'-29'		100		32	75	28	47
	30							29			
5							97	30			
				Tan Silt (ML), wet		97		25	NP	NP	NP
	35										



BORING DRILLED TO **17** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **17** FEET WHILE DRILLING ▽

WATER LEVEL AT **11.7** FEET AFTER **24 HRS** ▼

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-15A**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **4/27/15**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0				Silt (cont...)							
				Medium dense, tan Sandy Silt (ML), wet	29	58		24			
	40			Termination depth = 40 feet							
-5											
	45										
-10											
	50										
-15											
	55										
-20											
	60										
-25											
	65										
-30											
	70										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane

0.5 1 1.5 2

BORING DRILLED TO **17** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **17** FEET WHILE DRILLING
WATER LEVEL AT **11.7** FEET AFTER **24 HRS**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-16**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/12/14**

DESCRIPTION

Survey Coordinates (TSPC, Surface):

Easting: 3152738.1517

Northing: 13809971.2410

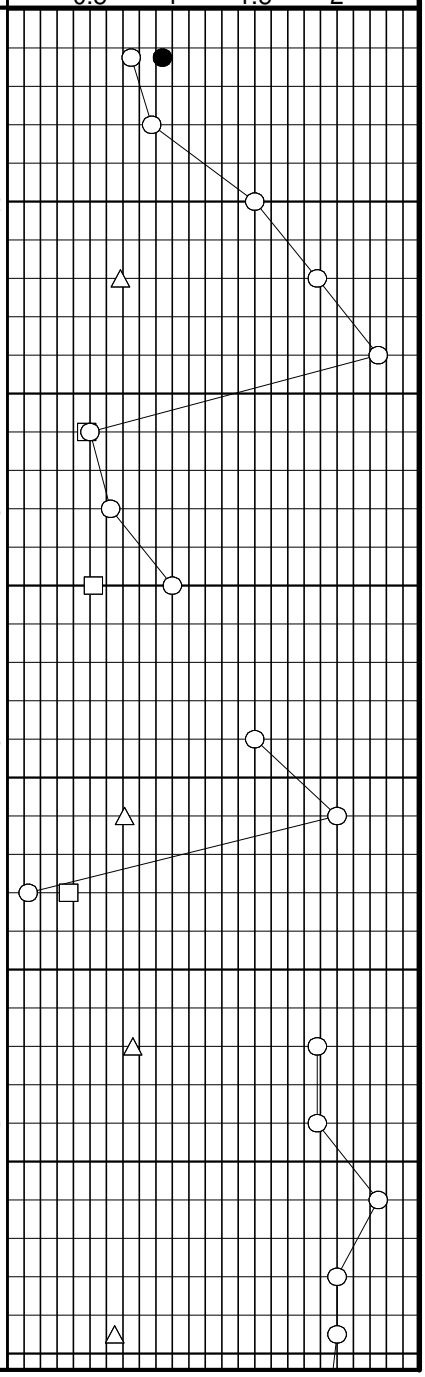
Elevation: 34.623

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane

0.5 1 1.5 2

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Pavement: 5.75" concrete							
				Base: 0.25" sand, gravel, and crushed shell			101	27			
				Stiff to hard, dark brown Fat Clay (CH), with slickensides				28			
				-gray and tan, with ferrous and abundant calcareous nodules 2'-6'							
30	5					88		23	64	22	42
				-red, brown, and gray, with silty clay pockets 6'-10'			103	21			
								20			
25	10			Firm to very stiff, gray and tan Lean Clay (CL)				25			
				-with abundant calcareous nodules 10'-14'							
				-with abundant silty clay seams and pockets 12'-16'		99		23	33	18	15
				-red, tan, and gray 14'-16'							
20	15							23			
				Stiff to very stiff, brown, red, and gray Fat Clay (CH), with slickensides	28			25			
						100		37	71	25	46
15	20			-dark tan 20'-22'			96	29			
				Medium dense, red and tan Silt w/Sand (ML), with clay partings				24			
				-wet 24'							
10	25				18	84		26			
				Stiff to hard, dark red and tan Fat Clay (CH), with slickensides			88	33			
						100		30	78	28	50
5	30			-red and brown 30'-35'							
								30			
								30			
0	35						92	31			



BORING DRILLED TO **18** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **16** FEET WHILE DRILLING

WATER LEVEL AT **15** FEET AFTER **1/4 HR**

DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-16**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/12/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Fat Clay (cont...)							
				-brown, with silt pockets 38'-40'		99		29	69	25	44
-5	40			Termination Depth = 40 feet							
-10	45										
-15	50										
-20	55										
-25	60										
-30	65										
-35	70										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane

0.5 1 1.5 2

BORING DRILLED TO **18** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **16** FEET WHILE DRILLING
WATER LEVEL AT **15** FEET AFTER **1/4 HR**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

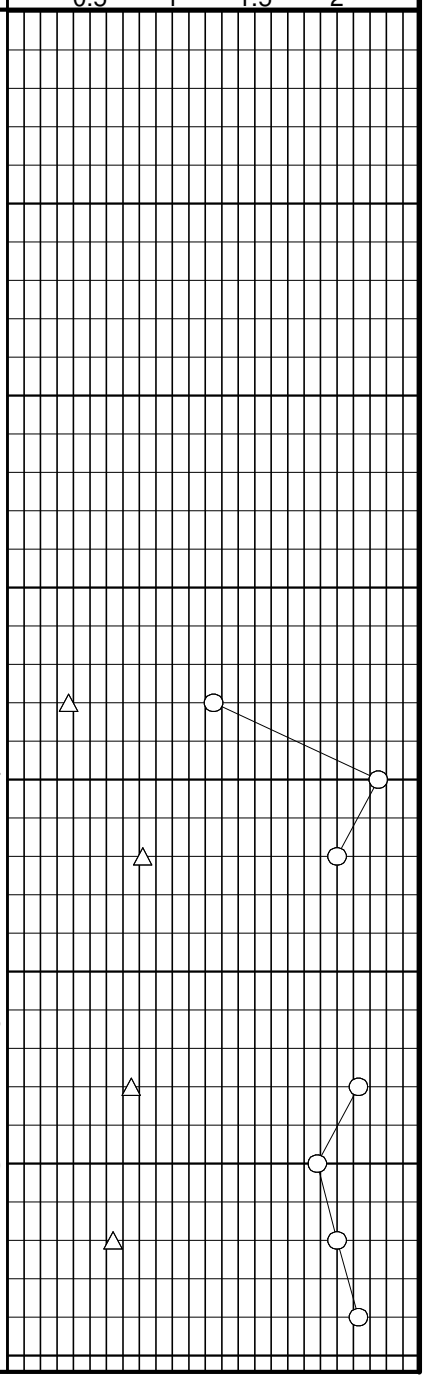
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-16A**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **4/27/15**

DESCRIPTION
Survey Coordinates (TSPC, Surface):
Easting: 3152746.791
Northing: 13809904.515
Elevation: 36.287

SHEAR STRENGTH, TSF: △ Confined Compression; ● Unconfined Compression; ○ Pocket Penetrometer; □ Torvane

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Auger to 15 feet below grade							
35											
	5										
30											
	10										
25											
	15			Firm, tan Lean Clay (CL), with abundant silt seams							
20				-wet at 16'	5	97		27	27	19	8
				Firm to hard, red and brown Fat Clay (CH), with slickensides			99	29			
	20			-with silty clay seams 17'-19' -red, brown, and light gray 19'-23', with silt and sand seams 19'-21'		100		31	73	26	47
15				-with calcareous nodules and siltstone fragments 21'-23'			96	31			
				Medium dense, tan Silt (ML), with clay partings, wet				26			
	25			-borehole cave in at 24.7' after 24 hours							
10				Stiff to hard, red and brown Fat Clay (CH), with slickensides	16	84		22	56	21	35
				-with silt pockets 27'-29'			93	33			
				-with siltstone fragments 29'-31'							
	30					100		33	78	28	50
5							91	30			
				-red, brown, and light gray, with siltstone fragments 33'-35'				29			
	35										



BORING DRILLED TO **17** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **17** FEET WHILE DRILLING
WATER LEVEL AT **12.3** FEET AFTER **24 HRS**
DRILLED BY **Van & Sons** DRAFTED BY **CHL** LOGGED BY **CHL**

AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-16A**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **4/27/15**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0				Fat Clay (cont...)							
				Medium dense, tan Sandy Silt (ML), wet	22	69		30			
	40			Termination depth = 40 feet							
-5											
	45										
-10											
	50										
-15											
	55										
-20											
	60										
-25											
	65										
-30											
	70										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane

0.5 1 1.5 2

BORING DRILLED TO **17** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **17** FEET WHILE DRILLING
WATER LEVEL AT **12.3** FEET AFTER **24 HRS**
DRILLED BY **Van & Sons** DRAFTED BY **CHL** LOGGED BY **CHL**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

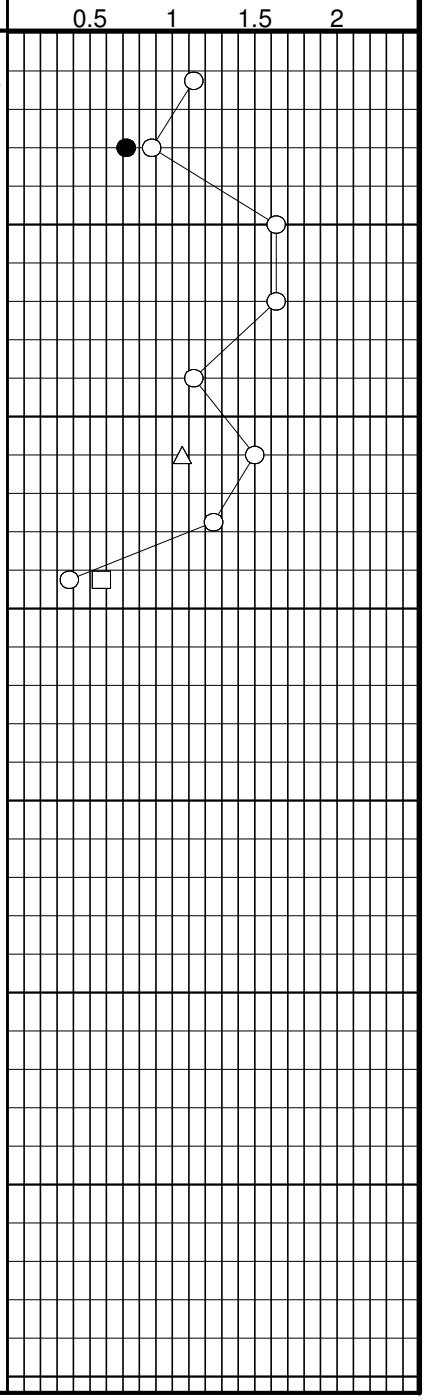
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-17**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger** DATE **9/11/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION *Survey Coordinates (TSPC, Surface):* *Easting: 3152366.2518* *Northing: 13809998.8436* *Elevation: 34.414*	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
	0			Pavement: 5.875" concrete							
				Base: 0.25" sand and shell		87		26	52	17	35
				Stiff to very stiff, dark gray and gray Fat Clay (CH), with slickensides			107	21			
				-with abundant calcareous nodules 0'-2'							
30	5			-gray and tan 4'-8'				20			
				-with ferrous nodules 6'-10'				23			
				-red, tan, and gray 8'-10'		97		30	65	24	41
25	10			Firm to very stiff, tan and gray Lean Clay (CL)			105	22			
								20			
20	15			-with silt partings, ferrous and calcareous nodules 14'-15'				26			
				Termination Depth = 15 feet							
15	20										
10	25										
5	30										
0	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **N/A** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **N/A** FEET WHILE DRILLING
WATER LEVEL AT **N/A** FEET AFTER **COMPLETED**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **CHL**

AVILES ENGINEERING CORP.
GEOTECHNICAL ENGINEERS

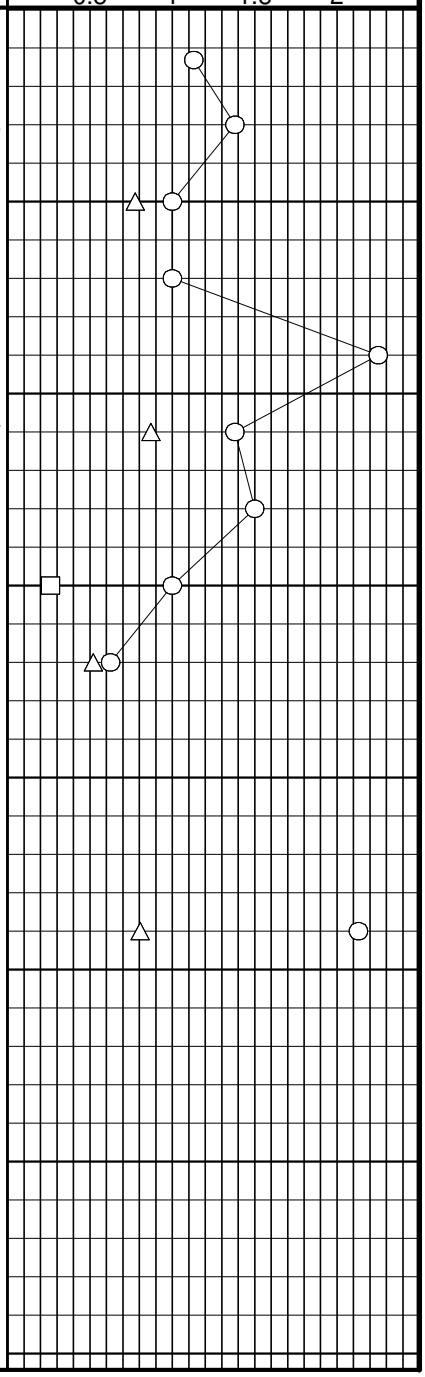
PROJECT: **60 Inch Waterline Along Monroe and Rockhill** BORING **B-18**

COH WBS No. **S-000900-0129-4** TYPE **4" Dry Auger/ Wet Rotary** DATE **9/15/14**

ELEVATION IN FEET	DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	-200 MESH	DRY DENSITY, PCF	MOISTURE CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
				Survey Coordinates (TSPC, Surface): *Easting: 3151903.6282* *Northing: 13809972.7935* *Elevation: 33.186*							
	0			Pavement: 5.5" concrete							
				Base: 0.50" crushed shell				22			
30				Stiff to very stiff, gray and tan Fat Clay (CH), with slickensides -with calcareous and ferrous nodules 2'-6'		77		22	55	17	38
	5						104	26			
				-reddish tan and gray 6'-8'				26			
25				Firm to hard, tan and gray Lean Clay (CL) -with fat clay seams 8'-12'				20			
	10			-with ferrous stains 10'-12' and calcareous nodules 10'-18'		97	106	21	43	16	27
20								24			
	15					86		26	29	18	11
				-with abundant silt seams 16'-18' -boring cave-in at 16.2' during drilling			106	22			
15				Stiff to hard, red and tan Fat Clay (CH), with slickensides -with silt seams 18'-20'	35	99		24			
	20										
10							93	29			
	25			Termination Depth = 25 feet							
5											
	30										
0											
	35										

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **18** FEET WITHOUT DRILLING FLUID
WATER ENCOUNTERED AT **18** FEET WHILE DRILLING
WATER LEVEL AT **12.8** FEET AFTER **1/4 HR**
DRILLED BY **Van & Sons** DRAFTED BY **MRB** LOGGED BY **BPJ**

KEY TO SYMBOLS

Symbol	Description
Strata symbols	
	High plasticity clay
	Silty low plasticity clay
	Silt
	Low plasticity clay
	Fill
	Paving
	Silty sand
	Clayey sand
Misc. Symbols	
	Water table depth during drilling
	Subsequent water table depth
○	Pocket Penetrometer
●	Unconfined Compression
△	Confined Compression
□	Torvane

Symbol	Description
Soil Samplers	
	Undisturbed thin wall Shelby tube
	Standard penetration test
	Rock core
	No recovery

AYLES ENGINEERING CORP.

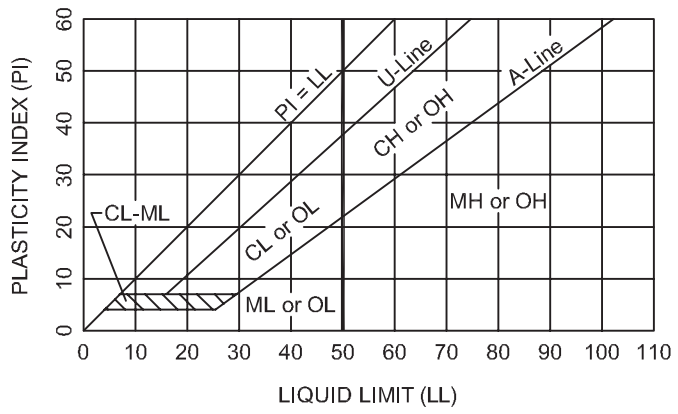
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

ASTM Designation D-2487

MAJOR DIVISIONS				GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (Less than 50% of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)		GW	Well-graded gravel, well-graded gravel with sand
				GP	Poorly-graded gravel, poorly-graded gravel with sand
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	GM	Silty gravel, silty gravel with sand
			Limits plot above "A" line & hatched zone on plasticity chart	GC	Clayey gravel, clayey gravel with sand
	SANDS (50% or more of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)		SW	Well-graded sand, well-graded sand with gravel
				SP	Poorly-graded sand, poorly-graded sand with gravel
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	SM	Silty sand, silty sand with gravel
			Limits plot above "A" line & hatched zone on plasticity chart	SC	Clayey sand, clayey sand with gravel
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)		SILTS AND CLAYS (Liquid Limit Less Than 50%)		ML	Silt, silt with sand, silt with gravel, sandy silt, gravelly silt
				CL	Lean clay, lean clay with sand, lean clay with gravel, sandy lean clay, gravelly lean clay
				OL	Organic clay, organic clay with sand, sandy organic clay, organic silt, sandy organic silt
		SILTS AND CLAYS (Liquid Limit 50% or More)		MH	Elastic silt, elastic silt with sand, sandy elastic silt, gravelly elastic silt
				CH	Fat clay, fat clay with sand, fat clay with gravel, sandy fat clay, gravelly fat clay
				OH	Organic clay, organic clay with sand, sandy organic clay, organic silt, sandy organic silt

NOTE: Coarse soils between 5% and 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone of the plasticity chart are to have dual symbols.

PLASTICITY CHART



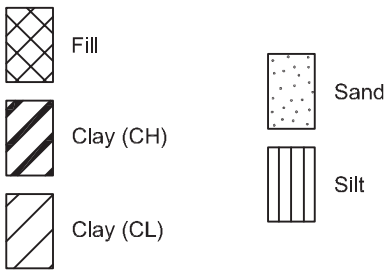
Equation of A-Line: Horizontal at PI=4 to LL=25.5, then PI=0.73(LL-20)

Equation of U-Line: Vertical at LL=16 to PI=7, then PI=0.9(LL-8)

DEGREE OF PLASTICITY OF COHESIVE SOILS

Degree of Plasticity	Plasticity Index
None	0 - 4
Slight	5 - 10
Medium	11 - 20
High	21 - 40
Very High	>40

SOIL SYMBOLS



AYLES ENGINEERING CORP.

TERMS USED ON BORING LOGS

SOIL GRAIN SIZE

U.S. STANDARD SIEVE

6"	3"	3/4"	#4	#10	#40	#200	
BOULDERS	COBBLES	GRAVEL		SAND		SILT	CLAY
		COARSE	FINE	COARSE	MEDIUM	FINE	
152	76.2	19.1	4.76	2.00	0.420	0.074	0.002

SOIL GRAIN SIZE IN MILLIMETERS

STRENGTH OF COHESIVE SOILS

Consistency	Undrained Shear Strength, Kips per Sq. ft.
Very Soft	less than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	greater than 4.00

RELATIVE DENSITY OF COHESIONLESS SOILS FROM STANDARD PENETRATION TEST

Very Loose	<4 bpf
Loose	5-10 bpf
Medium Dense	11-30 bpf
Dense	31-50 bpf
Very Dense	>50 bpf

SPLIT-BARREL SAMPLER DRIVING RECORD

Blows per Foot	Description
25	25 blows driving sampler 12 inches, after initial 6 inches of seating.
50/7"	50 blows driving sampler 7 inches, after initial 6 inches of seating.
Ref/3"	50 blows driving sampler 3 inches, during initial 6-inches seating interval.

NOTE: To avoid change to sampling tools, driving is limited to 50 blows during or after seating interval.

DRY STRENGTH ASTM D2488

None	Dry specimen crumbles into powder with mere pressure of handling
Low	Dry specimen crumbles into powder with some finger pressure
Medium	Dry specimen breaks into pieces or crumbles with considerable pressure
High	Dry specimen cannot be broken with finger pressure, it can be broken between thumb and hard surface
Very High	Dry specimen cannot be broken between thumb and hard surface

MOISTURE CONDITION ASTM D2488

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water

SOIL STRUCTURE

Slickensided	Having planes of weakness that appear slick and glossy. The degree of slickensidedness depends upon the spacing of slickensides and the easiness of breaking along these planes.
Fissured	Containing shrinkage or relief cracks, often filled with fine sand or silt; usually more or less vertical.
Pocket	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	Inclusion less than 1/8 inch thick extending through the sample.
Seam	Inclusion 1/8 inch to 3 inches thick extending through the sample.
Layer	Inclusion greater than 3 inches thick extending through the sample.
Laminated	Soil sample composed of alternating partings or seams of different soil types.
Interlayered	Soil sample composed of alternating layers of different soil types.
Intermixed	Soil sample composed of pockets of different soil types and layered or laminated structure is not evident.
Calcareous	Having appreciable quantities of calcium material.

AVILES ENGINEERING CORP.

ASTM & TXDOT DESIGNATION FOR SOIL LABORATORY TESTS

NAME OF TEST	ASTM TEST DESIGNATION	TXDOT TEST DESIGNATION
Moisture Content	D 2216	Tex-103-E
Specific Gravity	D 854	Tex-108-E
Sieve Analysis	D 421 D 422	Tex-110-E (Part 1)
Hydrometer Analysis	D 422	Tex-110-E (Part 2)
Minus No. 200 Sieve	D 1140	Tex-111-E
Liquid Limit	D 4318	Tex-104-E
Plastic Limit	D 4318	Tex-105-E
Shrinkage Limit	D 427	Tex-107-E
Standard Proctor Compaction	D 698	Tex-114-E
Modified Proctor Compaction	D 1557	Tex-113-E
Permeability (constant head)	D 2434	-
Consolidation	D 2435	-
Direct Shear	D 3080	-
Unconfined Compression	D 2166	-
Unconsolidated-Undrained Triaxial	D 2850	Tex-118-E
Consolidated-Undrained Triaxial	D 4767	Tex-131-E
Pinhole Test	D 4647	-
California Bearing Ratio	D 1883	-
Unified Soil Classification System	D 2487	Tex-142-E

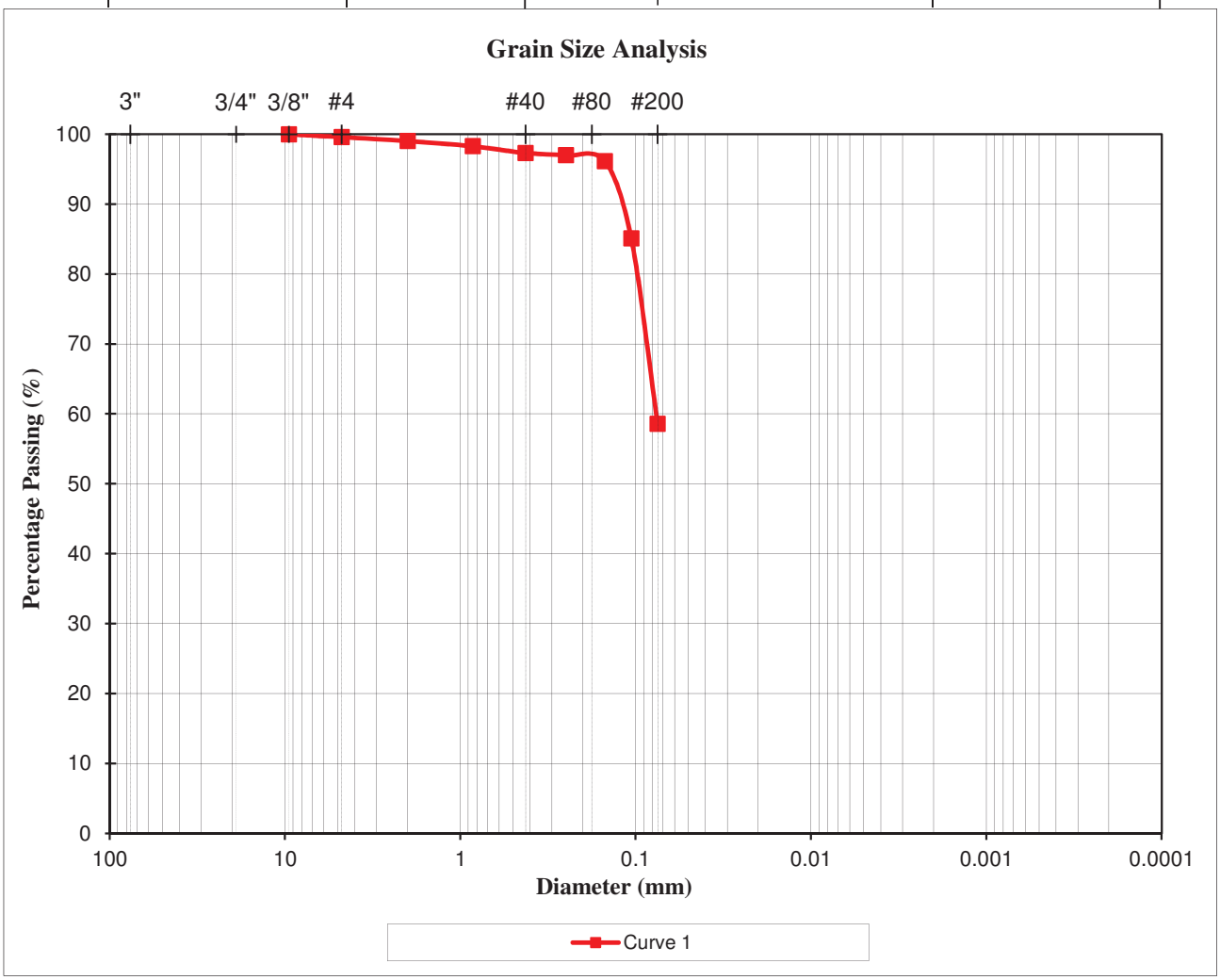
AVILES ENGINEERING CORPORATION

Consulting Engineers - Geotechnical, Construction Materials Testing, Environmental

GRAIN SIZE ANALYSIS - SIEVE

Project : 60 Inch Waterline along Monroe and Rockhill **Job No.:** G149-14
Location of Project: Houston, Texas **Date of Testing:**

Gravel	Sand		Silt	Clay
	Coarse to Medium	Fine		



Curve	Boring	Depth (ft)	Soil Description	Cu	Cc
1	B-8	18-20	Sandy Lean Clay (CL)	N/A	N/A

PINHOLE TEST DATA
ASTM D-4647 METHOD A

Project No.: G149-14 **Project Description:** 60-in. WL along Monroe and Rockhill

Sample Location and Description: B-5A, 4'-6', Fat Clay (CH)

Type of Specimen: UND **Curing Time:** N/A **Eroding Fluid:** Water

Temperature: **Before Test:** 72F **After Test:** 72F

Tested By: WT **Date of Test:** 5/19/2015

Time (min)	Time (sec)	Head (Inch)	Flow Through Specimen		Flow Rate (ml/s)	Color of Effluent						hole size after test (mm)	Remarks
			ml	Sec		very dark	dark	moderately dark	slightly dark	barely visible	completely clear		
0	58	2"	10	58	0.17						*		
2	7		10	69	0.14						*		
3	26		10	79	0.13						*		
0	36	2"	10	36	0.28						*		
1	15		10	39	0.26						*		
2	1		10	46	0.22						*		
2	46		10	45	0.22						*		
3	38		10	52	0.19						*		
4	33		10	55	0.18						*		
0	49	2"	20	49	0.41						*		
1	18		10	29	0.34						*		
1	43		10	25	0.40						*		
2	11		10	28	0.36						*		
2	36		10	25	0.40						*		
3	7		10	31	0.32						*		
3	36		10	29	0.34						*		
4	7		10	31	0.32						*		
4	36		10	29	0.34						*		
5	9		10	33	0.30						*		
5	40		10	31	0.32						*		
6	15		10	35	0.29						*		
6	48		10	33	0.30						*		
7	24		10	36	0.28						*		
7	59		10	35	0.29						*		
8	38		10	39	0.26						*		
9	15		10	37	0.27						*		
9	57		10	42	0.24						*		
10	41		10	44	0.23						*		

PINHOLE TEST DATA
ASTM D-4647 METHOD A

Project No.: G149-14 **Project Description:** 60-in. WL along Monroe and Rockhill

Sample Location and Description: B-5A, 4'-6', Fat Clay (CH)

Type of Specimen: UND **Curing Time:** N/A **Eroding Fluid:** Water

Temperature: **Before Test:** 72F **After Test:** 72F

Tested By: WT **Date of Test:** 5/19/2015

Time (min)	Time (sec)	Head (Inch)	Flow Through Specimen		Flow Rate (ml/s)	Color of Effluent						hole size after test (mm)	Remarks
			ml	Sec		very dark	dark	moderately dark	slightly dark	barely visible	completely clear		
11	36	7"	25	55	0.45						*		
12	43		25	67	0.37						*		
13	54		25	71	0.35						*		
15	10		25	76	0.33						*		
16	18		25	68	0.37						*		
16	58	15"	25	40	0.63						*		
17	44		25	46	0.54						*		
18	23		25	39	0.64						*		
19	3		25	40	0.63						*		
19	45		25	42	0.60						*		
20	32		25	47	0.53						*		
21	19		25	47	0.53						*		
22	6		25	47	0.53						*		
22	50	40"	50	44	1.14						*		
23	37		50	47	1.06						*		
24	25		50	48	1.04						*		
25	51		100	86	1.16						*		
27	40		100	109	0.92						*		
29	25		100	105	0.95						*		
30	9		50	44	1.14						*	1.0	ND1

PINHOLE TEST DATA
ASTM D-4647 METHOD A

Project No.: G149-14 **Project Description:** 60-in. WL along Monroe and Rockhill

Sample Location and Description: B-7A, 10'-12', Silty Clay w/Sand (CL-ML)

Type of Specimen: UND **Curing Time:** N/A **Eroding Fluid:** Water

Temperature: **Before Test:** 72F **After Test:** 72F

Tested By: WT **Date of Test:** 5/19/2015

Time (min)	Time (sec)	Head (Inch)	Flow Through Specimen		Flow Rate (ml/s)	Color of Effluent						hole size after test (mm)	Remarks
			ml	Sec		very dark	dark	moderately dark	slightly dark	barely visible	completely clear		
0	32	2"	10	32	0.31						*		
1	12		10	40	0.25						*		
1	48		10	36	0.28						*		
2	25		10	37	0.27						*		
2	57		10	32	0.31						*		
3	31		10	34	0.29						*		
4	2		10	31	0.32						*		
4	45		10	43	0.23						*		
5	15		10	30	0.33						*		
5	48		10	33	0.30						*		
6	20		10	32	0.31						*		
6	54		10	34	0.29						*		
7	28		10	34	0.29						*		
8	0		10	32	0.31						*		
8	33		10	33	0.30						*		
9	7		10	34	0.29						*		
9	39		10	32	0.31						*		
10	11		10	32	0.31						*		
10	53	7"	25	42	0.60						*		
11	36		25	43	0.58						*		
12	19		25	43	0.58						*		
13	3		25	44	0.57						*		
13	47		25	44	0.57						*		
14	32		25	45	0.56						*		
15	17		25	45	0.56						*		
16	9	15"	50	52	0.96						*		
17	1		50	52	0.96						*		
17	54		50	53	0.94						*		
18	47		50	53	0.94						*		
19	37		50	50	1.00						*		
20	31		50	54	0.93						*		

PINHOLE TEST DATA
ASTM D-4647 METHOD A

Project No.: G149-14 **Project Description:** 60-in. WL along Monroe and Rockhill

Sample Location and Description: B-7A, 10'-12', Silty Clay w/Sand (CL-ML)

Type of Specimen: UND **Curing Time:** N/A **Eroding Fluid:** Water

Temperature: **Before Test:** 72F **After Test:** 72F

Tested By: WT **Date of Test:** 5/19/2015

Time (min)	Time (sec)	Head (Inch)	Flow Through Specimen		Flow Rate (ml/s)	Color of Effluent						hole size after test (mm)	Remarks
			ml	Sec		very dark	dark	moderately dark	slightly dark	barely visible	completely clear		
21	27	15"	100	56	1.79						*		
22	26		100	59	1.69						*		
23	22		100	56	1.79						*		
24	19		100	57	1.75						*		
25	16		100	57	1.75						*		
26	14		100	58	1.72						*	1	ND1

AVILES ENGINEERING CORPORATION

Consulting Engineers - Geotechnical, Construction Materials Testing, Environmental

RESULTS OF CRUMB TESTS (ASTM D 6572)

Project Name: 60-Inch Waterline along Monroe and Rockhill
Project No.: G149-14 Test Date: 5/19/2015

Boring Number	Depth, feet	2 Minutes		1 Hour		6 Hours	
		Grade	C (deg)	Grade	C (deg)	Grade	C (deg)
B-5A	2-4	1	23.0	1	23.0	1	23.0
B-5A	10-12	1	23.0	1	23.0	1	23.0
B-7A	2-4	1	23.0	1	23.0	1	23.0
B-7A	8-10	2	23.0	4	23.0	4	23.0

Grade Classification:

Grade 1 Non-dispersive; No reaction
Grade 2 Intermediate; Slight reaction
Grade 3 Dispersive; Moderate reaction
Grade 4 Highly Dispersive; Strong reaction

Interpretation:

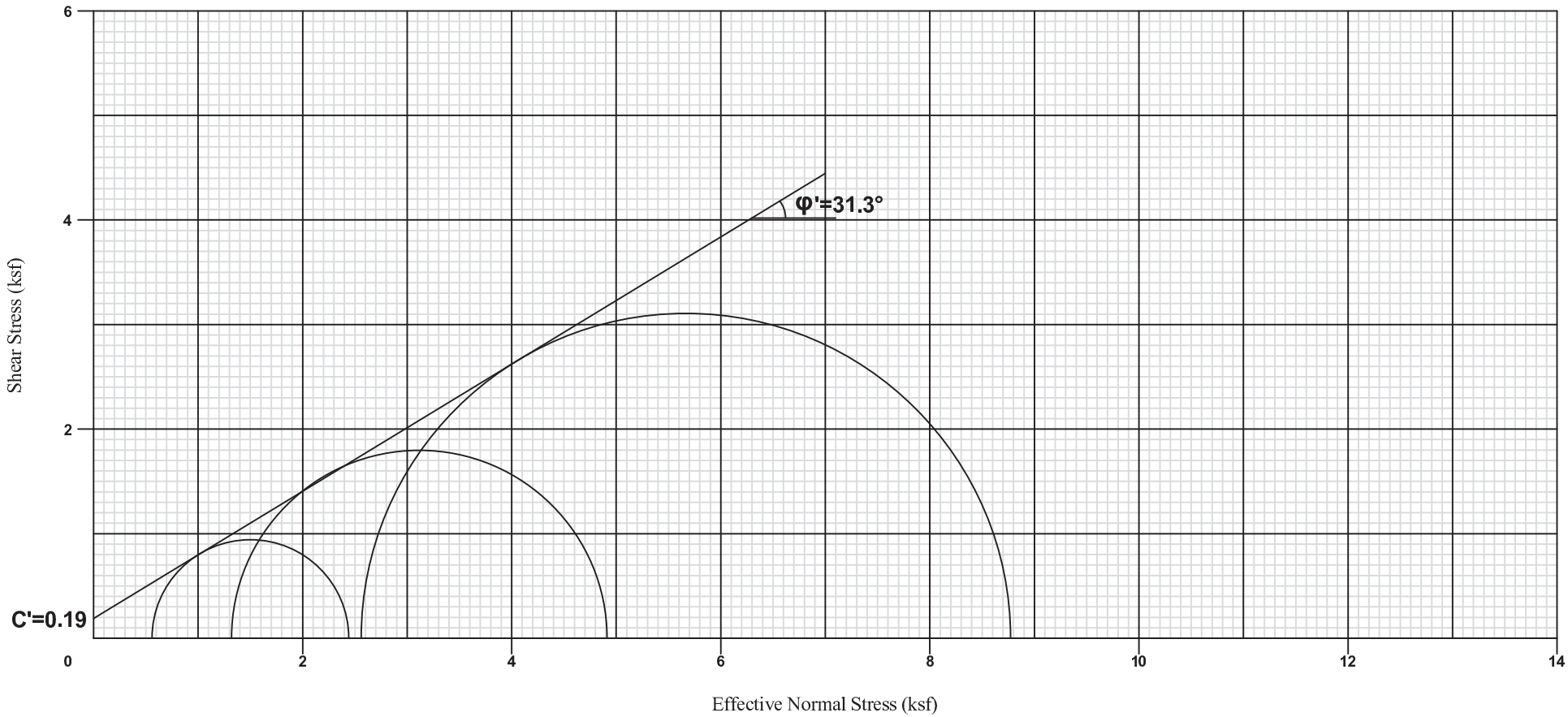
Under normal conditions, use the 1 hour reading to determine dispersive grade.
However, if the dispersive grade changes from 2 to 3 or from 3 to 4 between the 1 and 6 hour readings, use the 6 hour reading instead.

AYLES ENGINEERING CORP.

Tan and gray LEAN CLAY (CL)

LL = 46, PL = 18, PI = 28

W_n = 24.81%, r_d = 99.2 pcf, e_o = 0.730



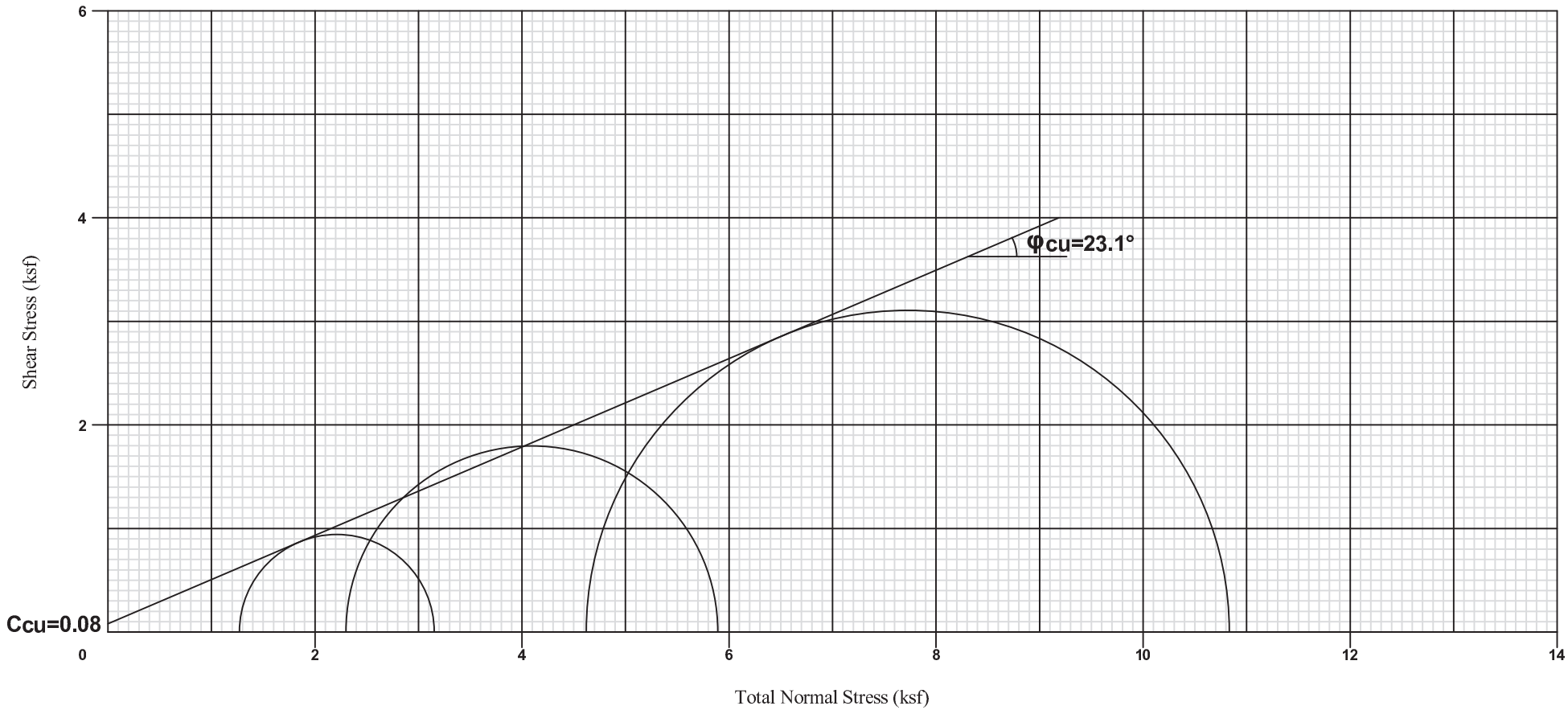
TRIAXIAL CU TESTS
MOHR'S CIRCLES
Effective Stress
G149-14 Boring B-5A, 14'-16'

AYLES ENGINEERING CORP.

Tan and gray LEAN CLAY (CL)

LL = 46, PL = 18, PI = 28

W_n = 24.81%, r_d = 99.2 pcf, e_o = 0.730



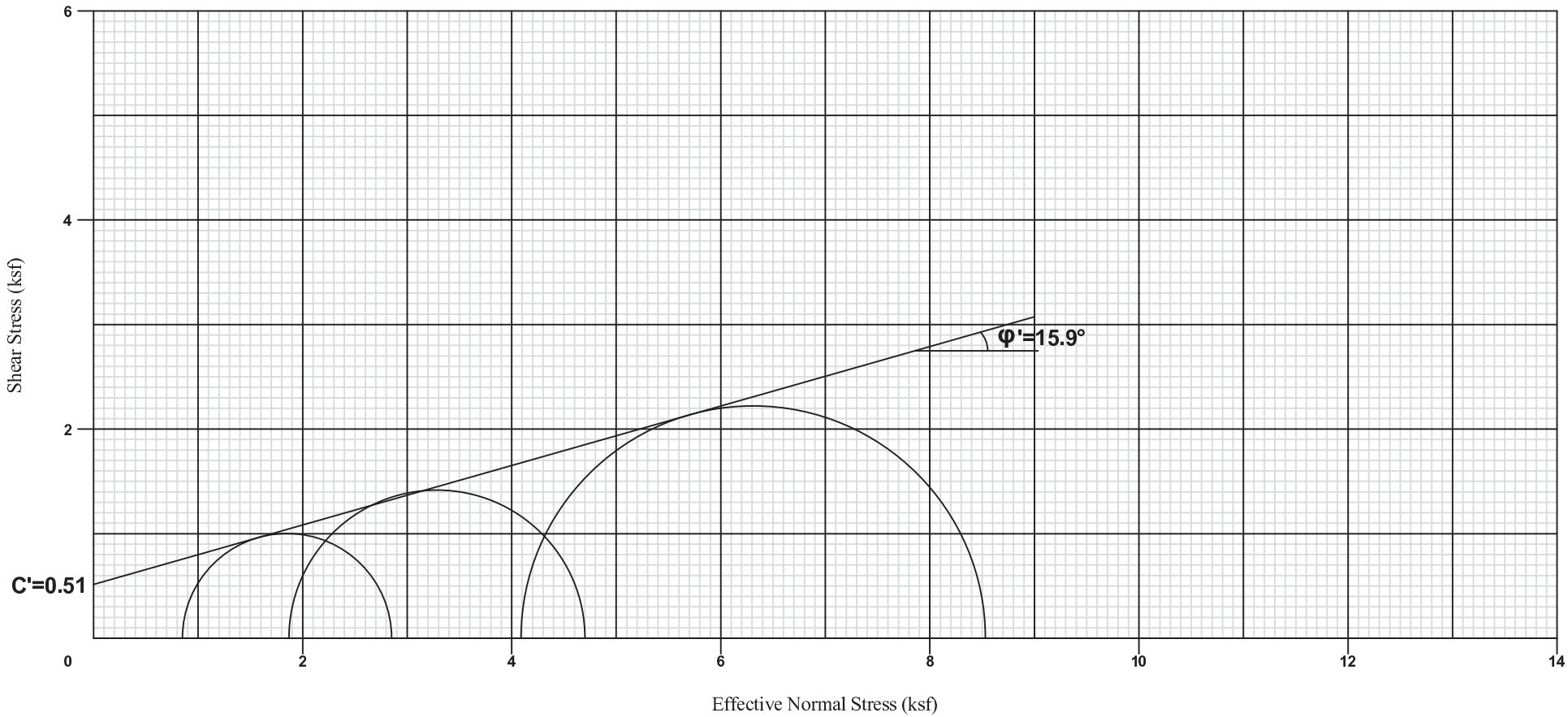
TRIAXIAL CU TESTS
MOHR'S CIRCLES
Total Stress
G149-14 Boring B-5A, 14'-16'

AYLES ENGINEERING CORP.

Tan and gray FAT CLAY (CH)

LL = 64, PL = 22, PI = 42

W_n = 26.96%, r_d = 96.9 pcf, e_o = 0.739



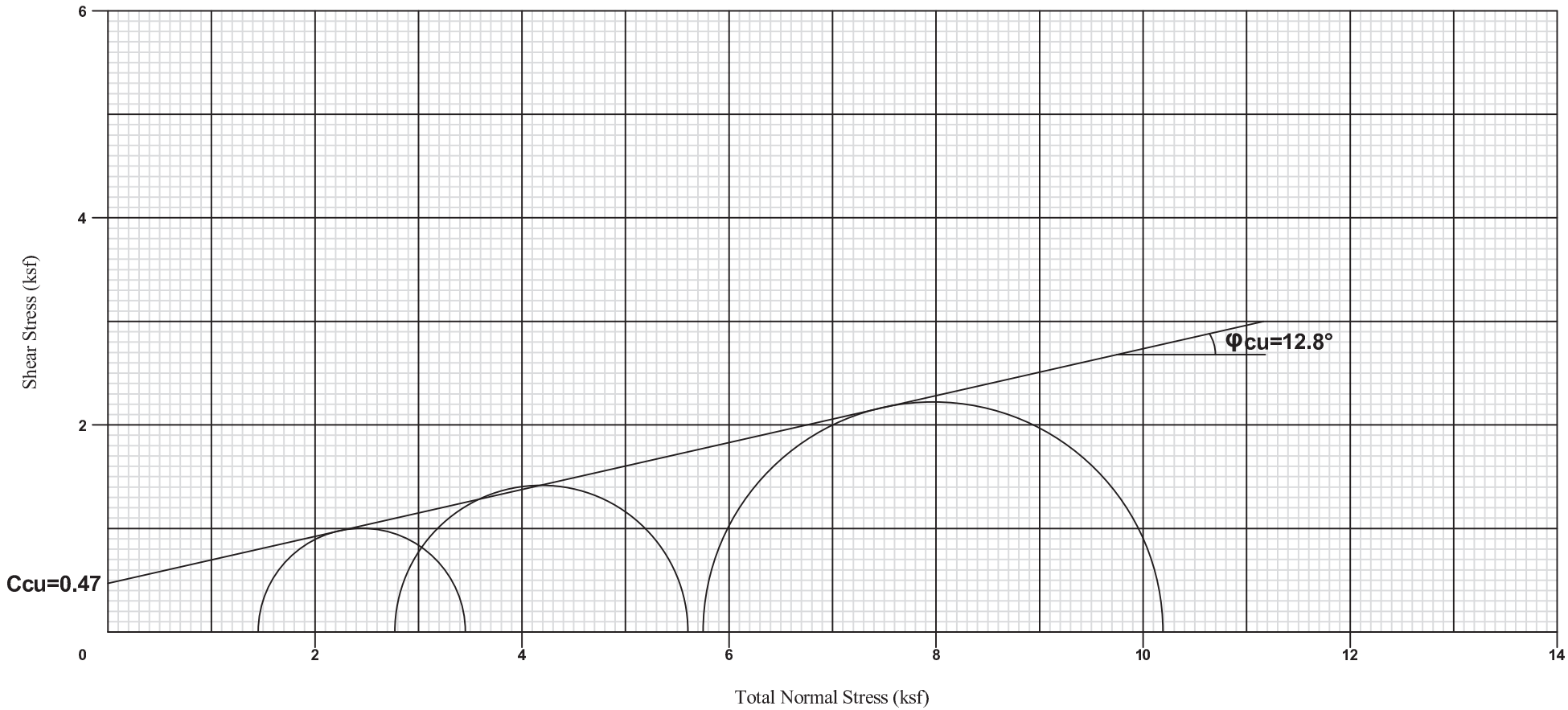
TRIAXIAL CU TESTS
MOHR'S CIRCLES
Effective Stress
G149-14 Boring B-7A, 6'-8'

AYLES ENGINEERING CORP.

Tan and gray FAT CLAY (CH)

LL = 64, PL = 22, PI = 42

W_n = 26.96%, r_d = 96.9 pcf, e_o = 0.739



TRIAXIAL CU TESTS
MOHR'S CIRCLES
Total Stress
G149-14 Boring B-7A, 6'-8'

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample				SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits			Percent Passing Sieve #200 (%)	Shear Strength (tsf)				Type of Material
	No.	Depth (ft)		Type				LL (%)	PL (%)	PI (%)		Unconfined Compression	UU (confining pressure, psi)	Torvane	Pocket Penetrometer	
		Top	Bottom													
B-1	1	0.0	2.0	UD		29									1.00	Fat Clay (CH)
	2	2.0	4.0	UD		21	105.9					2.91			4.00	Fat Clay (CH)
	3	4.0	6.0	UD		29		71	22	49	93.5				2.75	Fat Clay (CH)
	4	6.0	8.0	UD		28									2.50	Fat Clay (CH)
	5	8.0	10.0	UD		36									1.25	Fat Clay (CH)
	6	10.0	12.0	UD		27	100.8						1.75 (7)		2.00	Fat Clay (CH)
	7	12.0	14.0	UD		29		54	20	34	97.0				0.50	Fat Clay (CH)
	8	14.0	16.0	UD		24									1.75	Fat Clay (CH)
	9	16.0	18.0	UD		25	102.3						0.70 (9)		1.00	Fat Clay (CH)
	10	18.0	20.0	UD		24		26	20	6	86.4				1.25	Silty Clay (CL-ML)
	11	20.0	22.0	UD		24									1.00	Silty Clay (CL-ML)
	12	22.0	24.0	UD		23	101.5						1.39 (11)		2.50	Fat Clay (CH)
	13	24.0	25.0	AG		22		np	np	np	49.5					Sandy Silt (ML)
	14	28.0	30.0	UD		27									4.50	Fat Clay (CH)
B-2	1	0.0	2.0	UD		22		67	23	44	90.1				4.50	Fat Clay (CH)
	2	2.0	4.0	UD		21									4.50	Fat Clay (CH)
	3	4.0	6.0	UD		22	103.6						5.32 (3)		4.50	Fat Clay (CH)
	4	6.0	8.0	UD		34									1.25	Fat Clay (CH)
	5	8.0	10.0	UD		25		75	22	53	93.8				3.50	Fat Clay (CH)
	6	10.0	12.0	UD		28	96.1						1.24 (7)		1.25	Fat Clay (CH)
	7	12.0	14.0	UD		27					96.3			0.07		Silt (ML)
	8	14.0	16.0	UD		26	101.4						1.04 (9)		1.25	Lean Clay (CL)
	9	16.0	18.0	UD		21		40	16	24	87.0			0.81	2.75	Lean Clay (CL)
	10	18.5	20.0	SPT		23		24	22	2	90.8			0.17		Silt (ML)
	11	20.5	22.0	SPT		25					88.8					Silt (ML)
	12	22.5	24.0	SPT		26		45	19	26	99.2					Lean Clay (CL)
	13	24.0	25.0	UD		37	87.7						2.13 (12)		3.25	Lean Clay (CL)
	14	28.0	30.0	UD		28									3.75	Lean Clay (CL)
B-3	1	0.0	2.0	UD		19									4.25	Fat Clay (CH)
	2	2.0	4.0	UD		17	110.5					9.99			4.50	Fat Clay (CH)
	3	4.0	6.0	UD		22		75	21	54	93.5				4.50	Fat Clay (CH)
	4	6.0	8.0	UD		26									4.50	Fat Clay (CH)
	5	8.0	10.0	UD		24									3.25	Fat Clay (CH)
	6	10.0	12.0	UD		23	105.6						1.49 (7)		2.50	Lean Clay (CL)

Legend			
	UD = UnDisturbed sample, extruded in field	LL = Liquid Limit	Notes:
	SS = Split Spoon sample	PL = Plastic Limit	
	AG = Auger Cuttings	PI = Plasticity Index	
	SPT = Standard Penetration Test	UU = Triaxial Compession	

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample				SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits			Percent Passing Sieve #200 (%)	Shear Strength (tsf)				Type of Material
	No.	Depth (ft)		Type				LL (%)	PL (%)	PI (%)		Unconfined Compression	UU (confining pressure, psi)	Torvane	Pocket Penetrometer	
		Top	Bottom													
B-3	7	12.0	14.0	UD		23		38	16	22	95.6				1.00	Lean Clay (CL)
	8	14.0	15.0	UD		32									0.50	Lean Clay (CL)
B-4	1	0.0	2.0	UD		19		63	20	43	95.1				4.50	Fill: Fat Clay (CH)
	2	2.0	4.0	UD		19	110.0					10.45			4.50	Fat Clay (CH)
	3	4.0	6.0	UD		22									4.50	Fat Clay (CH)
	4	6.0	8.0	UD		27		84	24	60	94.1				4.00	Fat Clay (CH)
	5	8.0	10.0	UD		31									2.00	Fat Clay (CH)
	6	10.0	12.0	UD		32	90.6						0.64 (7)		0.75	Lean Clay (CL)
	7	12.0	14.0	UD		30									0.50	Lean Clay (CL)
	8	14.0	16.0	UD		22		33	17	16	95.0				1.25	Lean Clay (CL)
	9	16.0	18.0	UD		21	109.5						1.74 (10)		3.75	Fat Clay (CH)
	10	18.5	20.0	SPT	36	25					74.6					Sandy Silt (ML)
	11	23.5	25.0	SPT	83/10"	20										Sandy Silt (ML)
B-5	1	0.0	2.0	UD		37	85.7					1.06			1.50	Fat Clay (CH)
	2	2.0	4.0	UD		33									1.75	Fat Clay (CH)
	3	4.0	6.0	UD		29		82	24	58	78.8				2.75	Fat Clay (CH)
	4	6.0	8.0	UD		34									2.00	Fat Clay (CH)
	5	8.0	10.0	UD		30	92.0						1.01 (6)		2.25	Fat Clay (CH)
	6	10.0	12.0	UD		20									3.50	Fat Clay (CH)
	7	12.0	14.0	UD		21		33	20	13	85.1				3.25	Lean Clay w/Sand (CL)
	8	14.0	16.0	UD		22									3.25	Lean Clay w/Sand (CL)
	9	16.0	18.0	UD		23	105.5						0.96 (11)		4.25	Lean Clay w/Sand (CL)
	10	18.5	20.0	SPT	24	24					66.9					Sandy Silt (ML)
	11	23.5	25.0	SPT	25	28										Fat Clay (CH)
B-5A	1	0.0	2.0	UD		25		70	20	50	92.8				3.00	Fill: Fat clay (CH)
	2	2.0	4.0	UD		28	93.6					2.54			3.50	Fat Clay (CH)
	3	4.0	6.0	UD		24									4.50	Fat Clay (CH)
	4	6.0	8.0	UD		24		76	23	53	95.3				4.50	Fat Clay (CH)
	5	8.0	10.0	UD		32	90.4						1.43 (6)		3.75	Fat Clay (CH)
	6	10.0	12.0	UD		24									3.75	Fat Clay (CH)
	7	12.0	14.0	UD		26	100.0						1.59 (8)		3.75	Lean Clay (CL)
	8	14.0	16.0	UD		25	99.2	46	18	28	97.1				2.50	Fat Clay (CH)
	9	16.5	18.0	SPT	10	24									1.50	Fat Clay (CH)

Legend			
	UD = UnDisturbed sample, extruded in field	LL = Liquid Limit	Notes:
	SS = Split Spoon sample	PL = Plastic Limit	
	AG = Auger Cuttings	PI = Plasticity Index	
	SPT = Standard Penetration Test	UU = Triaxial Compession	

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample				SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits			Percent Passing Sieve #200 (%)	Shear Strength (tsf)				Type of Material
	No.	Depth (ft)		Type				LL (%)	PL (%)	PI (%)		Unconfined Compression	UU (confining pressure, psi)	Torvane	Pocket Penetrometer	
		Top	Bottom													
B-5A	10	18.0	20.0	UD		28	98.1					2.07			4.50	Fat Clay (CH)
	11	23.0	25.0	UD		33		43	19	24	99.6				1.25	Lean Clay (CL)
B-6	1	0.0	2.0	UD		32	90.7					1.36			2.50	Fat Clay (CH)
	2	2.0	4.0	UD		31		79	22	57	94.7				1.75	Fat Clay (CH)
	3	4.0	6.0	UD		36									1.75	Fat Clay (CH)
	4	6.0	8.0	UD		23	104.3						1.64 (5)		2.25	Fat Clay (CH)
	5	8.0	10.0	UD		20		26	19	7	89.9			0.43	3.25	Silty Clay (CL-ML)
	6	10.5	12.0	SPT	11	24					90.4					Silty Clay (CL-ML)
	7	12.0	14.0	UD		31									3.25	Lean Clay (CL)
	8	14.0	16.0	UD		22		43	18	25	97.9			0.58	3.50	Lean Clay (CL)
	9	16.0	18.0	UD		24	102.2						0.85 (10)		0.75	Silt (ML)
	10	18.5	20.0	SPT	18	26										Silt (ML)
	11	23.5	25.0	SPT	28	27										Silt (ML)
B-7	1	0.0	2.0	UD		25	97.7					1.20			1.50	Fat Clay (CH)
	2	2.0	4.0	UD		30		72	22	50	89.4				1.50	Fat Clay (CH)
	3	4.0	6.0	UD		31									2.00	Fat Clay (CH)
	4	6.0	8.0	UD		34									1.25	Fat Clay (CH)
	5	8.0	10.0	UD		29	97.0						1.08 (6)		1.00	Lean Clay (CL)
	6	10.0	12.0	UD		24		32	18	14	95.2			0.58	1.00	Lean Clay (CL)
	7	12.0	13.5	SPT	11	28										Lean Clay (CL)
	8	13.5	15.0	SPT	15	24					97.8					Lean Clay (CL)
B-7A	1	0.0	2.0	UD		23	97.0	79	23	56	89.2	1.88			4.00	Fat Clay (CH)
	2	2.0	4.0	UD		20									4.50	Fat Clay (CH)
	3	4.0	6.0	UD		22	100.8						1.83 (3)		4.50	Fat Clay (CH)
	4	6.0	8.0	UD		27	96.9	64	22	42	73.4				1.75	Fat Clay w/Sand (CH)
	5	8.0	10.0	UD		24									3.00	Fat Clay w/Sand (CH)
	6	10.0	12.0	UD		24	109.9						0.77 (6)		1.75	Silty Clay w/Sand (CL-ML)
	7	12.0	14.0	UD		22		26	19	7	78.6				1.25	Silty Clay w/Sand (CL-ML)
	8	14.5	16.0	SPT	5	25										Silt (ML)
	9	16.0	18.0	UD		24									1.25	Silt (ML)
	10	18.5	20.0	SPT	11	25		25	23	2	88.4					Silt (ML)
	11	23.5	25.0	SPT	12	30										Silt (ML)

Legend			
	UD = UnDisturbed sample, extruded in field SS = Split Spoon sample AG = Auger Cuttings SPT = Standard Penetration Test	LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index UU = Triaxial Compession	Notes:

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample				SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits			Percent Passing Sieve #200 (%)	Shear Strength (tsf)				Type of Material
	No.	Depth (ft)		Type				LL (%)	PL (%)	PI (%)		Unconfined Compression	UU (confining pressure, psi)	Torvane	Pocket Penetrometer	
		Top	Bottom													
B-8	1	0.0	2.0	UD		22	102.6					1.66			2.25	Fat Clay (CH)
	2	2.0	4.0	UD		24		58	19	39	92.8				2.75	Fat Clay (CH)
	3	4.0	6.0	UD		22									2.75	Fat Clay (CH)
	4	6.0	8.0	UD		22	105.3						0.59 (5)		2.00	Sandy Fat Clay (CH)
	5	8.0	10.0	UD		23		54	20	34	53.4				1.25	Sandy Fat Clay (CH)
	6	10.5	12.0	SPT	4	25					34.1					Silty Sand (SM)
	7	12.5	14.0	SPT	7	27										Silty Sand (SM)
	8	14.5	16.0	SPT	13	25										Silty Sand (SM)
	9	16.5	18.0	SPT	14	29										Silty Sand (SM)
	10	18.5	20.0	SPT	41	27					58.6					Sandy Lean Clay (CL)
	11	23.5	25.0	SPT	29	25										Sandy Lean Clay (CL)
B-9	1	0.0	2.0	UD		27		63	19	44	95.4				2.50	Fat Clay (CH)
	2	2.0	4.0	UD		24	97.3					1.70			3.25	Fat Clay (CH)
	3	4.0	6.0	UD		25									2.25	Fat Clay (CH)
	4	6.0	8.0	UD		26		48	16	32	96.2				2.50	Lean Clay (CL)
	5	8.0	10.0	UD		23	106.8						0.62 (6)		1.00	Silty Clay (CL-ML)
	6	10.5	12.0	SPT	5	36					89.2					Silty Clay (CL-ML)
	7	12.5	14.0	SPT	6	30		28	23	5	97.7					Silty Clay (CL-ML)
	8	14.0	16.0	UD		25		31	23	8	96.9			0.47	0.75	Lean Clay (CL)
	9	16.5	18.0	SPT	5	29										Silt w/Sand (ML)
	10	18.5	20.0	SPT	15	27					78.5					Silt w/Sand (ML)
	11	23.0	25.0	UD		34									4.25	Fat Clay (CH)
B-10	1	0.0	2.0	UD		27									2.50	Fat Clay (CH)
	2	2.0	4.0	UD		23		67	20	47	91.8				2.25	Fat Clay (CH)
	3	4.0	6.0	UD		29	93.6						1.46 (3)		2.00	Fat Clay (CH)
	4	6.0	8.0	UD		22									2.50	Fat Clay (CH)
	5	8.0	10.0	UD		22									1.50	Fat Clay (CH)
	6	10.0	12.0	UD		21		59	25	34	99.0				4.00	Fat Clay (CH)
	7	12.0	14.0	UD		24	107.3						0.97 (7)		0.50	Silt w/Sand (ML)
	8	14.5	16.0	SPT	8	23					81.4					Silt w/Sand (ML)
	9	16.5	18.0	SPT	20	24		24	24	0	86.3					Silt (ML)
	10	18.5	20.0	SPT	12	25										Silt (ML)
	11	23.5	25.0	SPT	23	25					55.1					Sandy Silt (ML)

Legend			
	UD = UnDisturbed sample, extruded in field SS = Split Spoon sample AG = Auger Cuttings SPT = Standard Penetration Test	LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index UU = Triaxial Compession	Notes:

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample No.	Depth (ft) Top	Depth (ft) Bottom	Type	SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits LL (%)	Atterberg Limits PL (%)	Atterberg Limits PI (%)	Percent Passing Sieve #200 (%)	Shear Strength (tsf) Unconfined Compression	Shear Strength (tsf) UU (confining pressure, psi)	Shear Strength (tsf) Torvane	Shear Strength (tsf) Pocket Penetrometer	Type of Material
B-11	1	0.0	2.0	UD		29									2.25	Fat Clay (CH)
	2	2.0	4.0	UD		27		64	19	45	92.7				1.75	Fat Clay (CH)
	3	4.0	6.0	UD		29	94.6						1.33 (3)		2.00	Fat Clay (CH)
	4	6.0	8.0	UD		30									2.00	Fat Clay (CH)
	5	8.0	10.0	UD		22									3.00	Fat Clay (CH)
	6	10.0	12.0	UD		24		52	19	33	95.2				2.50	Fat Clay (CH)
	7	12.0	14.0	UD		23	107.3						0.59 (9)		0.25	Lean Clay (CL)
	8	14.5	16.0	UD		27									4.00	Fat Clay (CH)
	9	16.5	18.0	UD		26									4.50	Fat Clay (CH)
	10	18.5	20.0	UD		30		66	23	43	98.8				4.25	Fat Clay (CH)
	11	20.0	22.0	UD		25	104.1						0.85 (13)		1.25	Lean Clay (CL)
	12	22.0	24.0	UD		23					98.5			0.18	0.50	Lean Clay (CL)
	13	24.0	26.0	UD		22		39	20	19	41.1				2.00	Clayey Sand (SC)
	14	26.0	28.0	UD		30	92.7						2.22 (15)		4.25	Fat Clay (CH)
	15	28.0	30.0	UD		29									4.00	Fat Clay (CH)
	16	33.0	35.0	UD		23					72.6			0.31	0.25	Silt w/Sand (ML)
B-12	1	0.0	2.0	UD		24		63	18	45	91.3				2.75	Fat Clay (CH)
	2	2.0	4.0	UD		24	100.6					1.81			2.50	Fat Clay (CH)
	3	4.0	6.0	UD		27									2.00	Fat Clay (CH)
	4	6.0	8.0	UD		30									2.75	Fat Clay (CH)
	5	8.0	10.0	UD		20		42	17	25	98.9				3.75	Lean Clay (CL)
	6	10.0	12.0	UD		21	104.0						1.32 (7)		2.75	Lean Clay (CL)
	7	12.0	14.0	UD		22					87.5			0.36	0.75	Lean Clay (CL)
	8	14.0	16.0	UD		27									2.75	Fat Clay (CH)
	9	16.0	18.0	UD		26	100.7						1.86 (11)		4.25	Fat Clay (CH)
	10	18.0	20.0	UD		26		56	22	34	99.4				4.00	Fat Clay (CH)
	11	20.0	22.0	UD		30	94.4						1.40 (13)		3.50	Fat Clay (CH)
	12	22.0	24.0	UD		23					68.2					Sandy Silt (ML)
	13	24.0	26.0	UD		34									4.00	Fat Clay (CH)
	14	26.0	28.0	UD		31		68	28	40	100.0				4.25	Fat Clay (CH)
	15	28.0	30.0	UD		32	92.9						2.40 (15)		3.75	Fat Clay (CH)
	16	33.0	35.0	UD		28									3.75	Fat Clay (CH)
B-13	1	0.0	2.0	UD		32	88.6					0.78			1.50	Fat Clay (CH)
	2	2.0	4.0	UD		30									1.75	Fat Clay (CH)

Legend			
	UD = UnDisturbed sample, extruded in field	LL = Liquid Limit	Notes:
	SS = Split Spoon sample	PL = Plastic Limit	
	AG = Auger Cuttings	PI = Plasticity Index	
	SPT = Standard Penetration Test	UU = Triaxial Compession	

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample No.	Depth (ft) Top	Depth (ft) Bottom	Type	SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits LL (%)	Atterberg Limits PL (%)	Atterberg Limits PI (%)	Percent Passing Sieve #200 (%)	Shear Strength (tsf) Unconfined Compression	Shear Strength (tsf) UU (confining pressure, psi)	Shear Strength (tsf) Torvane	Shear Strength (tsf) Pocket Penetrometer	Type of Material
B-13	3	4.0	6.0	UD		31		72	23	49	87.2				1.25	Fat Clay (CH)
	4	6.0	8.0	UD		20									3.75	Lean Clay (CL)
	5	8.0	10.0	UD		20	107.3						1.96 (6)		1.00	Lean Clay (CL)
	6	10.0	12.0	UD		25									3.00	Lean Clay (CL)
	7	12.0	14.0	UD		21		44	18	26	97.6				3.00	Lean Clay (CL)
	8	14.0	15.0	UD		23	105.4						1.06 (10)		2.25	Lean Clay (CL)
B-14	1	0.0	2.0	UD		25	99.3					1.41			1.25	Fat Clay (CH)
	2	2.0	4.0	UD		27									1.75	Fat Clay (CH)
	3	4.0	6.0	UD		27		63	20	43	87.3				2.50	Fat Clay (CH)
	4	6.0	8.0	UD		29	96.2						1.19 (5)		3.25	Fat Clay (CH)
	5	8.0	10.0	UD		32									2.50	Fat Clay (CH)
	6	10.0	12.0	UD		18									4.00	Lean Clay (CL)
	7	12.0	14.0	UD		21	104.0	36	17	19	94.2		1.02 (9)		2.00	Lean Clay (CL)
	8	14.0	16.0	UD		25									2.00	Lean Clay (CL)
	9	16.0	18.0	UD		28					97.5			0.26	1.00	Lean Clay (CL)
	10	18.0	20.0	UD		27	97.9						0.59 (12)		0.75	Lean Clay (CL)
	11	23.0	25.0	UD		29		73	26	47	96.0				4.00	Fat Clay (CH)
B-15	1	0.0	2.0	UD		30									1.25	Fat Clay (CH)
	2	2.0	4.0	UD		28		58	19	39	87.3				1.75	Fat Clay (CH)
	3	4.0	6.0	UD		32	91.6						1.11 (3)		1.50	Fat Clay (CH)
	4	6.0	8.0	UD		22									2.50	Fat Clay (CH)
	5	8.0	10.0	UD		20									4.00	Lean Clay (CL)
	6	10.0	12.0	UD		21		36	15	21	85.2				1.25	Lean Clay (CL)
	7	12.0	14.0	UD		24	105.8						1.47 (8)		2.25	Lean Clay (CL)
	8	14.5	16.0	SPT	16	23					99.0					Lean Clay (CL)
	9	16.5	18.0	SPT	39	27								1.35		Fat Clay (CH)
	10	18.0	20.0	UD		25	96.9						1.84 (10)		2.50	Fat Clay (CH)
	11	20.0	22.0	UD		26		34	20	14	99.1				0.50	Lean Clay (CL)
	12	22.5	24.0	UD		28					86.3					Lean Clay (CL)
	13	24.5	26.0	UD		27										Fat Clay (CH)
	14	26.0	28.0	UD		28	92.9						1.61 (13)		3.50	Fat Clay (CH)
	15	28.0	30.0	UD		30		74	28	46	99.9				3.75	Fat Clay (CH)
	16	30.0	32.0	UD		30									3.50	Fat Clay (CH)
	17	32.0	34.0	UD		30									3.75	Fat Clay (CH)

Legend			
	UD = UnDisturbed sample, extruded in field	LL = Liquid Limit	Notes:
	SS = Split Spoon sample	PL = Plastic Limit	
	AG = Auger Cuttings	PI = Plasticity Index	
	SPT = Standard Penetration Test	UU = Triaxial Compession	

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample				SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits			Percent Passing Sieve #200 (%)	Shear Strength (tsf)				Type of Material
	No.	Depth (ft)		Type				LL (%)	PL (%)	PI (%)		Unconfined Compression	UU (confining pressure, psi)	Torvane	Pocket Penetrometer	
		Top	Bottom													
B-15	18	34.0	35.0	UD		27	98.5						2.21 (15)		4.25	Fat Clay (CH)
	19	38.5	40.0	SPT	28	25									3.50	Fat Clay (CH)
B-15A	1	15.5	17.0	SPT	5	26										
	2	17.0	19.0	UD		23		26	23	3	97.4				1.75	Silt (ML)
	3	19.5	21.0	SPT	14	25										Silt (ML)
	4	21.0	23.0	UD		29	97.4						1.55 (11)		3.75	Silt (ML)
	5	23.0	25.0	UD		32		28	24	4	68.6				0.00	Fat Clay (CH)
	6	25.0	27.0	UD		31	92.1						1.66 (13)		4.00	Sandy Silty Clay (CL-ML)
	7	27.0	29.0	UD		32		75	28	47	99.9				3.50	Fat Clay (CH)
	8	29.0	31.0	UD		29									4.50	Fat Clay (CH)
	9	31.0	33.0	UD		30	97.0						1.96 (15)		4.50	Fat Clay (CH)
	10	33.0	35.0	UD		25		np	np	np	97.1				0.75	Silt (ML)
	11	38.5	40.0	SPT	29	24										Sandy Silt (ML)
B-16	1	0.0	2.0	UD		27	100.5					1.88			1.50	Fat Clay (CH)
	2	2.0	4.0	UD		28									1.75	Fat Clay (CH)
	3	4.0	6.0	UD		23		64	22	42	87.5				3.00	Fat Clay (CH)
	4	6.0	8.0	UD		21	102.5						1.37 (5)		3.75	Fat Clay (CH)
	5	8.0	10.0	UD		20									4.50	Fat Clay (CH)
	6	10.0	12.0	UD		25								0.48	1.00	Lean Clay (CL)
	7	12.0	14.0	UD		23		33	18	15	98.6				1.25	Lean Clay (CL)
	8	14.0	16.0	UD		23								0.52	2.00	Lean Clay (CL)
	9	16.5	18.0	SPT	28	25										Fat Clay (CH)
	10	18.0	20.0	UD		37		71	25	46	99.9				3.00	Fat Clay (CH)
	11	20.0	22.0	UD		29	95.8						1.42 (12)		4.00	Fat Clay (CH)
	12	22.0	24.0	UD		24								0.37	0.25	Silt w/Sand (ML)
	13	24.5	26.0	SPT	18	26					84.4					Silt w/Sand (ML)
	14	26.0	28.0	UD		33	88.1						1.52 (14)		3.75	Fat Clay (CH)
	15	28.0	30.0	UD		30		78	28	50	99.8				3.75	Fat Clay (CH)
	16	30.0	32.0	UD		30									4.50	Fat Clay (CH)
	17	32.0	34.0	UD		30									4.00	Fat Clay (CH)
	18	34.0	35.0	UD		31	91.7						1.30 (17)		4.00	Fat Clay (CH)
	19	38.0	40.0	UD		29		69	25	44	99.1				3.75	Fat Clay (CH)
B-16A	1	15.5	17.0	SPT	5	27		27	19	8	97.1					Lean Clay (CL)

Legend			Notes:
	UD = UnDisturbed sample, extruded in field	LL = Liquid Limit	
	SS = Split Spoon sample	PL = Plastic Limit	
	AG = Auger Cuttings	PI = Plasticity Index	
	SPT = Standard Penetration Test	UU = Triaxial Compession	

SUMMARY OF TEST RESULTS	Project Name: 60-INCH WATER LINE ALONG MONROE FROM AIRPORT TO ROCKHILL AND ROCKHILL FROM MONROE TO GLEN VALLEY
	WBS Number: S-000900-0129-3
Aviles Engineering Corporation	AEC Project Number: G149-14

Boring No.	Sample				SPT (blows/ft)	Water Content (%)	Dry Density (pcf)	Atterberg Limits			Percent Passing Sieve #200 (%)	Shear Strength (tsf)				Type of Material
	No.	Depth (ft)		Type				LL (%)	PL (%)	PI (%)		Unconfined Compression	UU (confining pressure, psi)	Torvane	Pocket Penetrometer	
		Top	Bottom													
B-16A	2	17.0	19.0	UD		29	98.8						0.74 (10)		2.50	Fat Clay (CH)
	3	19.0	21.0	UD		31		73	26	47	99.8				4.50	Fat Clay (CH)
	4	21.0	23.0	UD		31	95.7						1.64 (12)		4.00	Fat Clay (CH)
	5	23.0	25.0	UD		26										Silt (ML)
	6	25.5	27.0	SPT	16	22		56	21	35	84.4					Silt (ML)
	7	27.0	29.0	UD		33	92.5						1.50 (14)		4.25	Fat Clay (CH)
	8	29.0	31.0	UD		33		78	28	50	99.6				3.75	Fat Clay (CH)
	9	31.0	33.0	UD		30	90.7						1.28 (15)		4.00	Fat Clay (CH)
	10	33.0	35.0	UD		29									4.25	Fat Clay (CH)
	11	38.5	40.0	SPT	22	30										Sandy Silt (ML)
B-17	1	0.0	2.0	UD		26		52	17	35	87.1				2.25	Fat Clay (CH)
	2	2.0	4.0	UD		21	107.0					1.44			1.75	Fat Clay (CH)
	3	4.0	6.0	UD		20									3.25	Fat Clay (CH)
	4	6.0	8.0	UD		23									3.25	Fat Clay (CH)
	5	8.0	10.0	UD		30		65	24	41	97.2				2.25	Fat Clay (CH)
	6	10.0	12.0	UD		22	104.9						2.11 (7)		3.00	Lean Clay (CL)
	7	12.0	14.0	UD		20									2.50	Lean Clay (CL)
	8	14.0	15.0	UD		26								0.57	0.75	Lean Clay (CL)
B-18	1	0.0	2.0	UD		22									2.25	Fat Clay (CH)
	2	2.0	4.0	UD		22		55	17	38	77.0				2.75	Fat Clay (CH)
	3	4.0	6.0	UD		26	103.5						1.55 (3)		2.00	Fat Clay (CH)
	4	6.0	8.0	UD		26									2.00	Fat Clay (CH)
	5	8.0	10.0	UD		20									4.50	Lean Clay (CL)
	6	10.0	12.0	UD		21	105.5	43	16	27	97.1		1.74 (7)		2.75	Lean Clay (CL)
	7	12.0	14.0	UD		24									3.00	Lean Clay (CL)
	8	14.0	16.0	UD		26		29	18	11	86.1			0.26	2.00	Lean Clay (CL)
	9	16.0	18.0	UD		22	105.7						1.04 (10)		1.25	Lean Clay (CL)
	10	18.5	20.0	SPT	35	24					98.8					Fat Clay (CH)
	11	23.0	25.0	UD		29	93.4						1.61 (12)		4.25	Fat Clay (CH)

Legend			
	UD = UnDisturbed sample, extruded in field	LL = Liquid Limit	Notes:
	SS = Split Spoon sample	PL = Plastic Limit	
	AG = Auger Cuttings	PI = Plasticity Index	
	SPT = Standard Penetration Test	UU = Triaxial Compession	

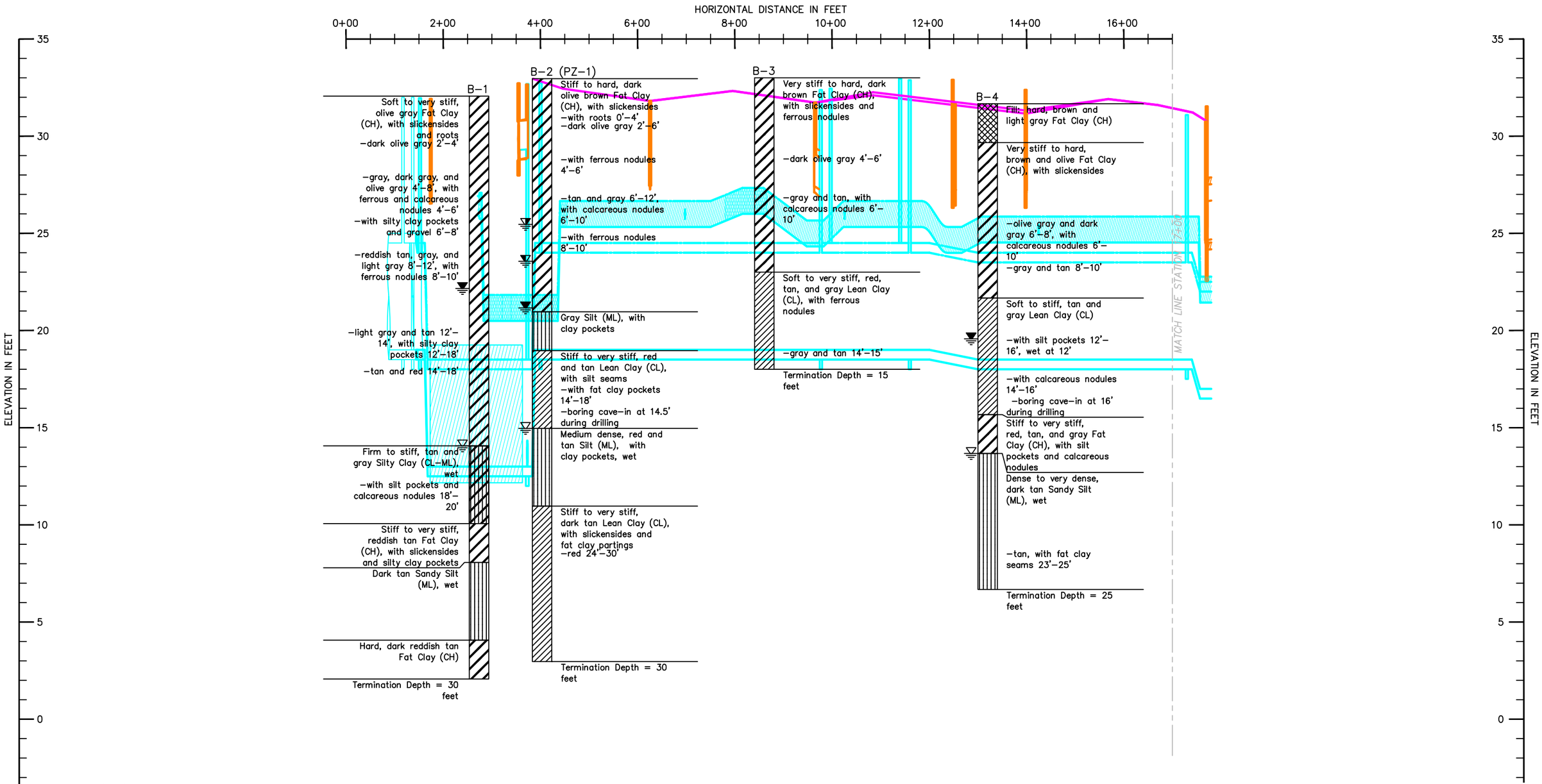
AVILES ENGINEERING CORP.

APPENDIX B

Plates B-1a and B-1b	Generalized Soil Profile along Monroe Road
Plates B-2a and B-2b	Generalized Soil Profile along Rockhill Street
Plates B-3 to B-5	Piezometer Installation Details
Plate B-6	Terrain Solutions, Inc. Drawing, "Principal Surface Faults of the Houston Central Metropolitan Area (After O'Neill & Van Siclen with additions by C. Norman)"
Plate B-7	Aviles Engineering Corporation Drawing, "Map Showing Surface Faults of Southeastern Houston Metropolitan Area, from Verbeek & Clanton, 1978, USGS Open File Report 78-797"
Plate B-8	Aviles Engineering Drawing, "Geotechnical Investigation, SMGCS/Civil Site Work for ILS CAT III, William P Hobby Airport"

GENERALIZED SUBSURFACE SOIL PROFILE

ALONG MONROE ROAD



LEGEND:

- Paving
- Fill
- Low plasticity clay
- Clayey sand
- High plasticity clay
- Silty low plasticity clay
- Silt
- Silty sand
- Depth of water encountered during drilling
- Depth of water ~15 minutes after initial encounter
- Depth of water measured 9/16/14 in piezometer
- Depth of water measured 3/20/15 in piezometer

Note: Soil stratigraphy and secondary soil structure (such as seams, layers, or pockets of sands, silts, slickensides, and fissures) that are different from what were identified in the actual borings may exist away from these borings.

AVILES ENGINEERING CORPORATION

GENERALIZED SOIL PROFILE

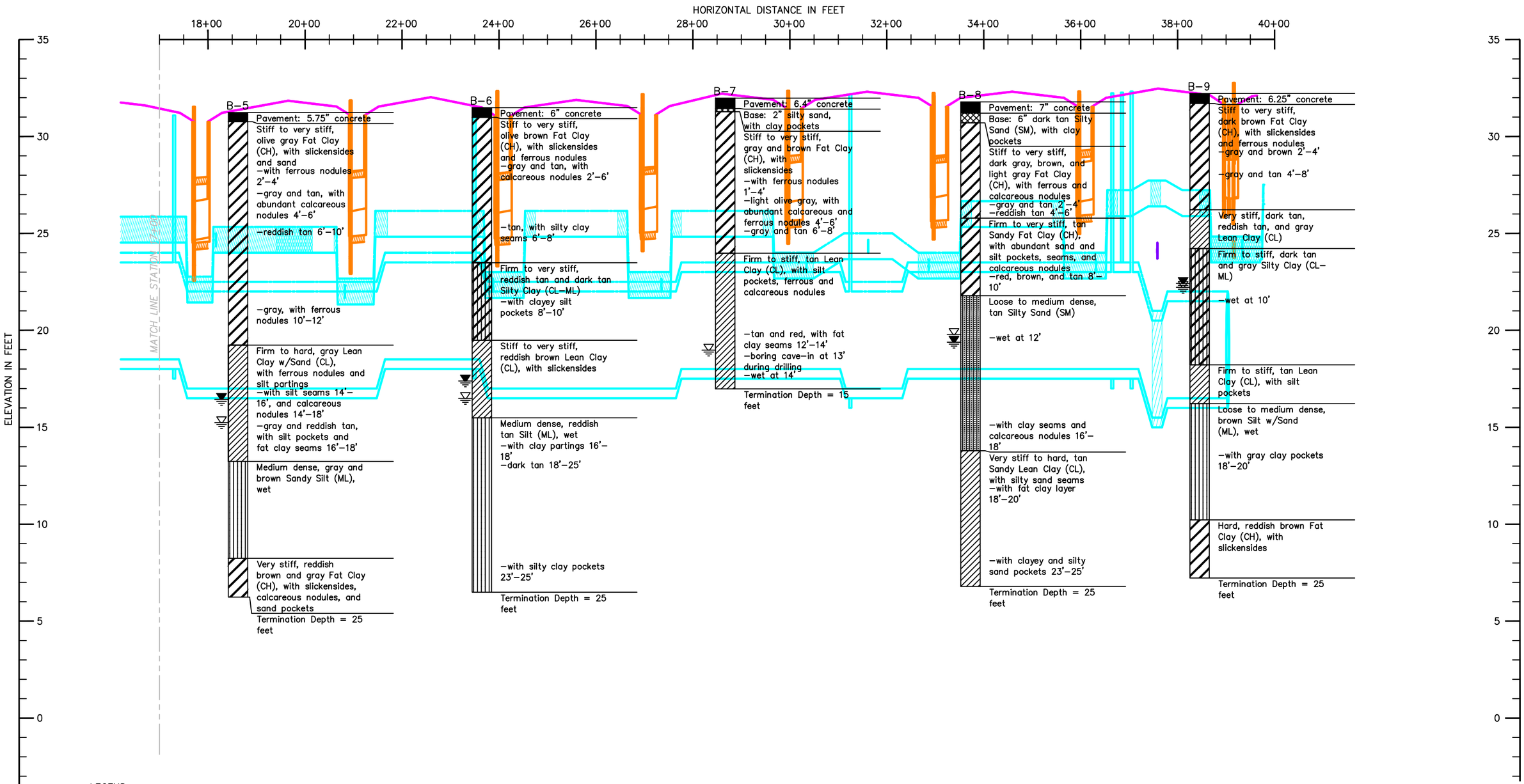
60 INCH WATERLINE ALONG MONROE AND ROCKHILL
WBS NO. S-000900-129-3
HOUSTON, TEXAS

AEC PROJECT NO. : G149-14	DATE : 06-04-15	SOURCE DRAWING PROVIDED BY: AVILES ENGINEERING CORP.
VERTICAL SCALE : 1" = 5' HORIZONTAL SCALE : 1" = 200'	DRAFTED BY : BpJ	PLATE NO. : PLATE B-1a

GENERALIZED SUBSURFACE SOIL PROFILE

ALONG MONROE ROAD

SOUTH — NORTH



LEGEND:

- Paving
- Fill
- Low plasticity clay
- Clayey sand
- High plasticity clay
- Silty low plasticity clay
- Silt
- Silty sand
- Depth of water encountered during drilling
- Depth of water ~15 minutes after initial encounter
- Depth of water measured 9/16/14 in piezometer
- Depth of water measured 3/20/15 in piezometer

Notes: Soil stratigraphy and secondary soil structure (such as seams, layers, or pockets of sands, silts, slickensides, and fissures) that are different from what were identified in the actual borings may exist away from these borings.

Additional borings B−5A and B−7A are not shown due to distance offset from water line alignment.

AVILES ENGINEERING CORPORATION

GENERALIZED SOIL PROFILE

60 INCH WATERLINE ALONG MONROE AND ROCKHILL

WBS NO. S-000900-129-3

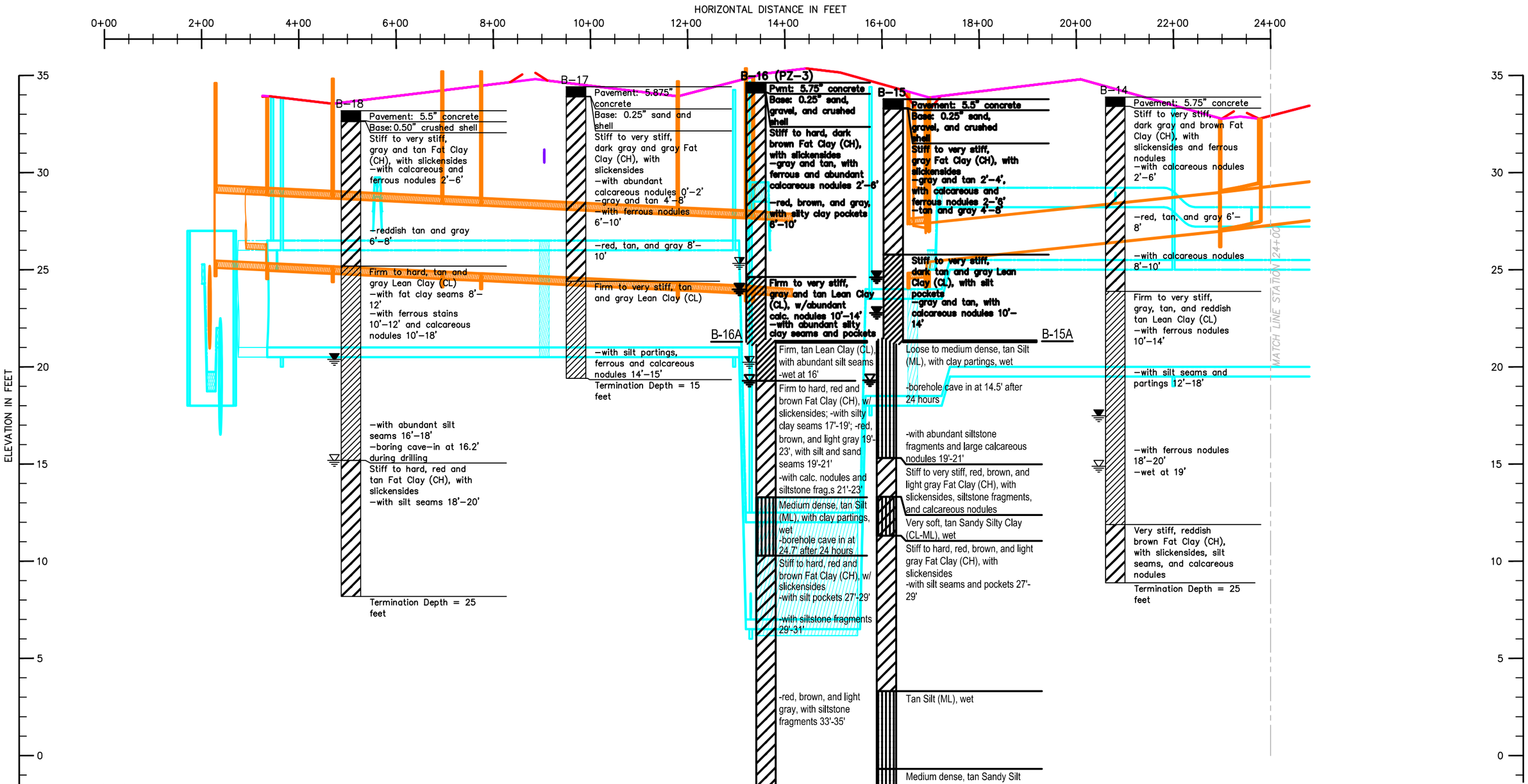
HOUSTON, TEXAS

AEC PROJECT NO. : G149-14	DATE : 06-04-15	SOURCE DRAWING PROVIDED BY: AVILES ENGINEERING CORP.
VERTICAL SCALE : 1" = 5' HORIZONTAL SCALE : 1" = 200'	DRAFTED BY : BpJ	PLATE NO. : PLATE B-1b

GENERALIZED SUBSURFACE SOIL PROFILE

ALONG ROCKHILL STREET

WEST — EAST



LEGEND:

- Paving
- Fill
- Low plasticity clay
- Clayey sand
- High plasticity clay
- Silty low plasticity clay
- Silt
- Silty sand
- Depth of water encountered during drilling
- Depth of water ~15 minutes after initial encounter
- Depth of water measured 9/16/14 in piezometer
- Depth of water measured 3/20/15 in piezometer

Notes: Soil stratigraphy and secondary soil structure (such as seams, layers, or pockets of sands, silts, slickensides, and fissures) that are different from what were identified in the actual borings may exist away from these borings.

Additional borings B−15A and B−16A (auger only from 0'−15') are shown instead of B−15 and B−16 because of proximity to revised water line alignment.

AVILES ENGINEERING CORPORATION

GENERALIZED SOIL PROFILE

60 INCH WATERLINE ALONG MONROE AND ROCKHILL
WBS NO. S-000900-129-3
HOUSTON, TEXAS

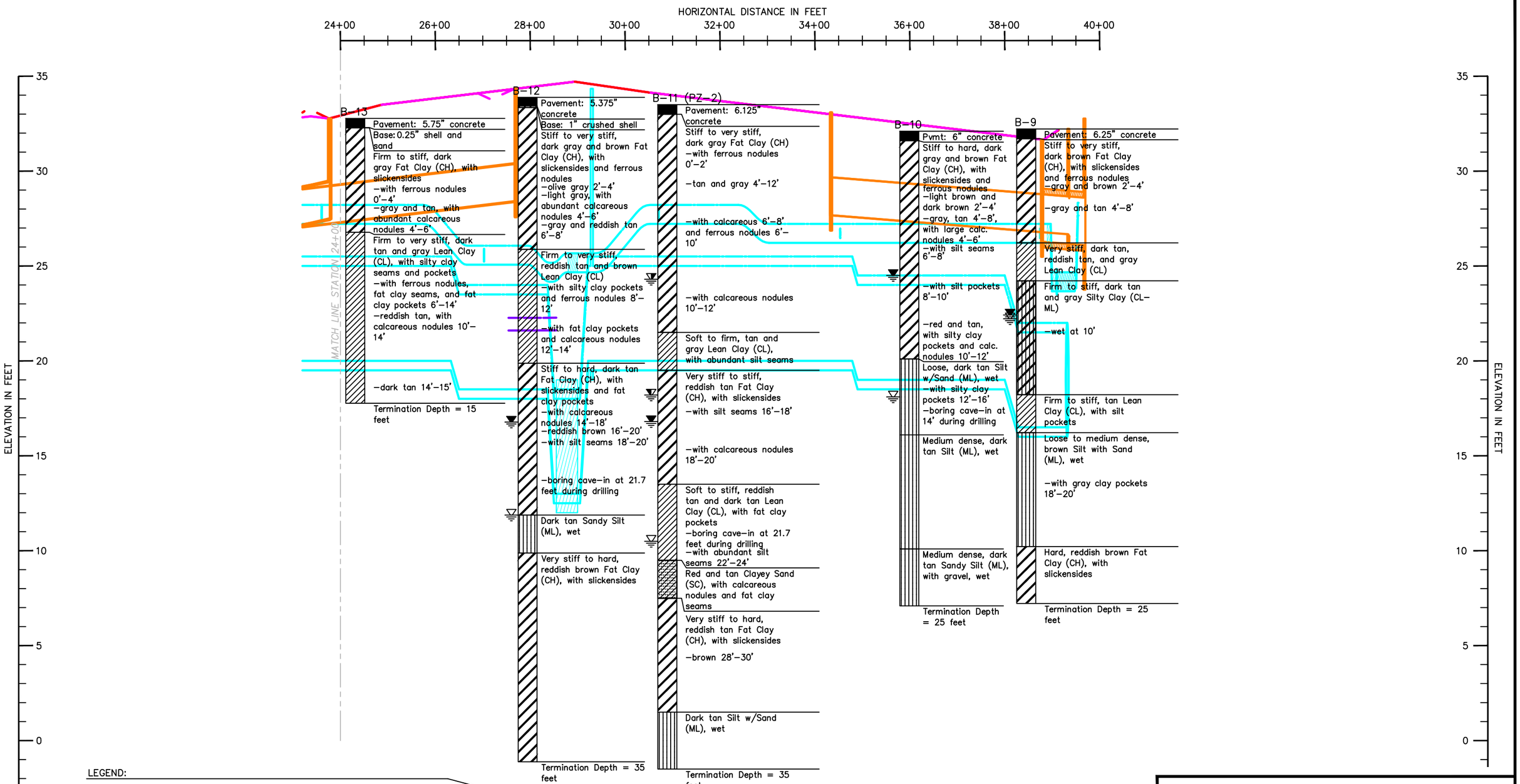
AEC PROJECT NO. : G149-14	DATE : 06-04-15	SOURCE DRAWING PROVIDED BY: AVILES ENGINEERING CORP.
VERTICAL SCALE : 1" = 5' HORIZONTAL SCALE : 1" = 200'	DRAFTED BY : BpJ	PLATE NO. : PLATE B-2a

GENERALIZED SUBSURFACE SOIL PROFILE

ALONG ROCKHILL STREET

WEST

EAST



LEGEND:

- Paving
- Fill
- Low plasticity clay
- Clayey sand
- High plasticity clay
- Silty low plasticity clay
- Silt
- Silty sand
- Depth of water encountered during drilling
- Depth of water ~15 minutes after initial encounter
- Depth of water measured 9/16/14 in piezometer
- Depth of water measured 3/20/15 in piezometer

Note: Soil stratigraphy and secondary soil structure (such as seams, layers, or pockets of sands, silts, slickensides, and fissures) that are different from what were identified in the actual borings may exist away from these borings.

AVILES ENGINEERING CORPORATION

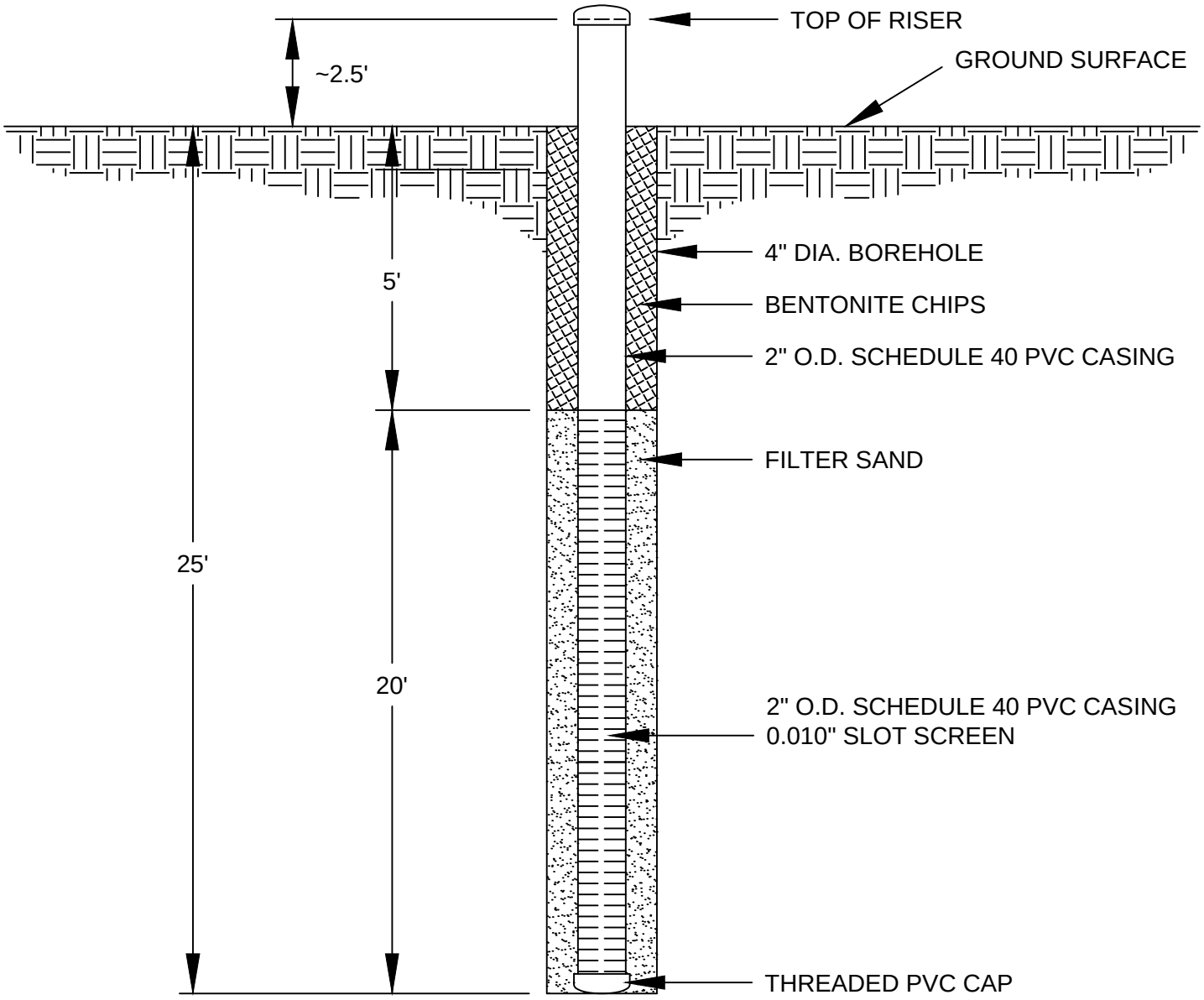
GENERALIZED SOIL PROFILE

60 INCH WATERLINE ALONG MONROE AND ROCKHILL

WBS NO. S-000900-129-3

HOUSTON, TEXAS

AEC PROJECT NO. : G149-14	DATE : 06-04-15	SOURCE DRAWING PROVIDED BY: AVILES ENGINEERING CORP.
VERTICAL SCALE : 1" = 5' HORIZONTAL SCALE : 1" = 200'	DRAFTED BY : BpJ	PLATE NO. : PLATE B-2b



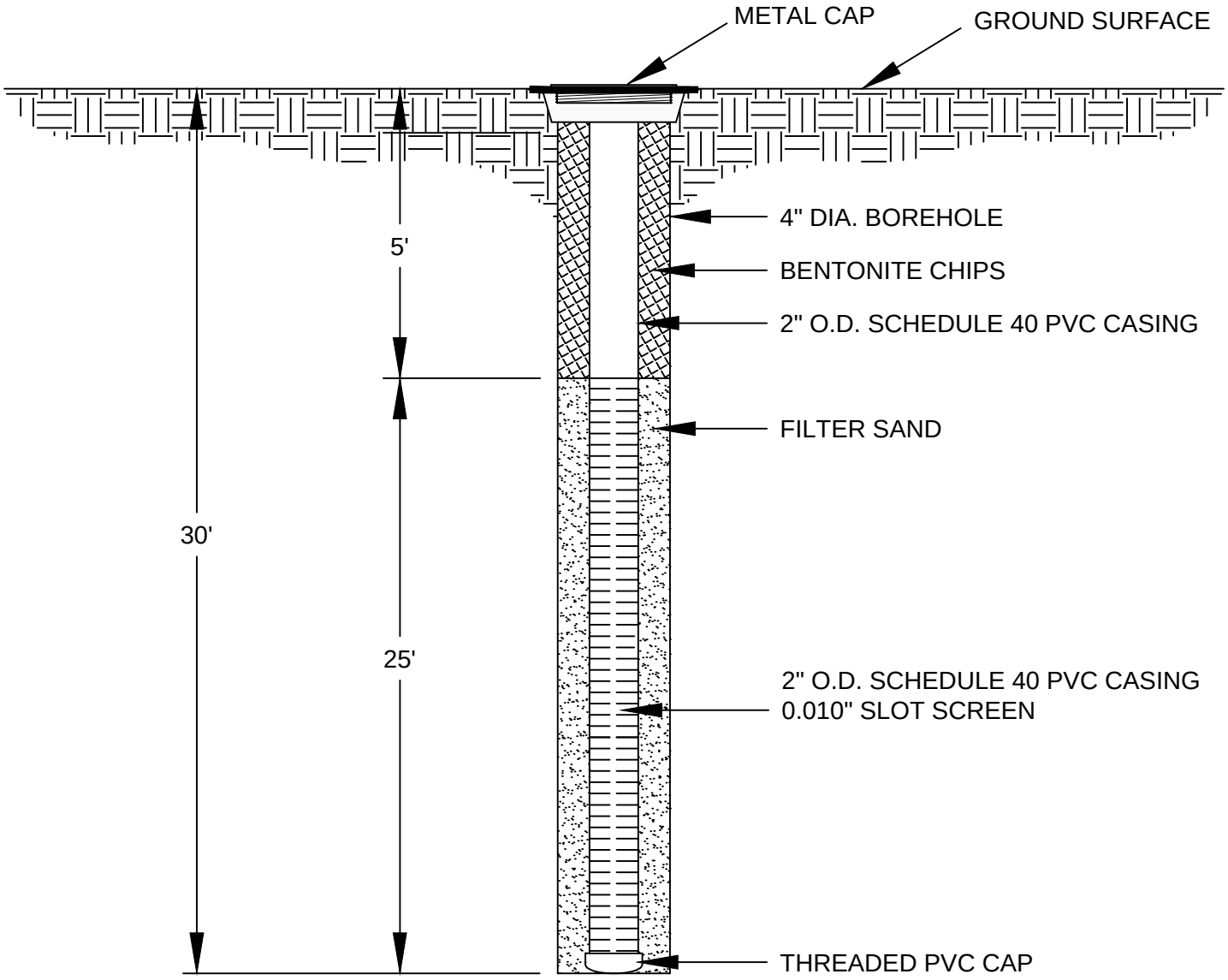
GROUNDWATER DEPTH FROM SURFACE:	DATE MEASURED:
9.4 FT	9/16/14
7.5 FT	3/20/15

AVILES ENGINEERING CORPORATION

PIEZOMETER INSTALLATION DETAILS
BORING B-2 (PZ-1)

60-INCH WATERLINE ALONG MONROE AND ROCKHILL
WBS NO. S-000900-0129-4
HOUSTON, TEXAS

AEC PROJECT NO. :	DATE:	SOURCE DWG. BY:
G149-14	10-28-14	AVILES ENGINEERING CORP.
SCALE:	DRAWN BY:	PLATE NO. :
N.T.S.	BpJ	PLATE B-3



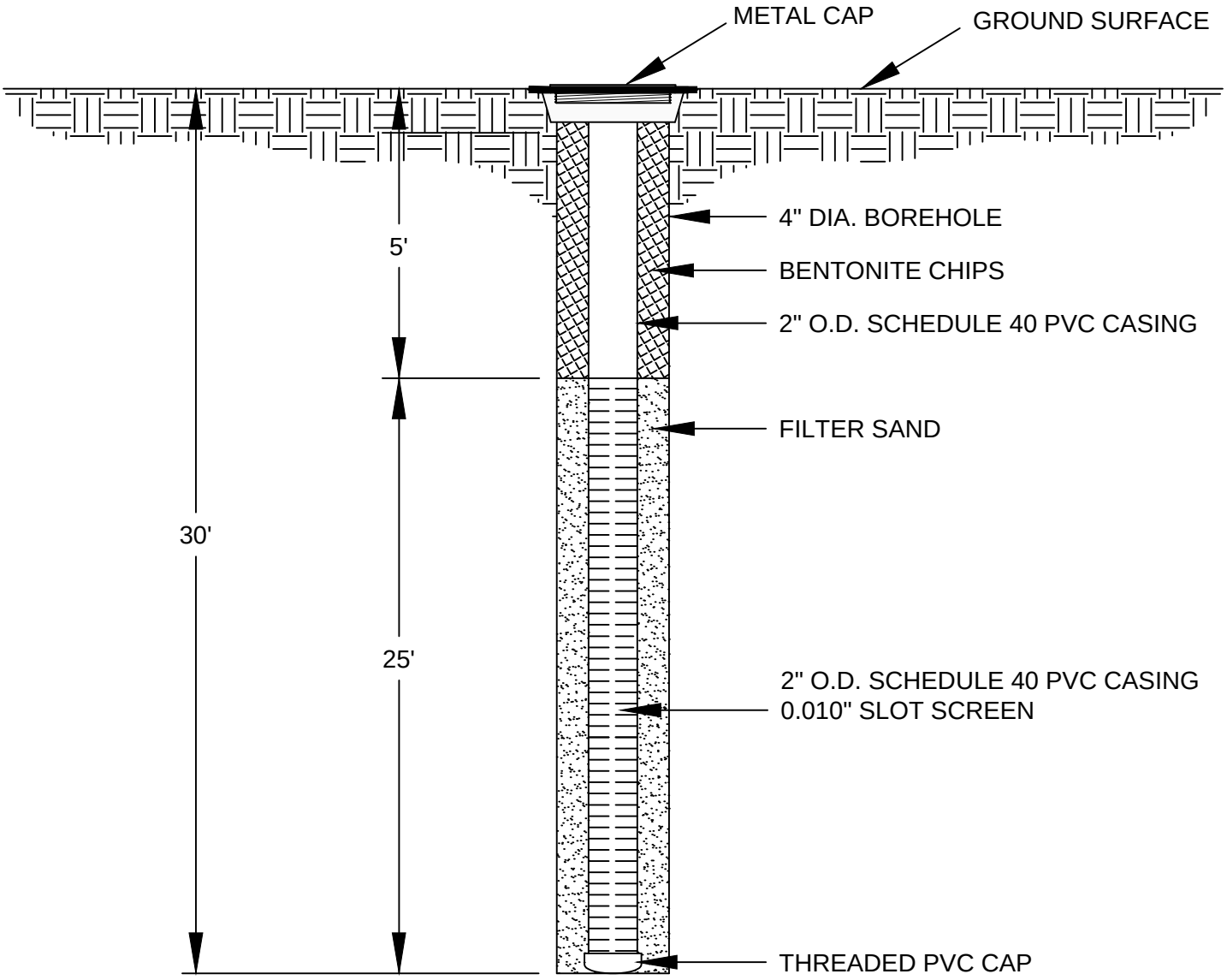
GROUNDWATER DEPTH FROM SURFACE:	DATE MEASURED:
15.3 FT	9/16/14
9.2 FT	3/20/15

AVILES ENGINEERING CORPORATION

PIEZOMETER INSTALLATION DETAILS
BORING B-11 (PZ-2)

60-INCH WATERLINE ALONG MONROE AND ROCKHILL
WBS NO. S-000900-0129-4
HOUSTON, TEXAS

AEC PROJECT NO. :	DATE:	SOURCE DWG. BY:
G149-14	10-28-14	AVILES ENGINEERING CORP.
SCALE:	DRAWN BY:	PLATE NO. :
N.T.S.	BpJ	PLATE B-4



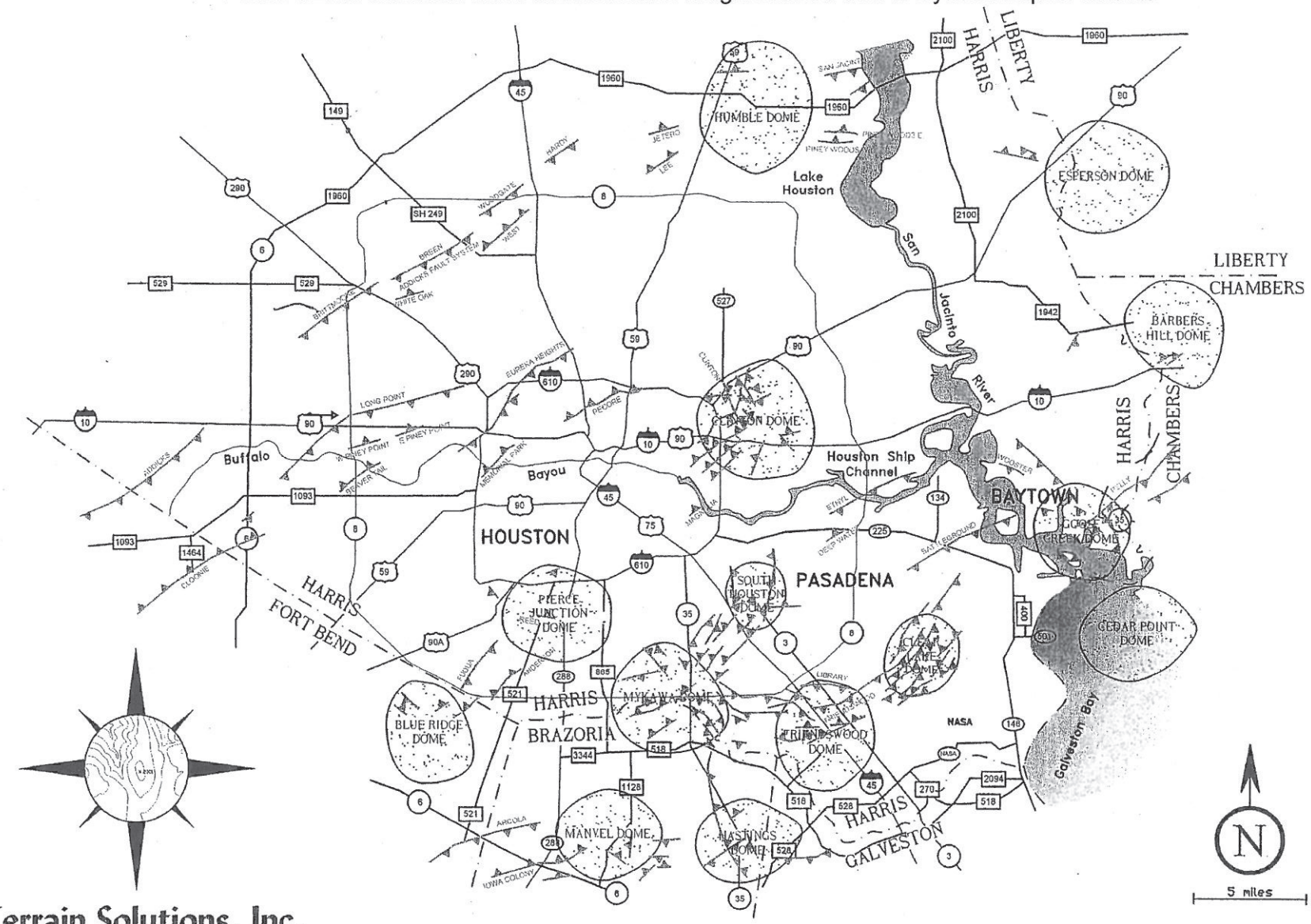
GROUNDWATER DEPTH FROM SURFACE:	DATE MEASURED:
14.4 FT	9/16/14
9.3 FT	3/20/15

AVILES ENGINEERING CORPORATION

PIEZOMETER INSTALLATION DETAILS
BORING B-16 (PZ-3)

60-INCH WATERLINE ALONG MONROE AND ROCKHILL
WBS NO. S-000900-0129-4
HOUSTON, TEXAS

AEC PROJECT NO. :	DATE:	SOURCE DWG. BY:
G149-14	10-28-14	AVILES ENGINEERING CORP.
SCALE:	DRAWN BY:	PLATE NO. :
N.T.S.	BpJ	PLATE B-5

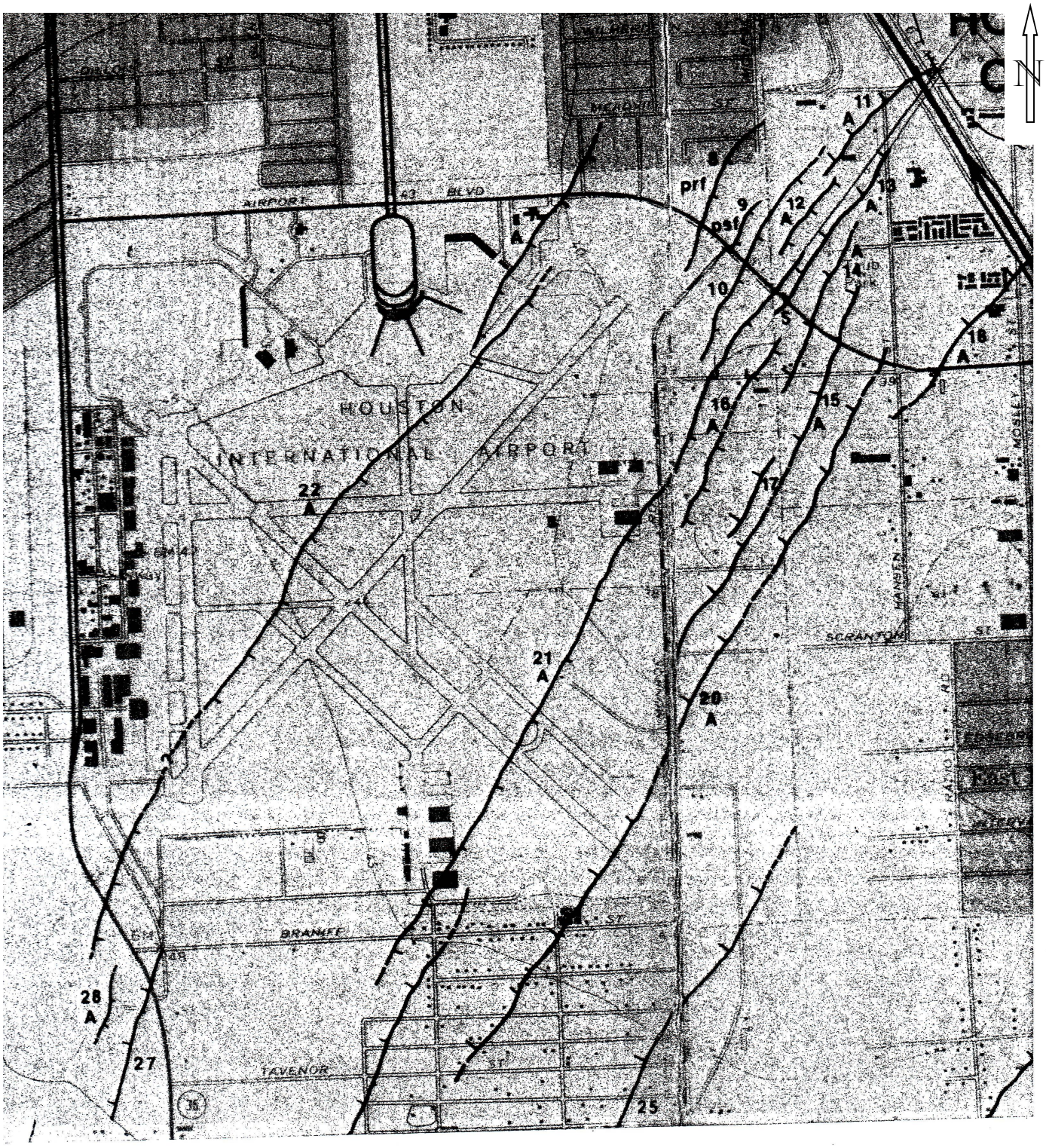


Terrain Solutions, Inc.

Principal Surface Faults of the Houston Central Metropolitan Area

(After O'Neill & Van Siclen with additions by C. Norman)

Rev. 05/13/04

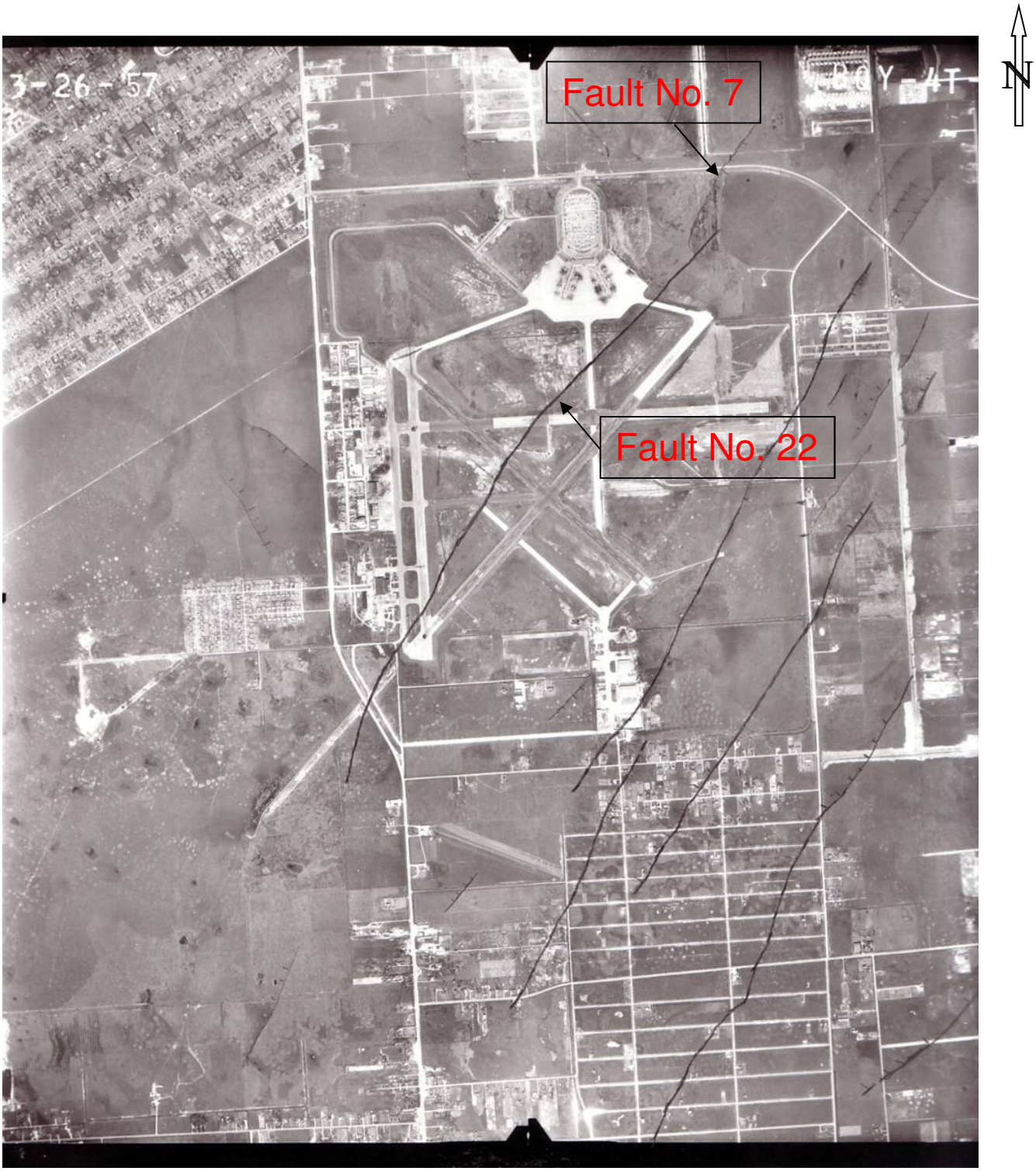


0 1500 3000
Feet

AVILES ENGINEERING CORPORATION

MAP SHOWING SURFACE FAULTS IN SOUTHEASTERN HOUSTON METROPOLITAN AREA, TEXAS
(From Verbeek & Clanton, 1978, U.S.G.S. Open File Report 78-797)

AEC PROJECT NO. :	DATE:	
G243-03	06-03-04	
SCALE: (see above)	DRAWN BY: B.P.J.	PLATE NO. : PLATE B-7



AVILES ENGINEERING CORPORATION

AERIAL PHOTO WITH FAULT LINES

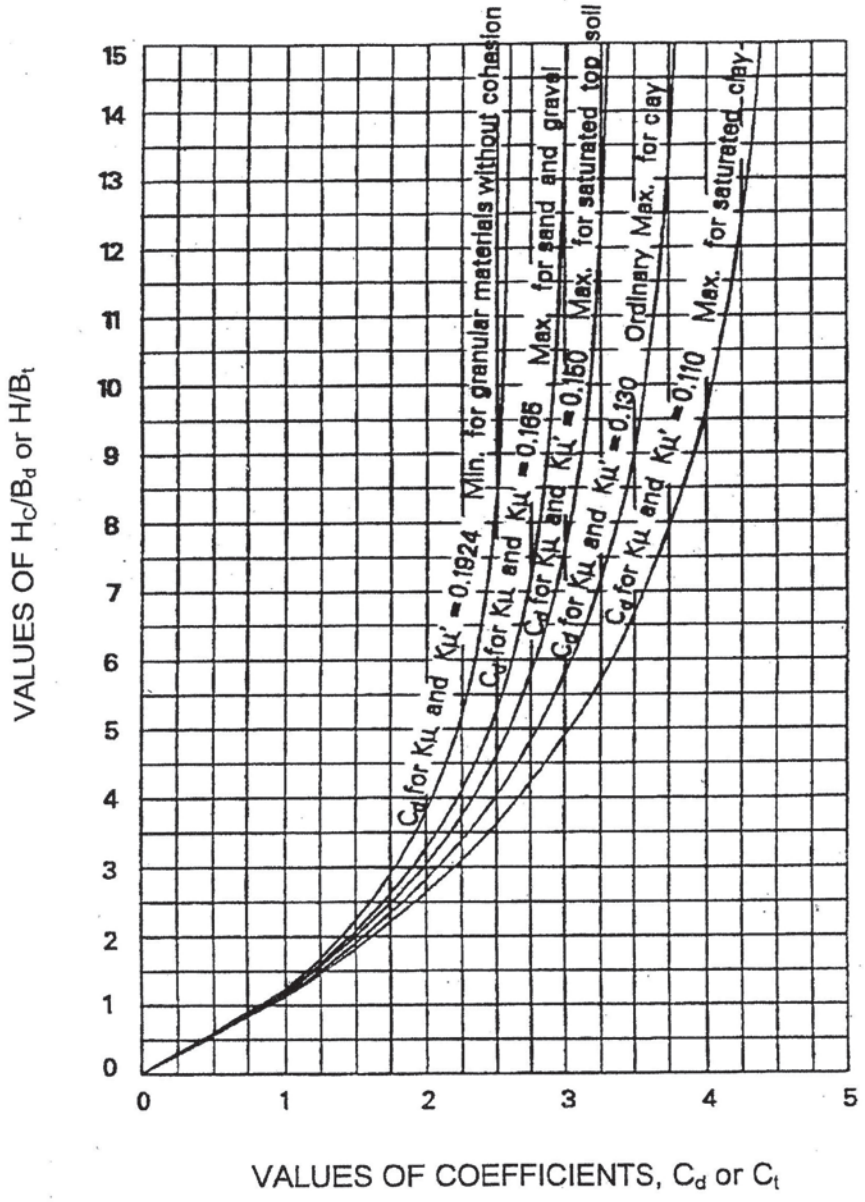
GEOTECHNICAL INVESTIGATION, SMGCS/CIVIL SITE WORK FOR ILS CAT III, WILLIAM P. HOBBY AIRPORT HAS PROJECT NO. 566B, CIP NO. A-0407

AEC PROJECT NO. :	DATE:	
G243-03	05-19-04	
SCALE:	DRAWN BY:	PLATE NO. :
N.T.S.	B.P.J.	PLATE B-8

AVILES ENGINEERING CORP.

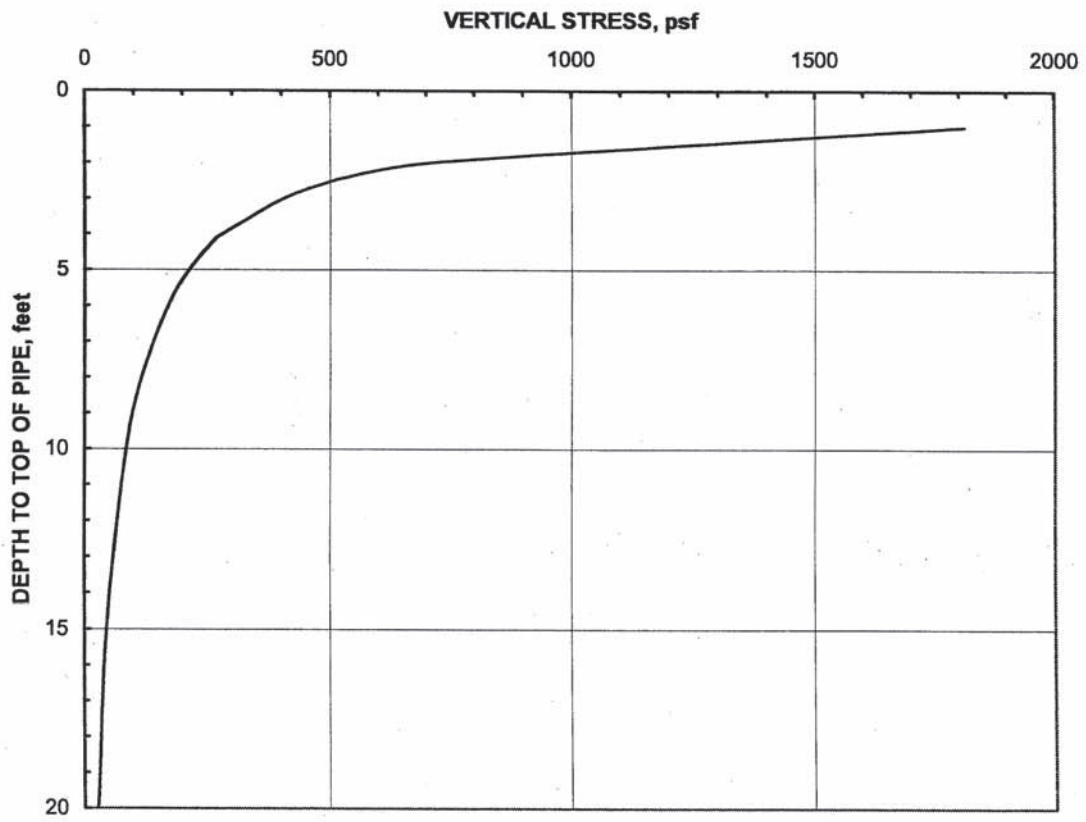
APPENDIX C

Plates C-1 to C-5	Recommended Geotechnical Design Parameters
Plate C-6	Load Coefficients for Pipe Loading
Plate C-7	Live Loads on Pipe Crossing Under Roadway



Reference: US Army Corps of Engineers Engineering Manual, EM 1110-2-2902, Oct. 31, 1997, Figure 2-5.

AVILES ENGINEERING CORP.



LIVE LOADS ON PIPE CROSSING UNDER ROADWAY

Note: 1. The vertical stress was estimated using AASHTO HS20 truck axle loadings on paved surfaces (Reference: ASCE 15-98, "Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standandard Installations").
2. Single truck passing.

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APPENDIX D

Plate D-1	Critical Heights of Cut Slopes in Nonfissured Clays
Plate D-2	Maximum Allowable Slopes
Plate D-3	A Combination of Bracing and Open Cuts
Plate D-4	Lateral Pressure Diagrams for Open Cuts in Cohesive Soil-Long Term Conditions
Plate D-5	Lateral Pressure Diagrams for Open Cuts in Cohesive Soil-Short Term Conditions
Plate D-6	Lateral Pressure Diagrams for Open Cuts in Sand
Plate D-7	Bottom Stability for Braced Excavation in Clay
Plate D-8	Thrust Force Calculation
Plate D-9	Thrust Force Example Calculation
Plate D-10	Design Parameters for Bearing Thrust Block
Plate D-11	Relation between the Width of Surface Depression and Depth of Cavity for Tunnels
Plate D-12	Tunnel Behavior and TBM Selection
Plate D-13	Methods of Controlling Ground Water in Tunnel and Grouting Material Selection

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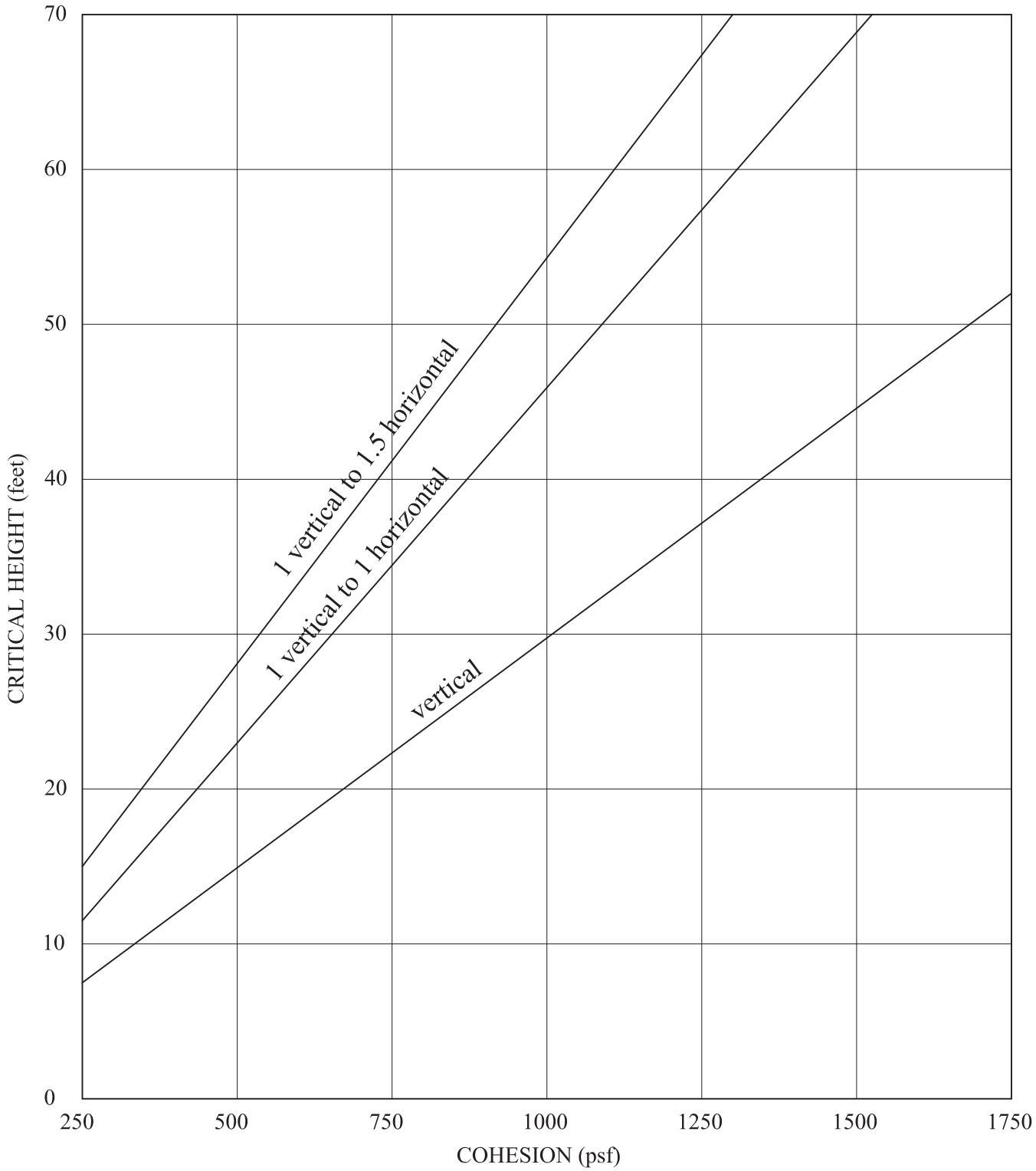
Critical Heights of Cut Slopes in Nonfissured Clays



Note: The charts are calculated based on NAVFAC DM7.1, Page 7.1-319, assuming the critical circles are toe circles, and wet unit weight of soils = 125pcf.

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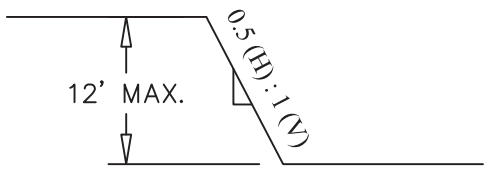
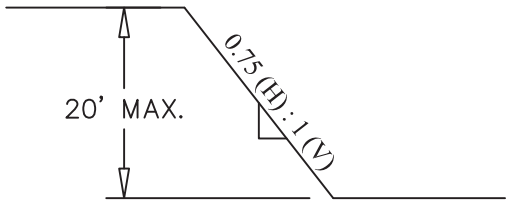
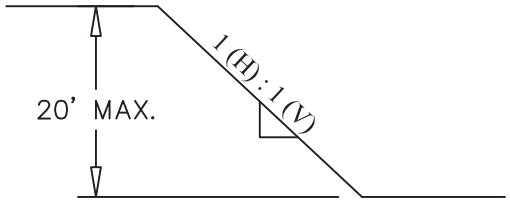
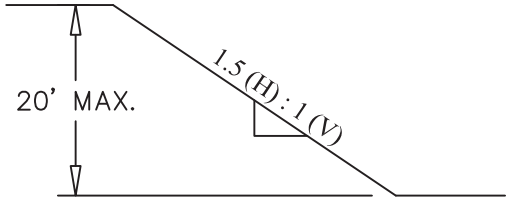
MAXIMUM ALLOWABLE SLOPES

	SHORT TERM	LONG TERM
TYPE A SOILS		
TYPE B SOILS	N/A	
TYPE C SOILS	N/A	

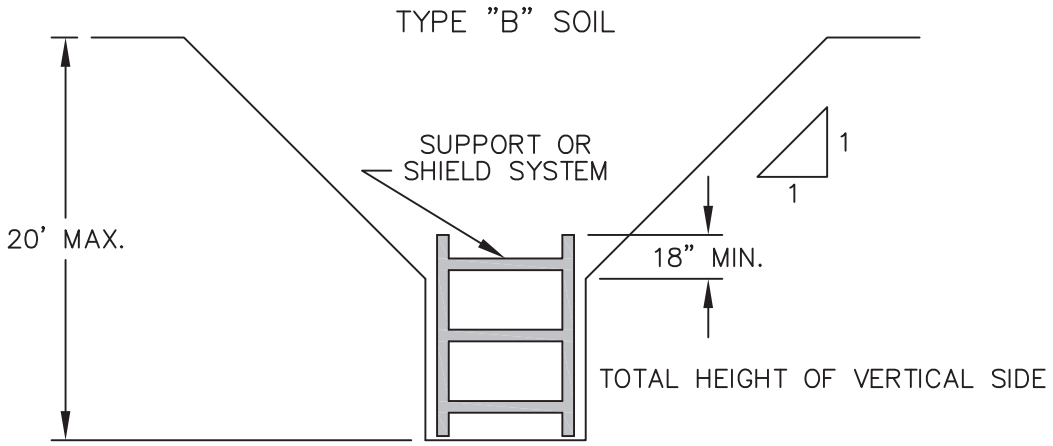
NOTES:

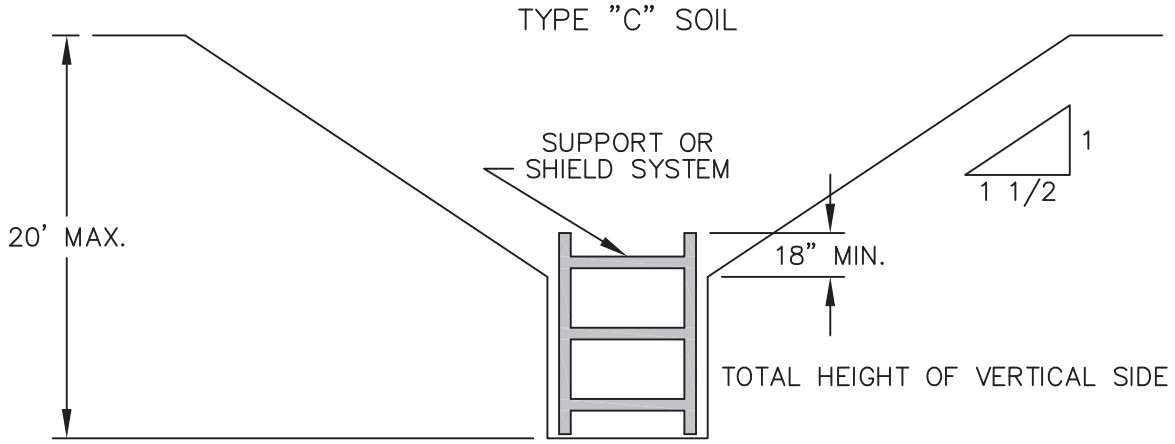
(1) For Type A soils, a short term maximum allowable slope of 0.5 (H) : 1 (V) is allowed in excavations that are 12 feet or less in depth; short term (24 hours or less) maximum allowable slopes for excavations greater than 12 feet in depth shall be 0.75 (H) : 1 (V).

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

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

A COMBINATION OF BRACING AND OPEN CUTS

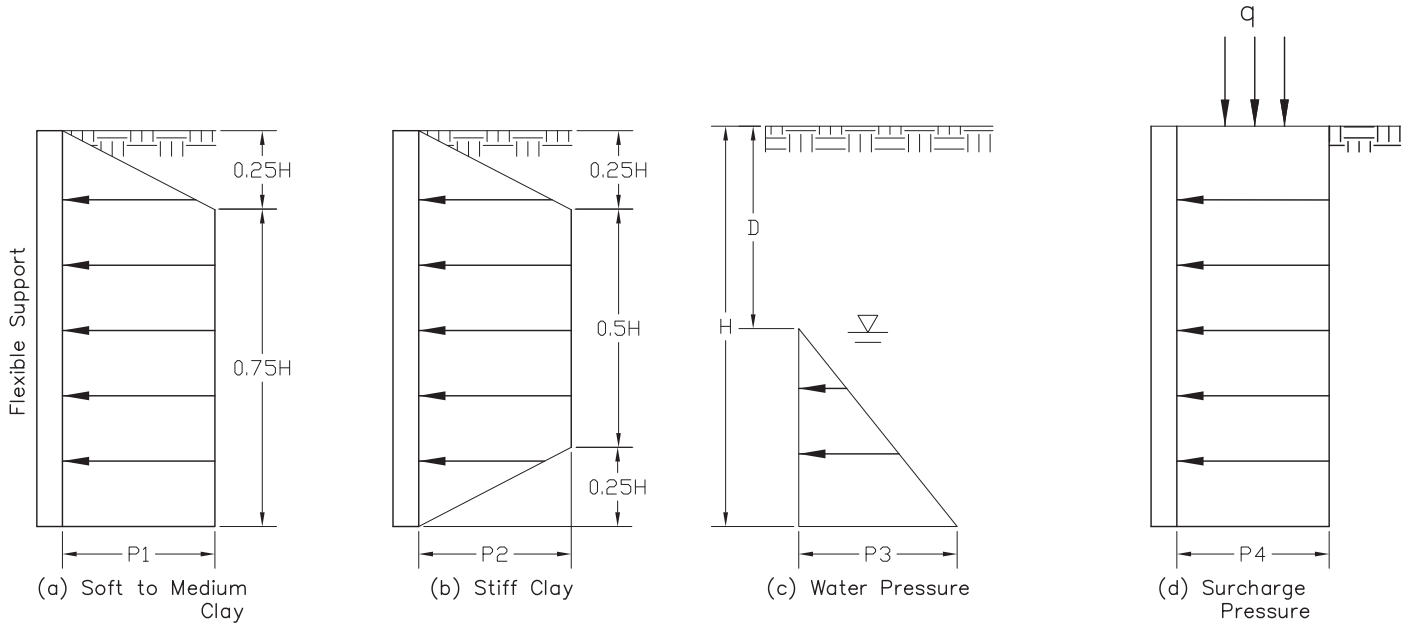




Reference: OSHA, Safety and Health Regulations for Construction, 1926 Subpart P.

AVILES ENGINEERING CORP.

LATERAL PRESSURE DIAGRAMS
FOR OPEN CUTS IN COHESIVE SOIL - LONG TERM CONDITIONS



Empirical Pressure Distributions

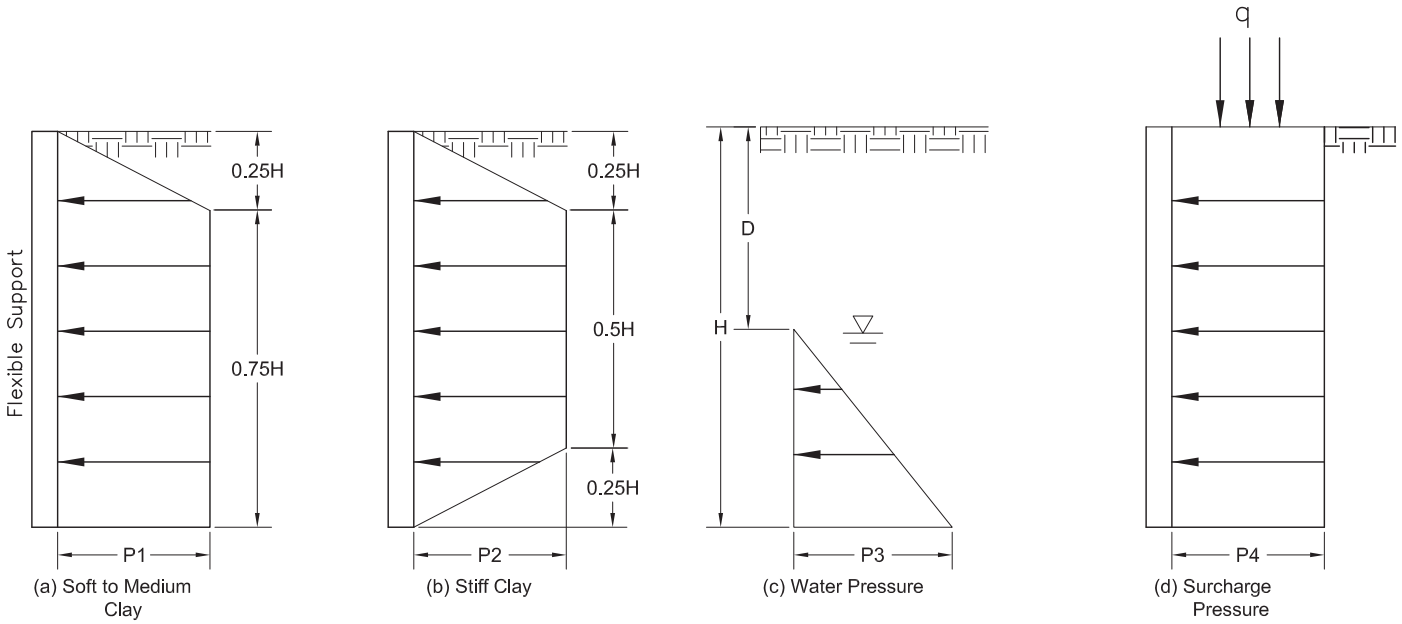
Where:
H = Total excavation depth, feet
D = Depth to water table, feet
P1 = Lateral earth pressure = γH-4C, psf
P2 = Lateral earth pressure = 0.4γH, psf
P3 = Water pressure = γ_w (H-D), psf
P4 = Lateral earth pressure caused by surcharge = qK_a, psf
γ = Effective unit weight of soil, pcf
γ_w = Unit weight of water, pcf
C = Drained shear strength or cohesion, psf
K_a = Coefficient of active earth pressure

Notes:
1. All pressures are additive.
2. No safety factors are included.
3. For use only during long term construction.
4. If γH/C < 4, use section (b),
   If 4 < γH/C < 6, use larger of section (a) or (b),
   If γH/C > 6, use section (a).

Reference: Peck, R.B. (1969), "Deep Excavation and Tunneling in soft Ground", 7th ICSMFE, State of art volume, pp. 225-290.

AYLES ENGINEERING CORP.

LATERAL PRESSURE DIAGRAMS
FOR OPEN CUTS IN COHESIVE SOIL - SHORT TERM CONDITIONS



Empirical Pressure Distributions

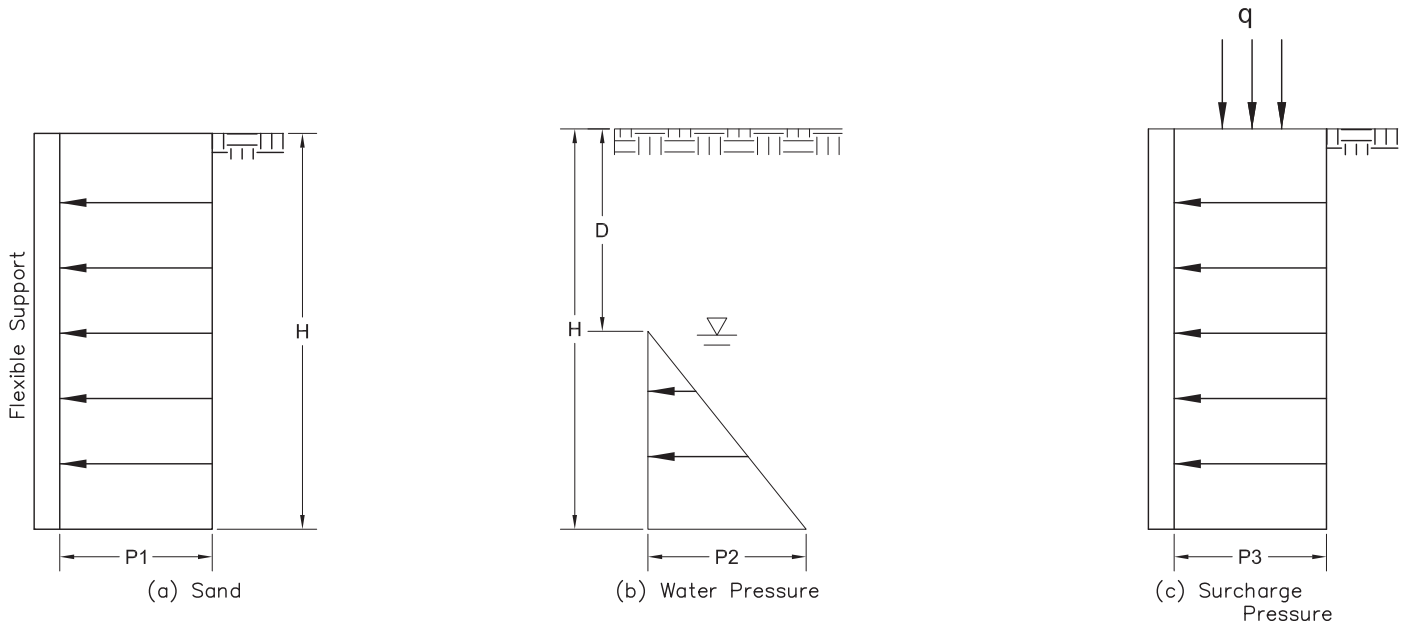
Where:
H = Total excavation depth, feet
D = Depth to water table, feet
P1 = Lateral earth pressure = $\gamma H - 4S_u$, psf
P2 = Lateral earth pressure = $0.2\gamma H$, psf
P3 = Water pressure = γ_w (H-D), psf
P4 = Lateral earth pressure caused by surcharge = qK_a, psf
γ = Effective unit weight of soil, pcf
γ_w = Unit weight of water, pcf
S_u = Undrained shear strength = $q_u/2$, psf
q_u = Unconfined compressive strength, psf
K_a = Coefficient of active earth pressure

Notes:
1. All pressures are additive.
2. No safety factors are included.
3. For use only during short term construction.
4. If $\gamma H/S_u < 4$, use section (b),
   If $4 < \gamma H/S_u < 6$, use larger of section (a) or (b),
   If $\gamma H/S_u > 6$, use section (a).

Reference: Peck, R.B. (1969), "Deep Excavation and Tunneling in soft Ground", 7th ICSMFE, State of art volume, pp. 225-290.

AYLES ENGINEERING CORP.

LATERAL PRESSURE DIAGRAMS
FOR OPEN CUTS IN SAND



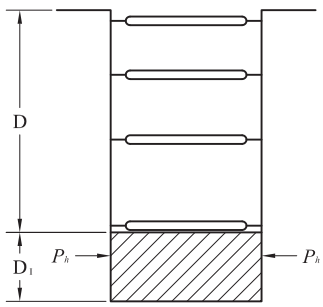
Empirical Pressure Distributions

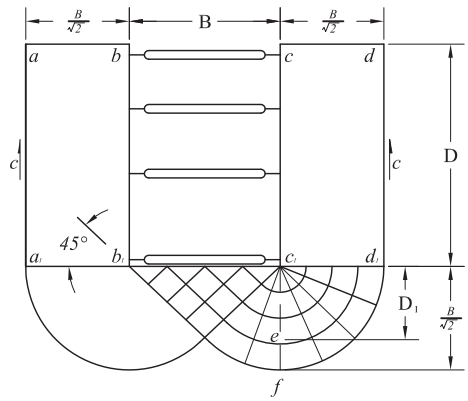
Where:
H = Total excavation depth, feet
D = Depth to water table, feet
P1 = Lateral earth pressure = $0.65*\gamma HK_a$, psf
P2 = Water pressure = γ_w (H-D), psf
P3 = Lateral earth pressure caused by surcharge = qK_a, psf
γ = Effective unit weight of soil, pcf
γ_w = Unit weight of water, pcf
K_a = Coefficient of active earth pressure = $(1-\sin\varphi)/(1+\sin\varphi)$
φ = Drained friction angle

Notes:
1. All pressures are additive.
2. No safety factors are included.

Reference: Peck, R.B. (1969), "Deep Excavation and Tunneling in soft Ground", 7th ICSMFE, State of art volume, pp. 225-290.

BOTTOM STABILITY FOR BRACED EXCAVATION IN CLAY





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

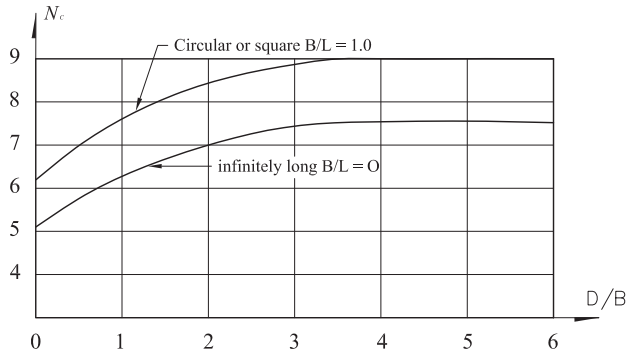
$$\textit{Depth of Buried Length, } (D_1) = \frac{1.5(\gamma D+q)-NcC}{(C/B)-0.5\gamma} \; ; D_1 \geq 5\ ft.$$

Pressure on buried length, P_h:

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

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

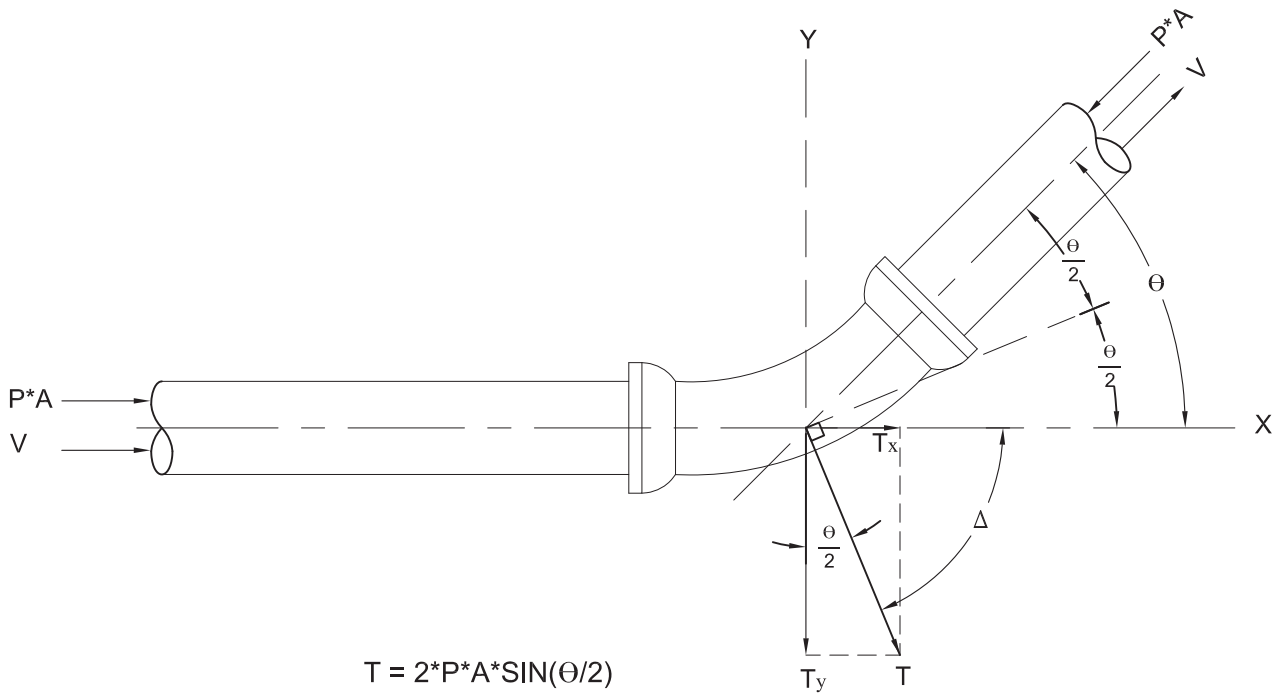
where; B = width of excavation



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

Reference: Bjerrum, L. and Eide, O., Stability of Strutted Excavations in Clay, Geotechnique, 6, 32-47 (1956).

THRUST FORCE CALCULATION



$T = 2*P*A*SIN(\Theta/2)$

$T_x = P*A*(1-COS\Theta)$

$T_y = P*A*SIN\Theta$

$\Delta = (90-\Theta/2)$

Where:

T = resultant thrust force

T_x= thrust force component along the X axis

T_y= thrust force component along the Y axis

P = maximum sustained pressure

A = cross-sectional area of pipe = $(\pi/4)*(D)^2$

D = inside diameter conduit

Θ = angle of bend

Δ = angle between X axis and T

V = fluid velocity

Reference: American Water Works Association, Manual MA, "Concrete Pressure Pipe".

THRUST FORCE EXAMPLE CALCULATION

Trust Force Example Calculation

$T = 2*P*A*SIN(\Theta/2)$

$T_x = P*A*SIN(1-COS\Theta)$

$T_y = P*A*SIN\ \Theta$

Where:

T = resultant thrust force

T_x = thrust force component along the X axis

T_y = thrust force component along the Y axis

P = maximum sustained pressure

A = cross-section area of pipe = $(\pi/4)*(D)^2$

D = inside diameter of conduit

U = angle of bend

Given: D = 24", P = 200 psi, $\Theta = 60°$

Find: T, T_x and T_y

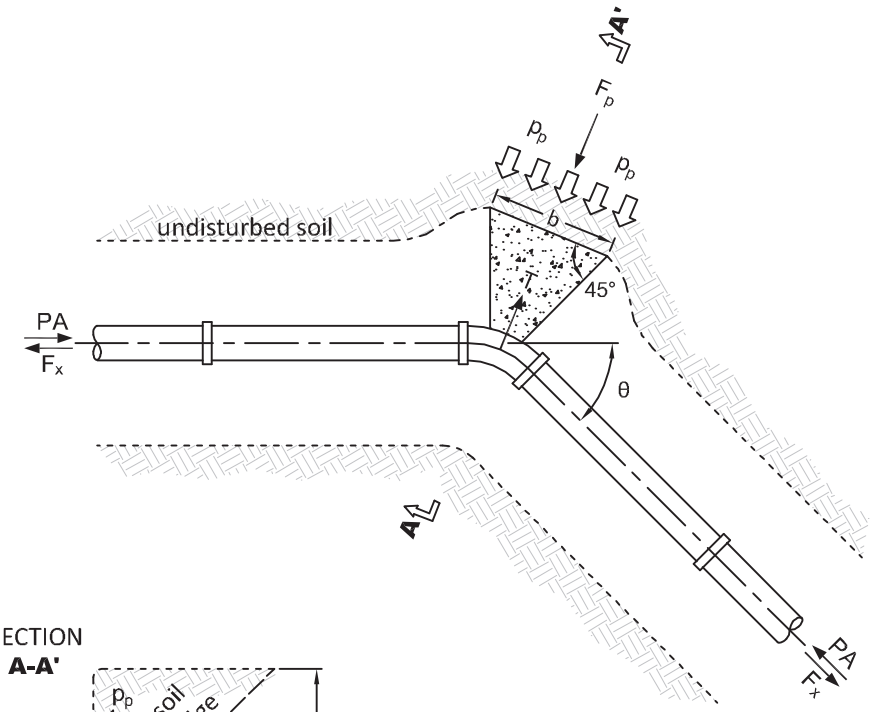
$A = (\pi/4)*(24)^2 = 452.39\ in^2$

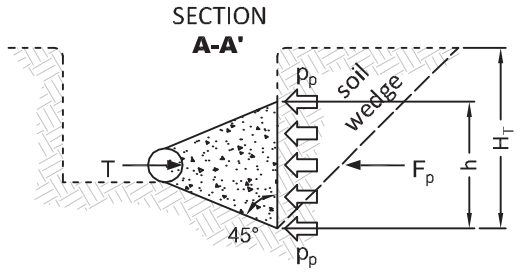
T = 2*200*452.39*SIN(60/2) = 90,478 lb

T_x = 200*452.39*(1-COS60) = 45,239 lb

T_y = 200*452.39*SIN60 = 78,356 lb

DESIGN PARAMETERS FOR BEARING THRUST BLOCK





Required Bearing Area:

$$A_b = hb = \frac{F_s\, 2PA \sin\frac{\theta}{2}}{p_p}$$

Required Block Width:

$$b = \frac{2F_s\, PA \sin\frac{\theta}{2}}{h\, p_p}$$

Where:

$p_p = \Upsilon H_c K_p + 2C\sqrt{K_p}$

$K_p = \tan^2\left(45° + \frac{\varnothing}{2}\right)$

Where:

T = resultant thrust force on the bend

F_p = resistance force developed by passive soil pressure

A_b = minimum bearing area of block base

h = height of thrust block

b = width of thrust block

A = pipe cross-sectional area

θ = bend deflection angle

p_p = passive soil pressure

H_T = depth to bottom of block

Υ = soil unit weight

K_p = coefficient of passive earth pressure

$\varnothing$ = soil internal friction angle

C = soil cohesion

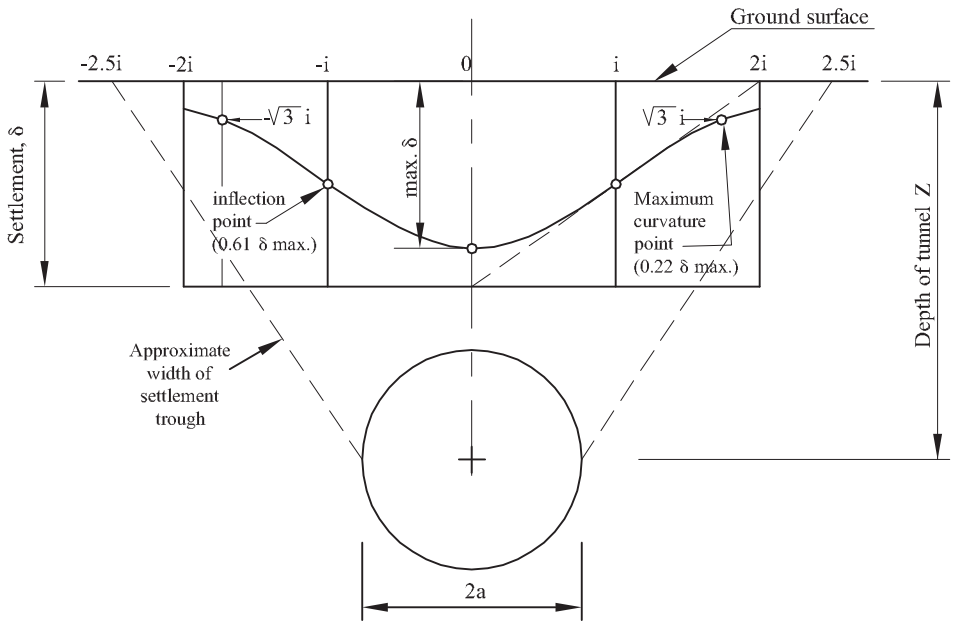
F_s = factor of safety (usually 1.5)

H_c = mean depth from ground surface to the plane of resistance (center of bearing area of a thrust block)

p = maximum sustained pressure

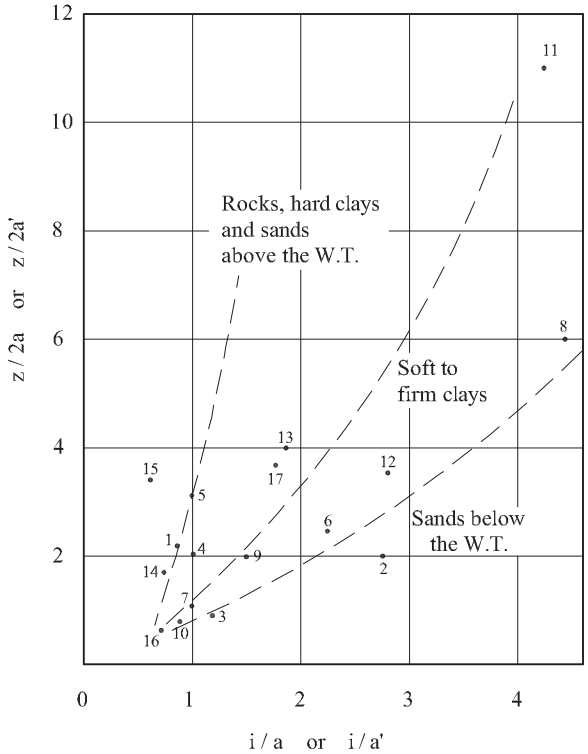
F_x = conduit frictional resistance per unit length

Relation between the Width of the Surface Depression (i/a) and the Depth of the Cavity (z/a) for Tunnels



Volume of depression = 2.5i δ max.

(a)



(b)

Reference: Peck, R. B. (1969) "Deep Excavations and Tunneling in Soft Ground," Proceedings, Seventh International Conference on Soil Mechanics and Foundation Engineering, Mexico City, State of the Art Volume, pp. 225-290.

AVILES ENGINEERING CORP.

Tunnel Behavior: Sands and Gravels
(Terzaghi, 1977)

Designation	Degree of Compactness	Tunnel Behavior	
		Above Water Table	Below Water Table
Very Fine Clean Sand	Loose, $N \leq 10$	Cohesive Running	Flowing
	Dense, $N > 30$	Fast Raveling	Flowing
Fine Sand with Clay Binder	Loose, $N \leq 10$	Rapid Raveling	Flowing
	Dense, $N > 30$	Firm or Slowly Raveling	Slowly Raveling
Sand or Sandy Gravel with Clay Binder	Loose, $N < 10$	Rapid Raveling	Rapidly Raveling or Flowing
	Dense, $N > 30$	Firm	Firm/slow Raveling
Sandy Gravel and Medium to Coarse Sand		Running Ground. Uniform ($C_u < 3$) and loose ($N < 10$) materials with round grains run much more freely than well graded ($C_u > 6$) and dense ($N > 30$) ones with angular grains.	Flowing Conditions combined with extremely heavy discharge of water.

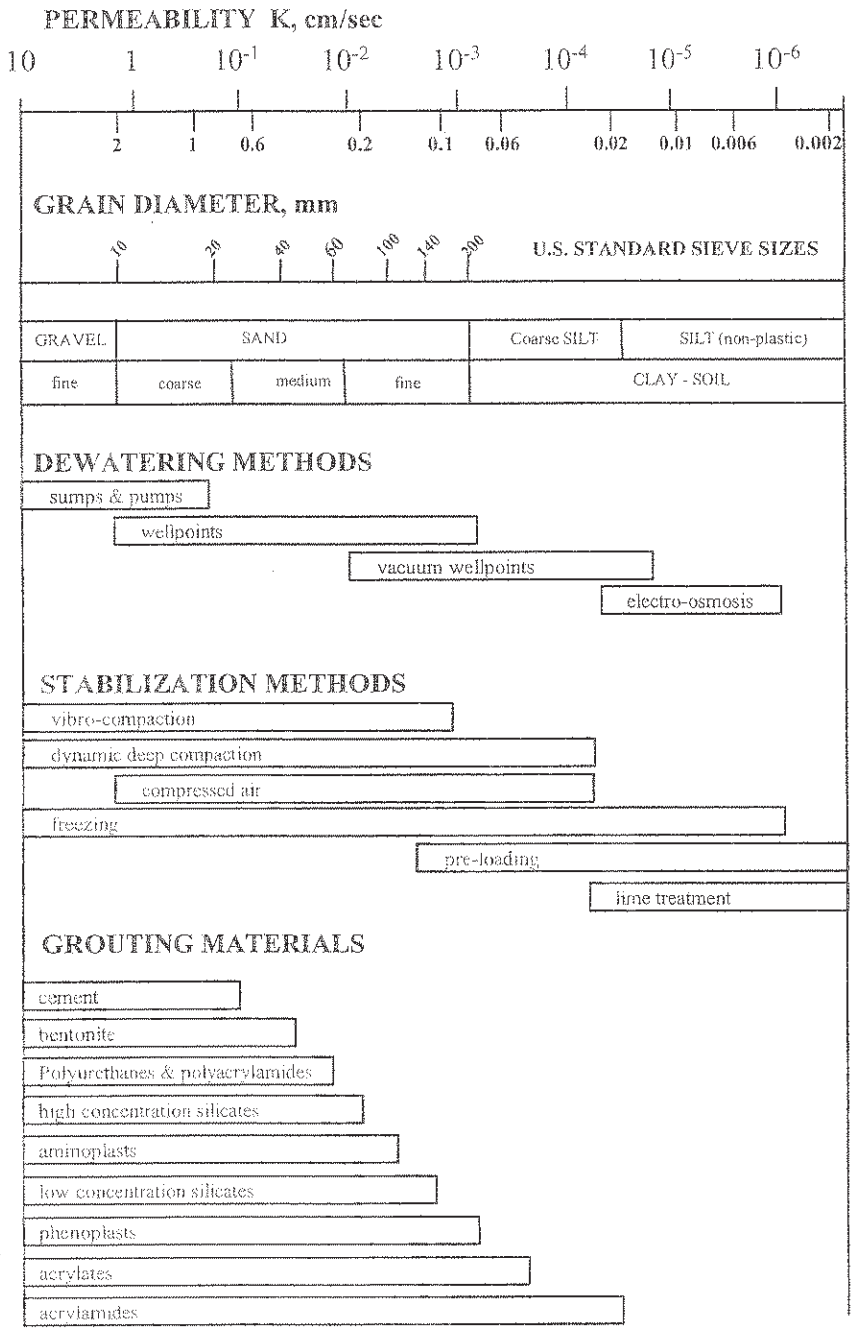
TBM FAMILY OF MACHINES
(From Kessler & Moore,)

Machine Type	Typical Machine Diameters	Ground Condition TBM is Best Suited For
Pipe Jacking Machines	Up to approx. 10 – 13 ft (3 - 4m)	Any ground
Small Bore Unit (SBU)	Up to 6.6 ft (2m)	Any ground
Shielded TBMs	6.6 – 46 ft (2 to 14m) plus	Soft ground above the water table
Mix Face TBMs	6.6 – 46 ft (2 to 14m) plus	Mixed ground above the water table
Slurry TBMs	6.6 – 46 ft (2 to 14m) plus	Coarse-grained soft ground below the water table
EPB TBMs	6.6 – 46 ft (2 to 14m) plus	Fine-grained soft ground below the water table
Hard Rock TBMs	6.6 – 46 ft (2 to 14m) plus	Hard rock
Reamer TBMs	Various	Hard rock
Multi-head TBMs	Various	Various

Reference: Dots Oyenuga (2004), "FHWA Road Tunnel Design Guidelines", Pages 8 and 10, published by U.S. Department of Transportation Federal Highway Administration, Report No. FHWA-IF-05-023, Washington DC.

AVILES ENGINEERING CORP.

Methods of Controlling Groundwater
(after Karol, 1990)



Note: 1 cm/sec = 0.4 in/sec; 1 mm = 0.04 in.

Reference: Dots Oyenuga (2004), "FHWA Road Tunnel Design Guidelines", Page 9, published by U.S. Department of Transportation Federal Highway Administration, Report No. FHWA-IF-05-023, Washington DC.

AVILES ENGINEERING CORP.

APPENDIX E

Plates E-1 to E-4 DARWin v3.0 Computer Program Output

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Aviles Engineering Corporation

Rigid Structural Design Module

Monroe Road - Thickness based on ESAL Loading

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	15,843,390
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	600 psi
28-day Mean Elastic Modulus of Slab	3,600,000 psi
Mean Effective k-value	97 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.35
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	10.82 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	1	4,500	30,000

Base Type	-
Base Thickness	8 in
Depth to Bedrock	100 ft
Projected Slab Thickness	8 in
Loss of Support Category	1
Effective Modulus of Subgrade Reaction	97 psi/in

PLATE E-1

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Aviles Engineering Corporation

Rigid Structural Design Module

Monroe Road - ESAL capacity based on 11 inch concrete

Rigid Structural Design

Pavement Type	JRCP
Slab Thickness for Performance Period Traffic	11 in
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	600 psi
28-day Mean Elastic Modulus of Slab	3,600,000 psi
Mean Effective k-value	97 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.35
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1.2
18-kip ESALs Over Initial Performance Period	17,603,163

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	1	4,500	30,000

Base Type	-
Base Thickness	8 in
Depth to Bedrock	100 ft
Projected Slab Thickness	8 in
Loss of Support Category	1
Effective Modulus of Subgrade Reaction	97 psi/in

PLATE E-2

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Aviles Engineering Corporation

Rigid Structural Design Module

Rockhill Street - Thickness based on ESAL Loading

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	793,624
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	600 psi
28-day Mean Elastic Modulus of Slab	3,600,000 psi
Mean Effective k-value	97 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.35
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	6.63 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	1	4,500	30,000

Base Type	-
Base Thickness	8 in
Depth to Bedrock	100 ft
Projected Slab Thickness	8 in
Loss of Support Category	1
Effective Modulus of Subgrade Reaction	97 psi/in

PLATE E-3

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Aviles Engineering Corporation

Rigid Structural Design Module

Rockhill Street - ESAL capacity based on 9 inch concrete

Rigid Structural Design

Pavement Type	JRCP
Slab Thickness for Performance Period Traffic	9 in
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	600 psi
28-day Mean Elastic Modulus of Slab	3,600,000 psi
Mean Effective k-value	97 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.35
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1.2
18-kip ESALs Over Initial Performance Period	4,827,520

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	1	4,500	30,000

Base Type	-
Base Thickness	8 in
Depth to Bedrock	100 ft
Projected Slab Thickness	8 in
Loss of Support Category	1
Effective Modulus of Subgrade Reaction	97 psi/in

PLATE E-4

AVILES ENGINEERING CORP.

APPENDIX F

Plate F-1	Design Soil Profile Parameters for Slope Stability Analyses at Station 19+00 (Based on Boring B-5)
Plate F-2	Design Soil Profile Parameters for Slope Stability Analyses at Station 30+00 (Based on Boring B-8)
Plate F-3	Slope Stability Analysis for Waterline Trench Excavation at Station 19+00, Based on Boring B-5, Short Term Condition
Plate F-4	Slope Stability Analysis for New Left Turn Lane at Station 19+00, Based on Boring B-5, Short Term Condition
Plate F-5	Slope Stability Analysis for New Left Turn Lane at Station 19+00, Based on Boring B-5, Long Term Condition
Plate F-6	Slope Stability Analysis for New Left Turn Lane at Station 19+00, Based on Boring B-5, Rapid Drawdown Condition
Plate F-7	Slope Stability Analysis for New Left Turn Lane at Station 30+00, Based on Boring B-8, Short Term Condition
Plate F-8	Slope Stability Analysis for New Left Turn Lane at Station 30+00, Based on Boring B-8, Long Term Condition
Plate F-9	Slope Stability Analysis for New Left Turn Lane at Station 30+00, Based on Boring B-8, Rapid Drawdown Condition

AVILES ENGINEERING CORP.

Design Soil Parameters for Slope Stability Analyses at Station 19+00
(Based on Boring B-5)

Elevation (ft)	Soil Type	γ (pcf)	Short-Term (UU)		Long-Term (CD)		Rapid Drawdown (CU)	
			C_u (psf)	ϕ_u (deg)	C' (psf)	ϕ' (deg)	C_{cu} (psf)	ϕ_{cu} (deg)
Varies	Concrete Liner	150	3000 psi	0	3000 psi	0	3000 psi	0
31 to 19	Stiff to very stiff CH	120	1,000	0	255 (C_r = 65)	16 (ϕ_r = 21)	470 (C_r = 65)	13 (ϕ_r = 21)
19 to 13	Firm to hard CL	130	1,000	0	190	31	80	23
13 to 8	Medium dense ML	120	0	30	0	30	0	30
8 to 6	Very stiff CH	120	1,500	0	255 (C_r = 65)	16 (ϕ_r = 21)	470 (C_r = 65)	13 (ϕ_r = 21)

Notes:
(1) γ = wet unit weight of soil;
(2) C_u =undrained cohesion, ϕ_u = angle of internal friction, under short term conditions. UU = strength parameters that were determined from Unconsolidated-Undrained triaxial tests;
(3) C' =effective cohesion, ϕ' =effective friction angle, under long term condition; CD = Consolidated-Drained strength parameters that were determined from CU triaxial tests with pore pressure measurements;
(4) C_{cu} = cohesion, ϕ_{cu} = friction angle, under rapid drawdown condition; CU = strength parameters developed from Consolidated-Undrained triaxial tests;
(5) C_r = cohesion for desiccated fat clay, ϕ_r = friction angle for desiccated fat clay;
(6) ML = Sandy Silt, CL = Sandy Lean Clay, CH = Fat Clay.

AVILES ENGINEERING CORP.

Design Soil Parameters for Slope Stability Analyses at Station 30+00
(Based on Boring B-8)

Elevation (ft)	Soil Type	γ (pcf)	Short-Term (UU)		Long-Term (CD)		Rapid Drawdown (CU)	
			C_u (psf)	ϕ_u (deg)	C' (psf)	ϕ' (deg)	C_{cu} (psf)	ϕ_{cu} (deg)
32 to 26	Stiff to very stiff CH	126	1,600	0	275 (C_r = 65)	16 (ϕ_r = 21)	470 (C_r = 65)	13 (ϕ_r = 21)
26 to 22	Firm to very stiff CH	128	600	0	275 (C_r = 65)	16 (ϕ_r = 21)	470 (C_r = 65)	13 (ϕ_r = 21)
22 to 18	Loose SM	115	0	26	0	26	0	26
18 to 14	Medium dense SM	120	0	28	0	28	0	28
14 to 7	Very stiff to hard CL	125	1,500	0	190	31	80	23

Notes:
(1) γ = wet unit weight of soil;
(2) C_u =undrained cohesion, ϕ_u = angle of internal friction, under short term conditions. UU = strength parameters that were determined from Unconsolidated-Undrained triaxial tests;
(3) C' =effective cohesion, ϕ' =effective friction angle, under long term condition; CD = Consolidated-Drained strength parameters that were determined from CU triaxial tests with pore pressure measurements;
(4) C_{cu} = cohesion, ϕ_{cu} = friction angle, under rapid drawdown condition; CU = strength parameters developed from Consolidated-Undrained triaxial tests;
(5) C_r = cohesion for desiccated fat clay, ϕ_r = friction angle for desiccated fat clay;
(6) SM = Silty Sand, CL = Sandy Lean Clay, CH = Fat Clay.

G149-14 IMPACT OF WATERLINE TRENCH EXCAVATION ON BERRY CREEK
SLOPE STABILITY ANALYSIS AT STATION 19+00
BASED ON BORING B-5, SHORT TERM (CONSTRUCTION) CONDITION

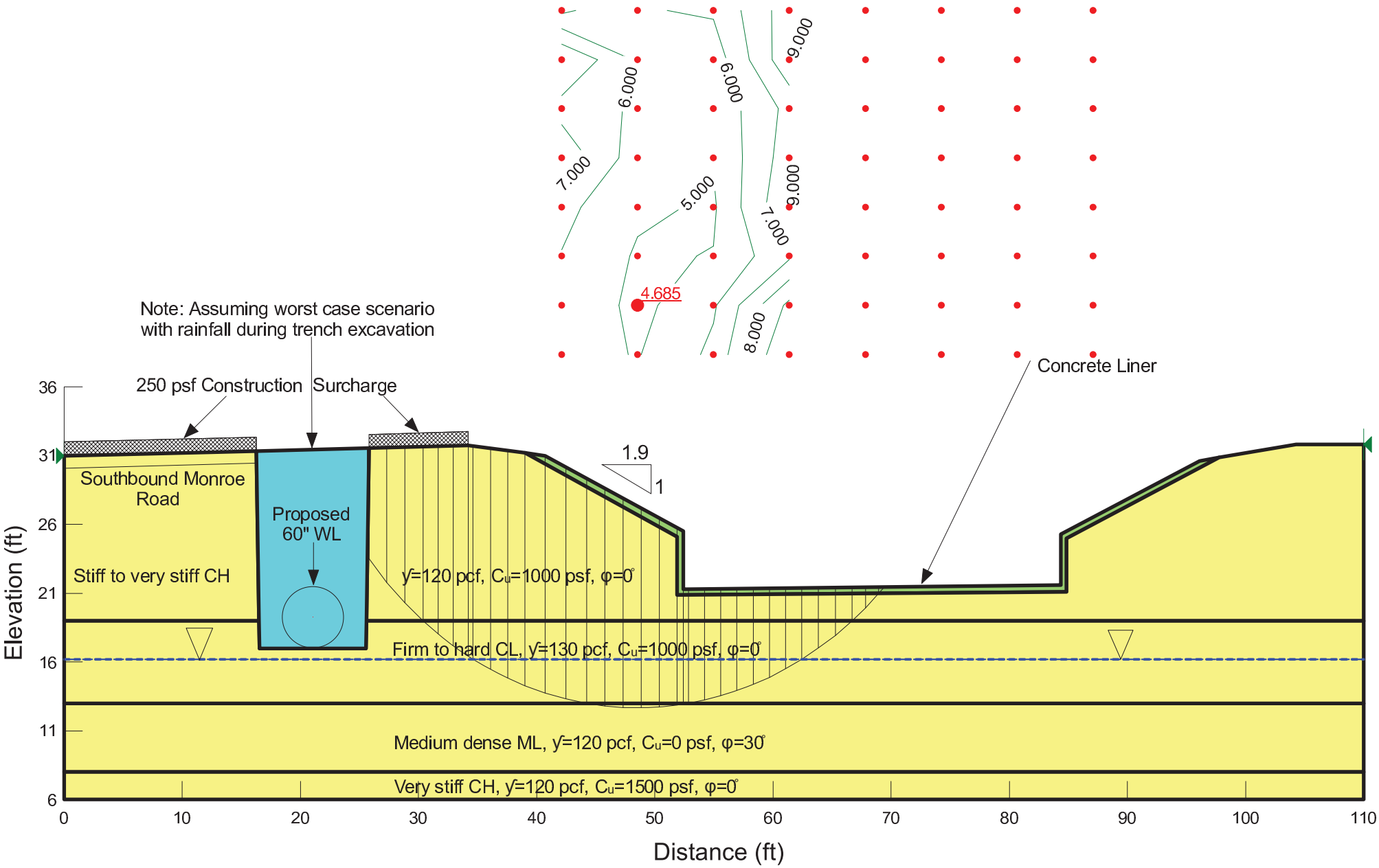


PLATE F-3

G149-14 TURNING LANES ALONG SOUTHBOUND MONROE ROAD
SLOPE STABILITY ANALYSIS AT STATION 19+00
BASED ON BORING B-5, SHORT TERM CONDITION

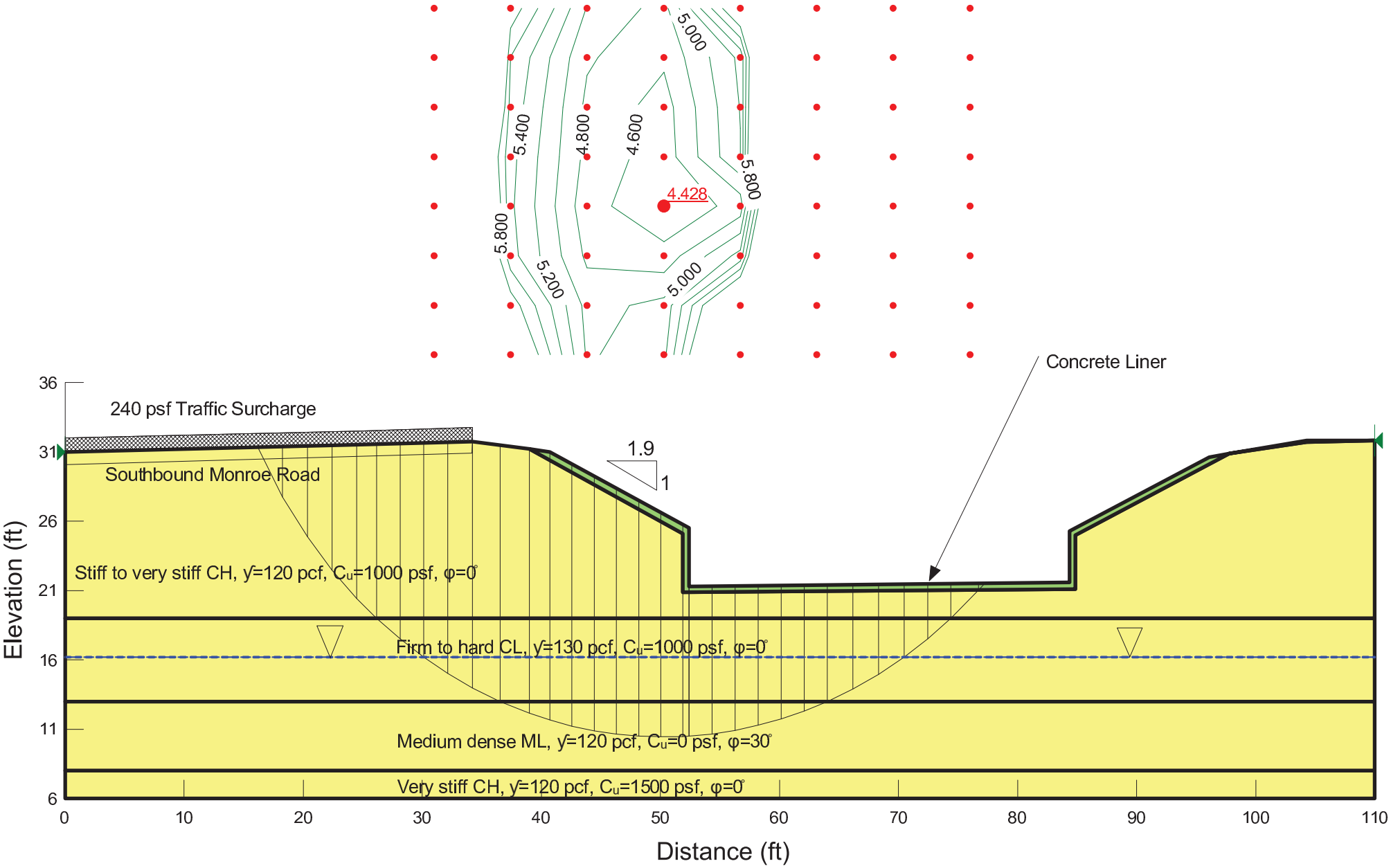


PLATE F-4

G149-14 TURNING LANES ALONG SOUTHBOUND MONROE ROAD
SLOPE STABILITY ANALYSIS AT STATION 19+00
BASED ON BORING B-5, LONG TERM CONDITION

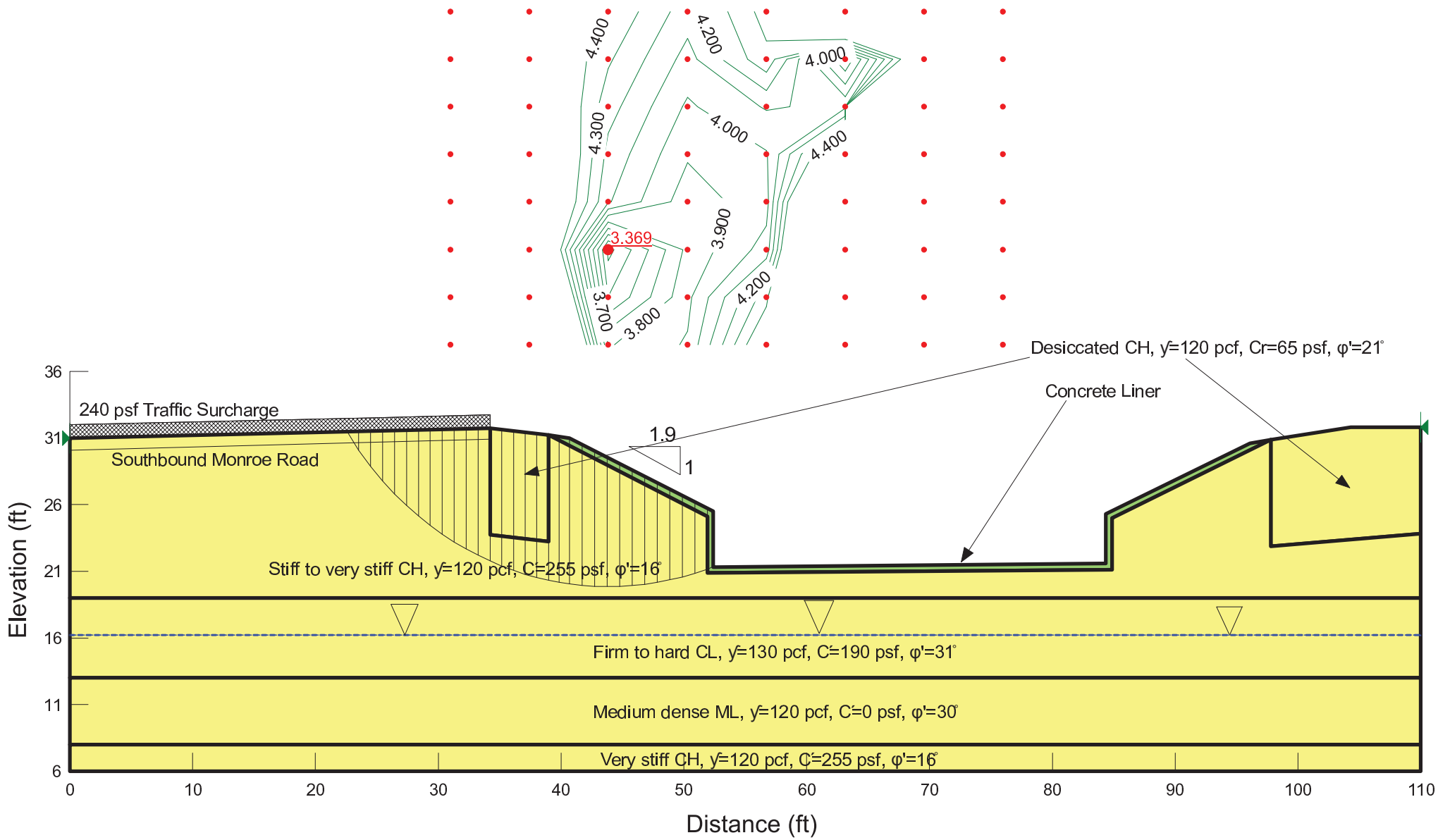


PLATE F-5

G149-14 TURNING LANES ALONG SOUTHBOUND MONROE ROAD
SLOPE STABILITY ANALYSIS AT STATION 19+00
BASED ON BORING B-5, RAPID DRAWDOWN CONDITION

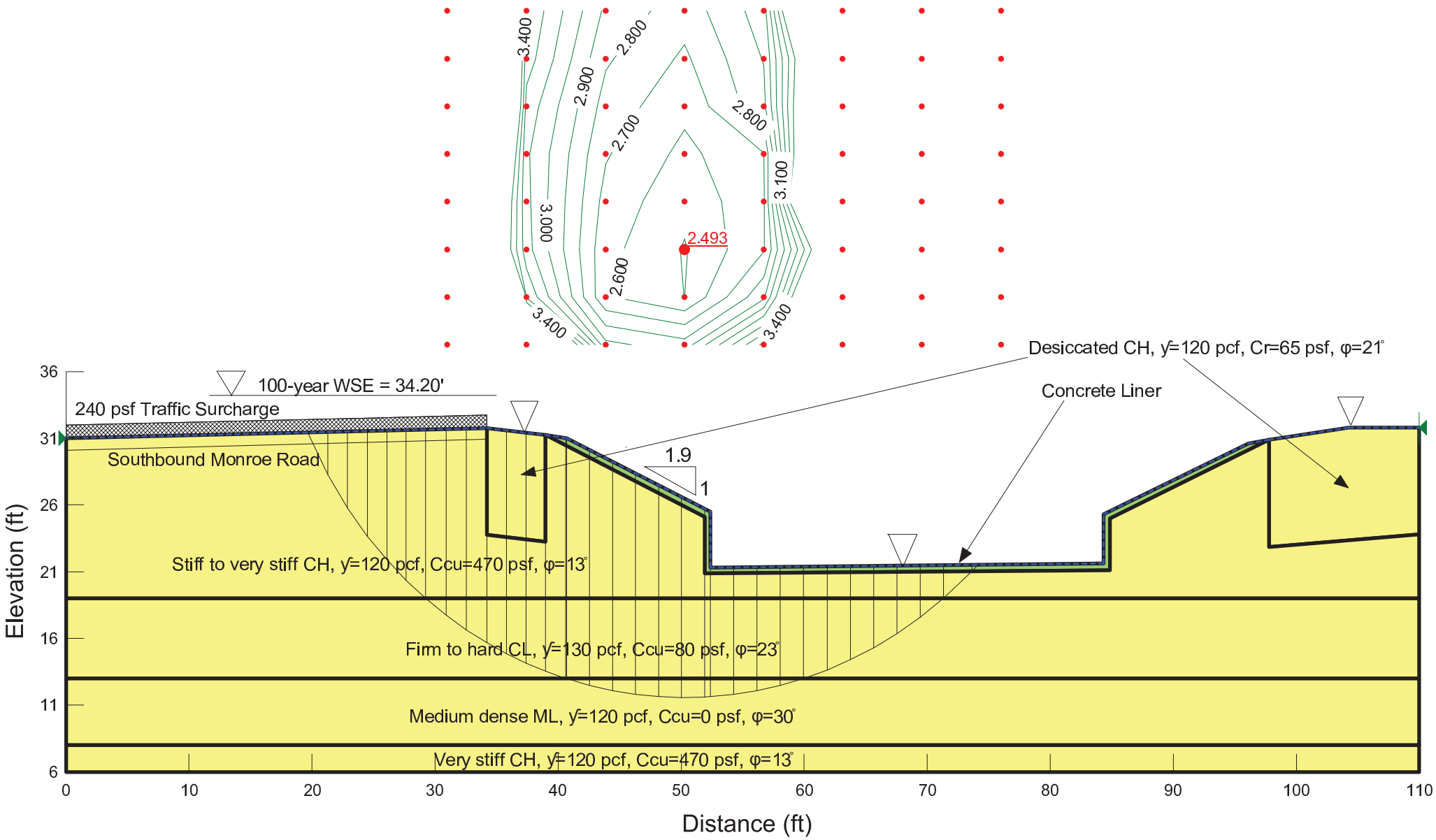


PLATE F-6

G149-14 TURNING LANES ALONG SOUTHBOUND MONROE ROAD
SLOPE STABILITY ANALYSIS AT STATION 30+00
BASED ON BORING B-8, SHORT TERM CONDITION

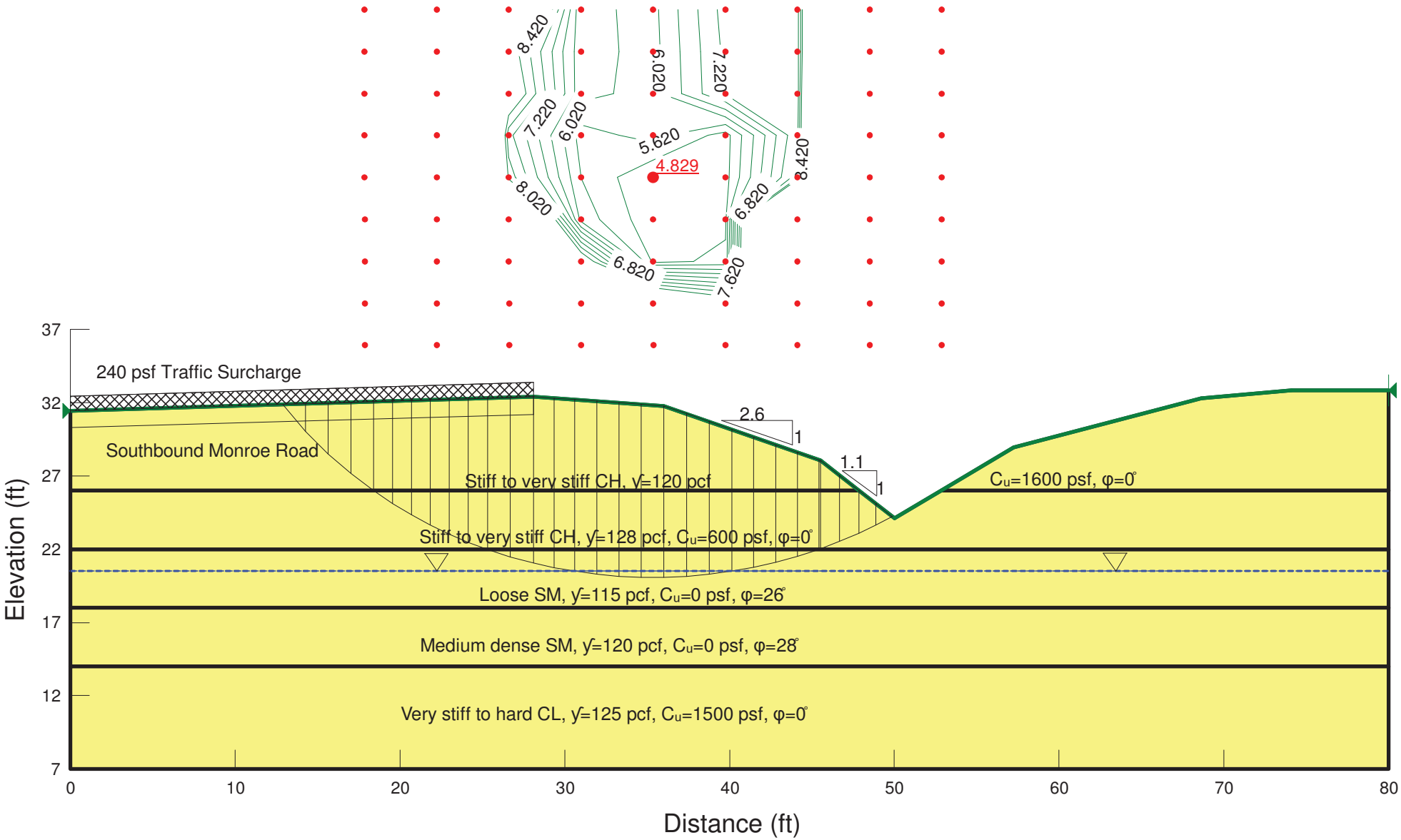


PLATE F-7

G149-14 TURNING LANES ALONG SOUTHBOUND MONROE ROAD
SLOPE STABILITY ANALYSIS AT STATION 30+00
BASED ON BORING B-8, LONG TERM CONDITION

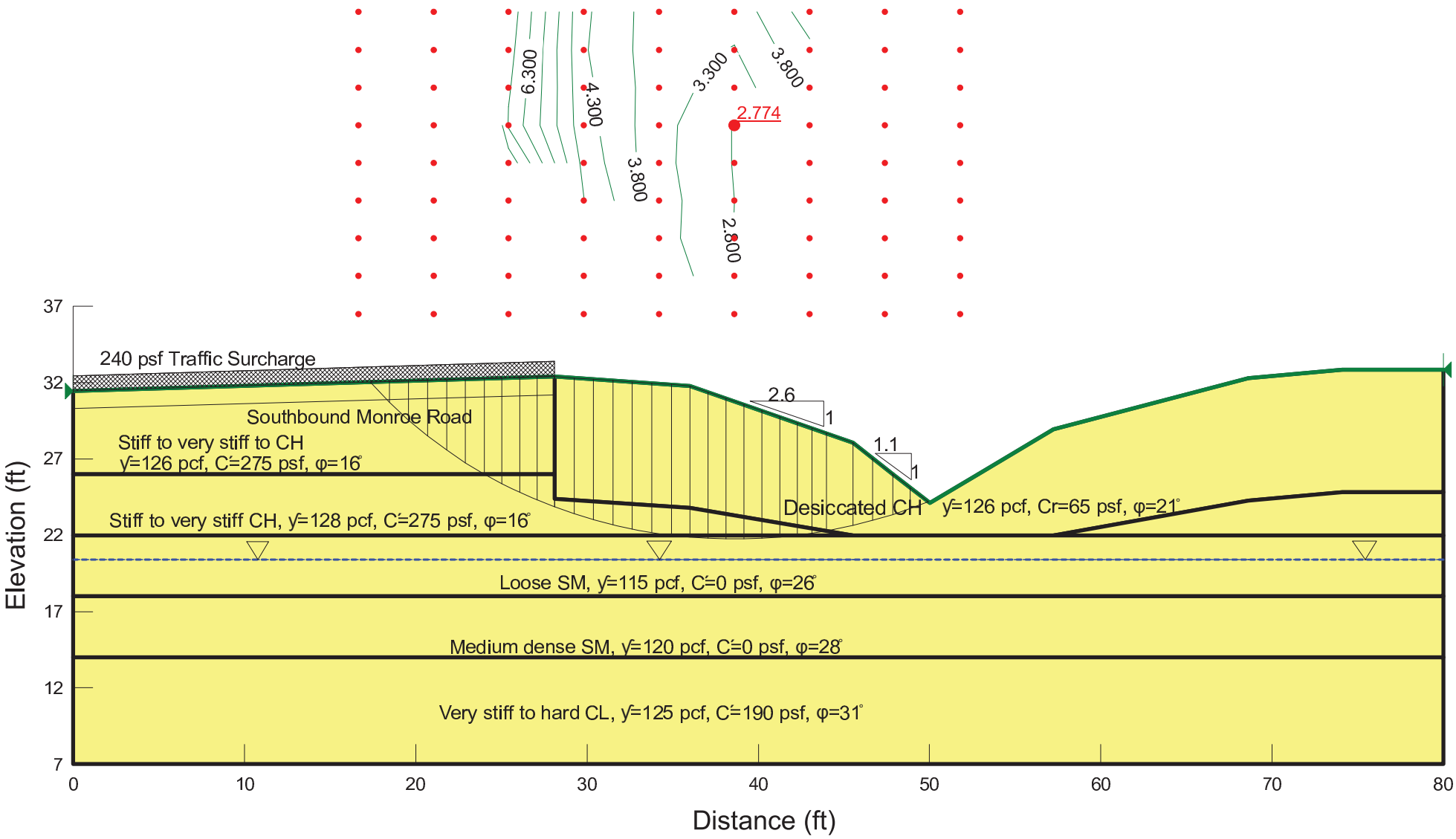


PLATE F-8

G149-14 TURNING LANES ALONG SOUTHBOUND MONROE ROAD
SLOPE STABILITY ANALYSIS AT STATION 30+00
BASED ON BORING B-8, RAPID DRAWDOWN CONDITION

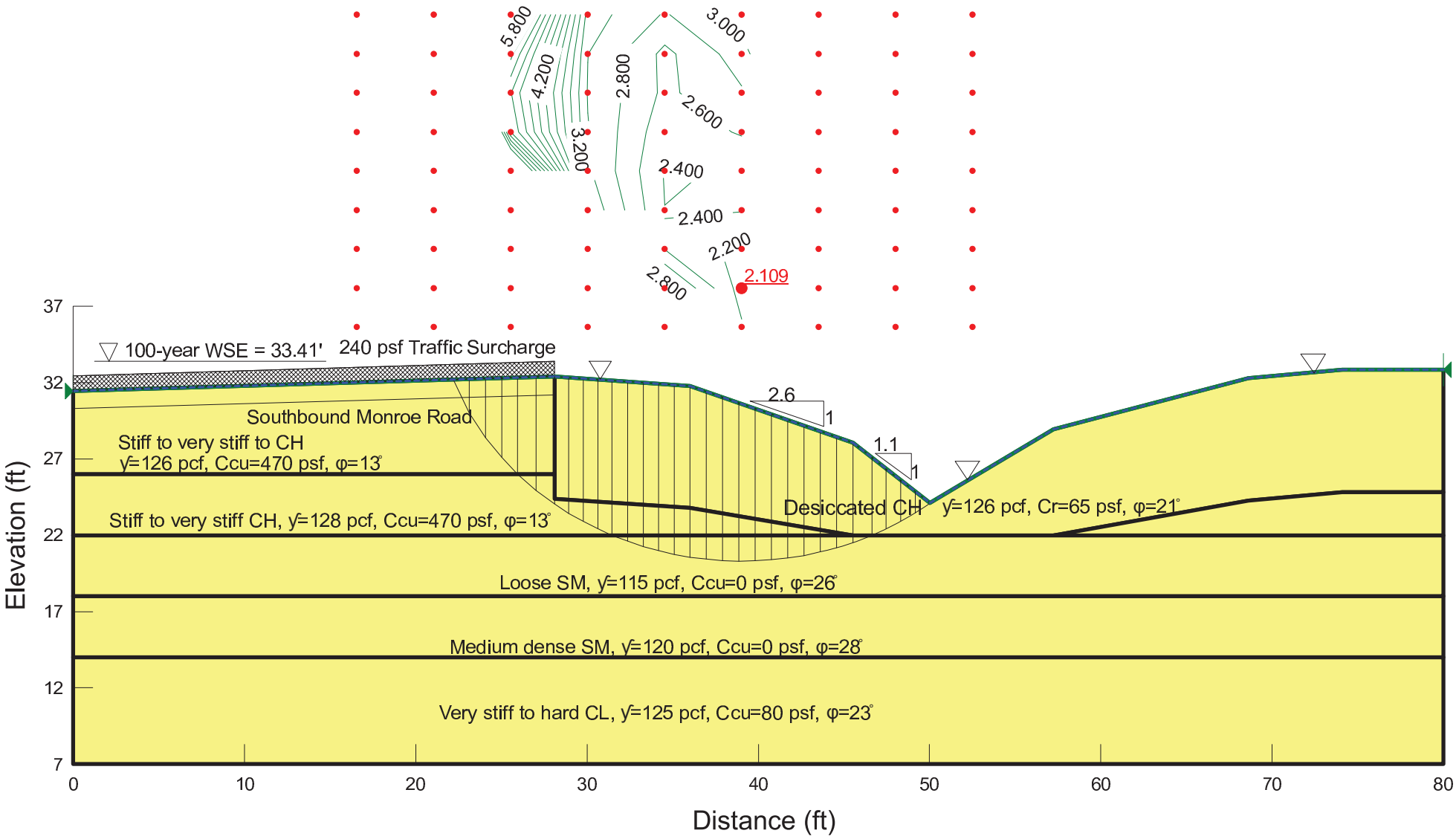


PLATE F-9

AVILES ENGINEERING CORP.

APPENDIX G

Plates G-1 to G-3 Piezometer Installation and Plugging Reports

STATE OF TEXAS WELL REPORT for Tracking #390944

Owner:	**City of Houston Geotechnical Dept**	Owner Well #:	**pz-1**
Address:	**611 Walker Floor 14 Houston , TX 77002**	Grid #:	**65-22-9**
Well Location:	**8100 Monroe Houston , TX 77061**	Latitude:	**29° 39' 21" N**
Well County:	**Harris**	Longitude:	**095° 15' 49" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date:	Started: **9/10/2014** Completed: **9/10/2014**
Diameter of Hole:	Diameter: **4 in From Surface To 30 ft**
Drilling Method:	**Mud Rotary**
Borehole Completion:	Other: **(No Data)**
Annular Seal Data:	1st Interval: **From 0 ft to 11 ft with 1 cement (#sacks and material)** 2nd Interval: **From 11 ft to 13 ft with 1 bentonite (#sacks and material)** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Alternative Procedure Used**

Water Level:	Static level: **7.5 ft. below land surface on 3/20/2015** Artesian flow: **No Data**
Packers:	**20/40 18-30**
Plugging Info:	Casing left in well: Cement/Bentonite left in well: From (ft) To (ft) From (ft) To (ft) Cem/Bent Sacks Used **25'of 2" sch 40 pvc well material was grouted in place via tremmie method on 03/20/2015 by Chris Olvera.**
Type Of Pump:	**No Data**
Well Tests:	**No Data**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.

PLATE G-1

Company Information:	**Van and Sons Drilling Service** **319 John Alber** **Houston , TX 77076**
Driller License Number:	**3286**
Licensed Well Driller Signature:	**Mark Thornton**
Registered Driller Apprentice Signature:	**Christopher Olvera**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking #**390944**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft)	To (ft)	Description
na		

CASING, BLANK PIPE & WELL SCREEN DATA

Dia.	New/Used	Type	Setting From/To
2	**n**	**sch 40 pvc riser**	**0-15**
2	**n**	**sch 40 pvc screen**	**15-25 .010**

PLATE G-1

STATE OF TEXAS WELL REPORT for Tracking #390943

Owner:	**City of Houston Geotechnical Dept**	Owner Well #:	**pz-2**
Address:	**611 Walker Floor 14 Houston , TX 77002**	Grid #:	**65-22-9**
Well Location:	**8510 Rockhill St Houston , TX 77061**	Latitude:	**29° 39' 55" N**
Well County:	**Harris**	Longitude:	**095° 16' 00" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date:	Started: **9/11/2014** Completed: **9/11/2014**
Diameter of Hole:	Diameter: **4 in From Surface To 30 ft**
Drilling Method:	**Mud Rotary**
Borehole Completion:	Other: **(No Data)**
Annular Seal Data:	1st Interval: **From 0 ft to 16 ft with 1 cement (#sacks and material)** 2nd Interval: **From 16 ft to 18 ft with 1 bentonite (#sacks and material)** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Alternative Procedure Used**

Water Level:	Static level: **9.17 ft. below land surface on 3/20/2015** Artesian flow: **No Data**
Packers:	**20/40 18-30**
Plugging Info:	Casing left in well: Cement/Bentonite left in well: From (ft) To (ft) From (ft) To (ft) Cem/Bent Sacks Used **30' of 2" sch 40 pvc well material was grouted in place via tremmie method on 03/20/2015 by Chris Olvera.**
Type Of Pump:	**No Data**
Well Tests:	**No Data**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.

PLATE G-2

Company Information:	**Van and Sons Drilling Service** **319 John Alber** **Houston , TX 77076**
Driller License Number:	**3286**
Licensed Well Driller Signature:	**Mark Thornton**
Registered Driller Apprentice Signature:	**Christopher Olvera**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking #**390943**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft)	To (ft)	Description
na		

CASING, BLANK PIPE & WELL SCREEN DATA

Dia.	New/Used	Type	Setting From/To
2	**n**	**sch 40 pvc riser**	**0-20**
2	**n**	**sch 40 pvc screen**	**20-30 .010**

PLATE G-2

STATE OF TEXAS WELL REPORT for Tracking #390942

Owner:	**City of Houston Geotechnical Dept**	Owner Well #:	**pz-3**
Address:	**611 Walker Floor 14 Houston , TX 77002**	Grid #:	**65-22-9**
Well Location:	**8100 Rockhill St pz-3 , TX 77061**	Latitude:	**29° 39' 55" N**
Well County:	**Harris**	Longitude:	**095° 16' 14" W**
Elevation:	**No Data**	GPS Brand Used:	**No Data**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date: Started: **9/11/2014**
Completed: **9/11/2014**

Diameter of Hole: Diameter: **4 in From Surface To 30 ft**

Drilling Method: **Mud Rotary**

Borehole Completion: Other: **(No Data)**

Annular Seal Data:
1st Interval: **From 0 ft to 16 ft with 1 cement (#sacks and material)**
2nd Interval: **From 16 ft to 18 ft with 1 bentonite (#sacks and material)**
3rd Interval: **No Data**
Method Used: **No Data**
Cemented By: **No Data**
Distance to Septic Field or other Concentrated Contamination: **No Data**
Distance to Property Line: **No Data**
Method of Verification: **No Data**
Approved by Variance: **No Data**

Surface Completion: **Alternative Procedure Used**

Water Level: Static level: **9.33 ft. below land surface on 3/20/2015**
Artesian flow: **No Data**

Packers: **20/40 18-30**

Plugging Info: Casing left in well: Cement/Bentonite left in well:
From (ft) To (ft) From (ft) To (ft) Cem/Bent Sacks Used
30' of 2" sch 40 pvc well material was grouted in place via tremmie method on 03/20/2015 by Chris Olvera.

Type Of Pump: **No Data**

Well Tests: **No Data**

Water Quality:
Type of Water: **No Data**
Depth of Strata: **No Data**
Chemical Analysis Made: **No**
Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.

PLATE G-3

Company Information:	**Van and Sons Drilling Service** **319 John Alber** **Houston , TX 77076**
Driller License Number:	**3286**
Licensed Well Driller Signature:	**Mark Thornton**
Registered Driller Apprentice Signature:	**Christopher Olvera**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking #**390942**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft)	To (ft)	Description
na		

CASING, BLANK PIPE & WELL SCREEN DATA

Dia.	New/Used	Type	Setting From/To
2	**n**	**sch 40 pvc riser**	**0-20**
2	**n**	**sch 40 pvc screen**	**20-30 .010**

PLATE G-3

AVILES ENGINEERING CORP.

APPENDIX H

Plates H-1 to H-6 Boring Logs B-5 to B-8 in HCFCD format

AVILES ENGINEERING CORP.
5790 Windfern
Houston, Texas
Telephone: (713) 895-7645
Fax: (713) 895-7943

LOG OF BORING B-5

PROJECT: SWTP Contract 70B, 60-inch Waterline along Monroe from Airport to Rockhill and Rockhill from Monroe to Glen Valley, WBS No. S-000900-0129-4, Houston Texas

PROJECT NO.: G149-14 BORING TYPE: 4" Dry Auger / Wet Rotary

DATE: 9/11/14

SURFACE ELEVATION (FT.): 31.24

LOCATION

Texas State Plane, Feet, Surface

Northing: 13807944.87
Easting: 3155424.48

MATERIAL DESCRIPTION

Depth (ft.)	USC	Material Description
0	CH	PAVEMENT 5-3/4" Concrete
	CH	FAT CLAY (CH), stiff to very stiff, very high plasticity, olive-gray, with slickensides and sand partings, moist
	CH	-with ferrous nodules 2'-4'
5	CH	-gray and tan, with abundant calcareous nodules 4'-6'
	CH	-reddish tan 6'-10'
10	CH	-gray, with ferrous nodules 10'-12'
	CL	LEAN CLAY WITH SAND (CL), firm to hard, medium plasticity, gray, with silt partings and ferrous nodules, moist
15	CL	-with silt seams 14'-16', and calcareous nodules 14'-18'
	ML	-gray and reddish tan, with silt pockets and fat clay seams 16'-18'
20	ML	SANDY SILT (ML), medium dense, no plasticity, gray and brown, wet
	CH	FAT CLAY (CH), very stiff, reddish brown and gray, with slickensides, calcareous nodules, and sand pockets, moist
25		Termination depth = 25'

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

Water Observations: Water encountered at 16' during drilling. Measured water at 14.8' approx 15 minutes after initial encounter.

Sample Key: ☒ SPT ☐ Shelby Tube ▤ Disturbed (Auger)

Field Strength Data	Dry Density (pcf)	UU / UC Shear Strength (tsf)	Failure Strain (%)	Confining Pressure (psi)	Moisture Content (%)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Passing #200 Sieve (%)	Estimated Angle of Internal Friction (°), Other Tests & Remarks
P=1.5	85.7	0.53	14.7	0	37					
P=1.75					33					
P=2.75					29	82	24	58	78.8	
P=2.0					34					
P=2.25	92.0	0.51	2.2	6	30					
P=3.5					20					
P=3.25					21	33	20	13	85.1	
P=3.25					22					
P=4.25	105.5	0.48	8.6	11	23					
N=24					24				66.9	
N=25					28					

Key to Abbreviations:

N -SPT Data (blows/ft)
P -Pocket Penetrometer (tsf)
T -Torvane
C_u -Undrained Cohesion (tsf)
SS-Shear Strength (P/2, tsf)

Notes:
(1) Wet rotary started at 16'.

AVILES ENGINEERING CORP.
5790 Windfern
Houston, Texas
Telephone: (713) 895-7645
Fax: (713) 895-7943

LOG OF BORING B-5A

PROJECT: SWTP Contract 70B, 60-inch Waterline along Monroe from Airport to Rockhill and Rockhill from Monroe to Glen Valley, WBS No. S-000900-0129-4, Houston Texas

PROJECT NO.: G149-14 BORING TYPE: 4" Dry Auger

DATE: 4/27/15

SURFACE ELEVATION (FT.): 31.83

LOCATION

Texas State Plane, Feet, Surface

Northing: 13807987.84
Easting: 3155438.08

MATERIAL DESCRIPTION

Depth (ft.)	USC	Material Description
0		FILL, FAT CLAY (CH), very stiff, very high plasticity, gray, with roots, moist
	CH	FAT CLAY (CH), stiff to hard, very high plasticity, dark gray, with slickensides, moist -gray and tan 4'-8'
5		
		-brown and light gray 8'-12' -borehole caved in at 8' after 24 hours
10		
		-with silt and sand partings, siltstone fragments, and ferrous nodules 12'-14'
15	CL	LEAN CLAY (CL), stiff, high plasticity, tan and gray, with abundant silt seams and partings, moist
	CH	FAT CLAY (CH), very stiff to hard, red, brown, and light gray, with slickensides and siltstone fragments, moist -with sand seams 18'-20'
20	CL	LEAN CLAY (CL), stiff, high plasticity, brown, with silt seams, moist -with abundant sand seams 23'-25'
25		Termination depth = 25'

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

Water Observations: Water encountered at 18' during drilling. Measured water at 8.0' approx 24 hours after initial encounter.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed (Auger)

Depth (ft.)	Field Strength Data	Dry Density (pcf)	UU / UC Shear Strength (tsf)	Failure Strain (%)	Confining Pressure (psi)	Moisture Content (%)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Passing #200 Sieve (%)	Estimated Angle of Internal Friction (°), Other Tests & Remarks
0	P=3.0					25	70	20	50	93	
	P=3.5	93.6	1.27	2.8	0	28					
	P=4.5					24					
5	P=4.5					24	76	23	53	95	
	P=3.25	90.4	0.72	2.7	6	32					
10	P=3.75					24					
	P=2.5	100.0	0.80	4.5	8	26					
15	P=1.5	99.2				25	46	18	28	97	14'-16' CU: C'=190psf ϕ'=31.3° C_{cu}=80psf ϕ_{cu}=23.1°
	N=10, P=3.5 P=4.5	98.1	1.04	6.0	0	24 28					
20											
25	P=1.25					33	43	19	24	100	

Key to Abbreviations:

N -SPT Data (blows/ft)
P -Pocket Penetrometer (tsf)
T -Torvane
C_u -Undrained Cohesion (tsf)
SS-Shear Strength (P/2, tsf)

Notes:
(1) Borehole caved in at 8.0', 24 hours after drilling.

AVILES ENGINEERING CORP.
5790 Windfern
Houston, Texas
Telephone: (713) 895-7645
Fax: (713) 895-7943

LOG OF BORING B-6

PROJECT: SWTP Contract 70B, 60-inch Waterline along Monroe from Airport to Rockhill and Rockhill from Monroe to Glen Valley, WBS No. S-000900-0129-4, Houston Texas

PROJECT NO.: G149-14 BORING TYPE: 4" Dry Auger / Wet Rotary

DATE: 9/11/14

SURFACE ELEVATION (FT.): 31.49

LOCATION

Texas State Plane, Feet, Surface

Northing: 13808447.17
Easting: 3155403.64

MATERIAL DESCRIPTION

Depth (ft.)	USC	Material Description
0	CH	PAVEMENT, 6" Concrete
		FAT CLAY (CH), stiff to very stiff, very high plasticity, olive-brown, with slickensides and ferrous nodules, moist
5		-tan, with silty clay seams 6'-8'
	CL ML	SILTY CLAY (CL-ML), firm to very stiff, slight plasticity, reddish tan and dark tan, moist
10		-with clayey silt pockets 8'-10'
	CL	LEAN CLAY (CL), stiff to very stiff, high plasticity, reddish brown, with slickensides, moist
15	ML	SILT (ML), medium dense, no plasticity, reddish tan, wet
		-with clay partings 16'-18'
20		-dark tan 18'-25'
		-with silty clay pockets 23'-25'
25		Termination depth = 25'

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

Water Observations: Water encountered at 15' during drilling. Measured water at 14.1' approx 15 minutes after initial encounter.

Sample Key: ☒ SPT ☐ Shelby Tube ▤ Disturbed (Auger)

Depth (ft.)	Field Strength Data	Dry Density (pcf)	UU / UC Shear Strength (tsf)	Failure Strain (%)	Confining Pressure (psi)	Moisture Content (%)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Passing #200 Sieve (%)
0	P=2.5	90.7	0.68	2.0	0	32				
	P=1.75					31	79	22	57	94.7
	P=1.75					36				
5	P=2.25	104.3	0.82	11.1	5	23				
	P=3.25					20	26	19	7	89.9
10	N=11					24				90.4
	P=3.25					31				
15	P=3.5					22	43	18	25	97.9
	P=0.75	102.2	0.43	15.0	10	24				
20	N=18					26				
25	N=28					27				96.6

Key to Abbreviations:

N -SPT Data (blows/ft)
P -Pocket Penetrometer (tsf)
T -Torvane
C_u -Undrained Cohesion (tsf)
SS-Shear Strength (P/2, tsf)

Notes:
(1) Wet rotary started at 16'.

AVILES ENGINEERING CORP.
5790 Windfern
Houston, Texas
Telephone: (713) 895-7645
Fax: (713) 895-7943

LOG OF BORING B-7

PROJECT: SWTP Contract 70B, 60-inch Waterline along Monroe from Airport to Rockhill and Rockhill from Monroe to Glen Valley, WBS No. S-000900-0129-4, Houston Texas

PROJECT NO.: G149-14 BORING TYPE: 4" Dry Auger

DATE: 9/11/14

SURFACE ELEVATION (FT.): 31.98

LOCATION

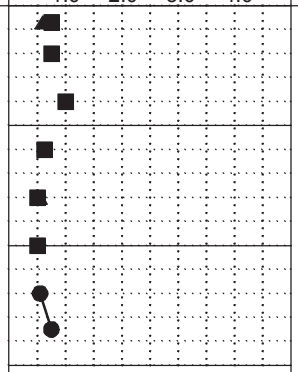
Texas State Plane, Feet, Surface

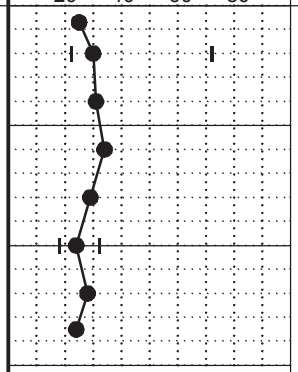
Northing: 13808948.81
Easting: 3155382.03

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION
0	CH	PAVEMENT, 6.4" Concrete
		BASE, 2" silty sand with clay pockets
		FAT CLAY (CH), stiff to very stiff, very high plasticity, gray and brown, with slickensides, moist
		-with ferrous nodules 1'-4'
5		-light olive-gray, with abundant calcareous and ferrous nodules 4'-6'
	CL	-gray and tan 6'-8'
10		LEAN CLAY (CL), firm to stiff, medium plasticity, tan, with silt pockets, and calcareous and ferrous nodules, moist
		-tan and red, with fat clay seams 12'-14'
15		-borehole caved in at 13' during drilling
		-wet at 14'
		Termination depth = 14'

FIELD STRENGTH DATA	DRY DENSITY (pcf)	UU / UC SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)	PASSING #200 SIEVE (%)
P=1.5	97.7	0.60	5.7	0	25				
P=1.5					30	72	22	50	89.4
P=2.0					31				
P=1.25					34				
P=1.0	97.0	0.54	11.1	6	29				
P=1.0					24	32	18	14	95.2
N=11					28				
N=15					24				97.8





ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS

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

Water Observations:

Sample Key: ☒ SPT ☐ Shelby Tube ▨ Disturbed (Auger)

Key to Abbreviations:

N -SPT Data (blows/ft)
P -Pocket Penetrometer (tsf)
T -Torvane
C_u -Undrained Cohesion (tsf)
SS-Shear Strength (P/2, tsf)

Notes:
(1) Borehole caved in at 13' after drilling.

AVILES ENGINEERING CORP.
5790 Windfern
Houston, Texas
Telephone: (713) 895-7645
Fax: (713) 895-7943

LOG OF BORING B-7A

PROJECT: SWTP Contract 70B, 60-inch Waterline along Monroe from Airport to Rockhill and Rockhill from Monroe to Glen Valley, WBS No. S-000900-0129-4, Houston Texas

PROJECT NO.: G149-14 BORING TYPE: 4" Dry Auger / Wet Rotary

DATE: 4/27/15

SURFACE ELEVATION (FT.): 32.13

LOCATION

Texas State Plane, Feet, Surface

Northing: 13809214.33
Easting: 3155388.94

MATERIAL DESCRIPTION

Depth (ft.)	USC	Material Description
0	CH	FAT CLAY (CH), stiff to hard, very high plasticity, tan and gray, moist -with roots 0'-4' -tan and gray, with siltstone fragments, and calcareous and ferrous nodules 2'-6'
5	CH	FAT CLAY WITH SAND (CH), stiff to very stiff, very high plasticity, tan and gray, moist -with abundant calcareous nodules 6'-8' -red, brown, and light gray, with siltstone fragments 8'-10'
10	CL ML	SILTY CLAY WITH SAND (CL-ML), firm to stiff, medium plasticity, red, brown, and light gray, with siltstone fragments and calcareous nodules, moist -borehole caved in at 10.8' during drilling -borehole caved in at 13.8' after 24 hours
15	ML	SILT (ML), loose to medium dense, no plasticity, brown, light gray, and tan, with abundant clay and sand seams, wet -with calcareous nodules and siltstone fragments 14'-16' -brown 16'-18' -tan 18'-25'
25		Termination depth = 25'

Field Strength Data	Dry Density (pcf)	UU / UC Shear Strength (tsf)	Failure Strain (%)	Confining Pressure (psi)	Moisture Content (%)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Passing #200 Sieve (%)	Estimated Angle of Internal Friction (°), Other Tests & Remarks
P=4.0	97.0	0.94	7.2	0	23	79	23	56	89	
P=4.5					20					
P=4.5	100.8	0.92	4.2	3	22					
P=1.75	96.9				27	64	22	42	73	6'-8' CU: C'=510psf, ϕ'=15.9°, C_{cu}=470psf, ϕ_{cu}=12.8°
P=3.0					24					
P=1.75	109.9	0.39	7.8	6	24					
P=1.25					22	26	19	7	79	
N=5					25					
P=1.25					24					
N=11					25	25	23	2	88	
N=12					30					

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

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

Water Observations: Water encountered at 13' during drilling. Measured water at 6.1' approx 24 hours after initial encounter.

Sample Key: SPT, Shelby Tube, Disturbed (Auger)

Key to Abbreviations:

N -SPT Data (blows/ft)
P -Pocket Penetrometer (tsf)
T -Torvane
C_u -Undrained Cohesion (tsf)
SS-Shear Strength (P/2, tsf)

Notes:
(1) Wet rotary started at 16'.
(2) Borehole caved in at 13.8', 24 hours after drilling.

AVILES ENGINEERING CORP.
5790 Windfern
Houston, Texas
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Fax: (713) 895-7943

LOG OF BORING B-8

PROJECT: SWTP Contract 70B, 60-inch Waterline along Monroe from Airport to Rockhill and Rockhill from Monroe to Glen Valley, WBS No. S-000900-0129-4, Houston Texas

PROJECT NO.: G149-14 BORING TYPE: 4" Dry Auger / Wet Rotary

DATE: 9/11/14

SURFACE ELEVATION (FT.): 31.79

LOCATION

Texas State Plane, Feet, Surface

Northing: 13809454.23
Easting: 3155361.01

MATERIAL DESCRIPTION

Depth (ft.)	USC	Material Description
0		PAVEMENT, 7" Concrete
	CH	BASE, 6" dark tan silty sand with clay pockets
		FAT CLAY (CH), stiff to very stiff, high plasticity, dark gray, brown, and light gray, with calcareous and ferrous nodules, moist
5	CH	-gray and tan 2'-4'
		=reddish tan 4'-6'
10	SM	SANDY FAT CLAY (CH), firm to very stiff, high plasticity, tan, with abundant sand and silt pockets, seams, and calcareous nodules, moist
		-red, brown, and tan 8'-10'
15		SILTY SAND (SM), loose to medium dense, no plasticity, tan, moist
		-wet at 12'
	CL	-with clay seams and calcareous nodules 16'-18'
20		SANDY LEAN CLAY (CL), very stiff to hard, tan, with silty sand seams, moist
		-with fat clay layers 18'-20'
		-with clayey and silty sand pockets 23'-25'
25		Termination depth = 25'

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

Water Observations: Water encountered at 12' during drilling. Measured water at 12.4' approx 15 minutes after initial encounter.

Sample Key: ☒ SPT ☐ Shelby Tube ☐ Disturbed (Auger)

Depth (ft.)	Field Strength Data	Dry Density (pcf)	UU / UC Shear Strength (tsf)	Failure Strain (%)	Confining Pressure (psi)	Moisture Content (%)	Atterberg Limits (%) LL	PL	PI	Passing #200 Sieve (%)
0	P=2.25	102.6	0.83	13.2	0	22				
	P=2.75					24	58	19	39	92.8
	P=2.75					22				
5	P=2.0	105.3	0.30	8.1	5	22				
	P=1.25					23	54	20	34	53.4
10	N=4					25				34.1
	N=7					27				
15	N=13					25				
	N=14					29				
	N=41					27				58.6
20										
	N=29					25				
25										

Key to Abbreviations:

N -SPT Data (blows/ft)
P -Pocket Penetrometer (tsf)
T -Torvane
C_u -Undrained Cohesion (tsf)
SS-Shear Strength (P/2, tsf)

Notes:
(1) Wet rotary started at 12'.

AVILES ENGINEERING CORP.

APPENDIX J-1

CU Test Results - B-5A, 14’-16’

CALCULATION OF TRIAXIAL CU TESTING RESULTS

Job Name: SWTP Contract 70B Waterline
Client: Kuo & Associates
Sample ID: B-5A, 14-16

Job No.: G149-14
5/20/2015
File @: Z:\Engineering\Reports\2014\149-14

Three Staged Consolidated-Undrained Triaxial Tests

Tan and Gray Lean Clay (CL)

1) Initial Condition (before testing) [14 to 16 ft]

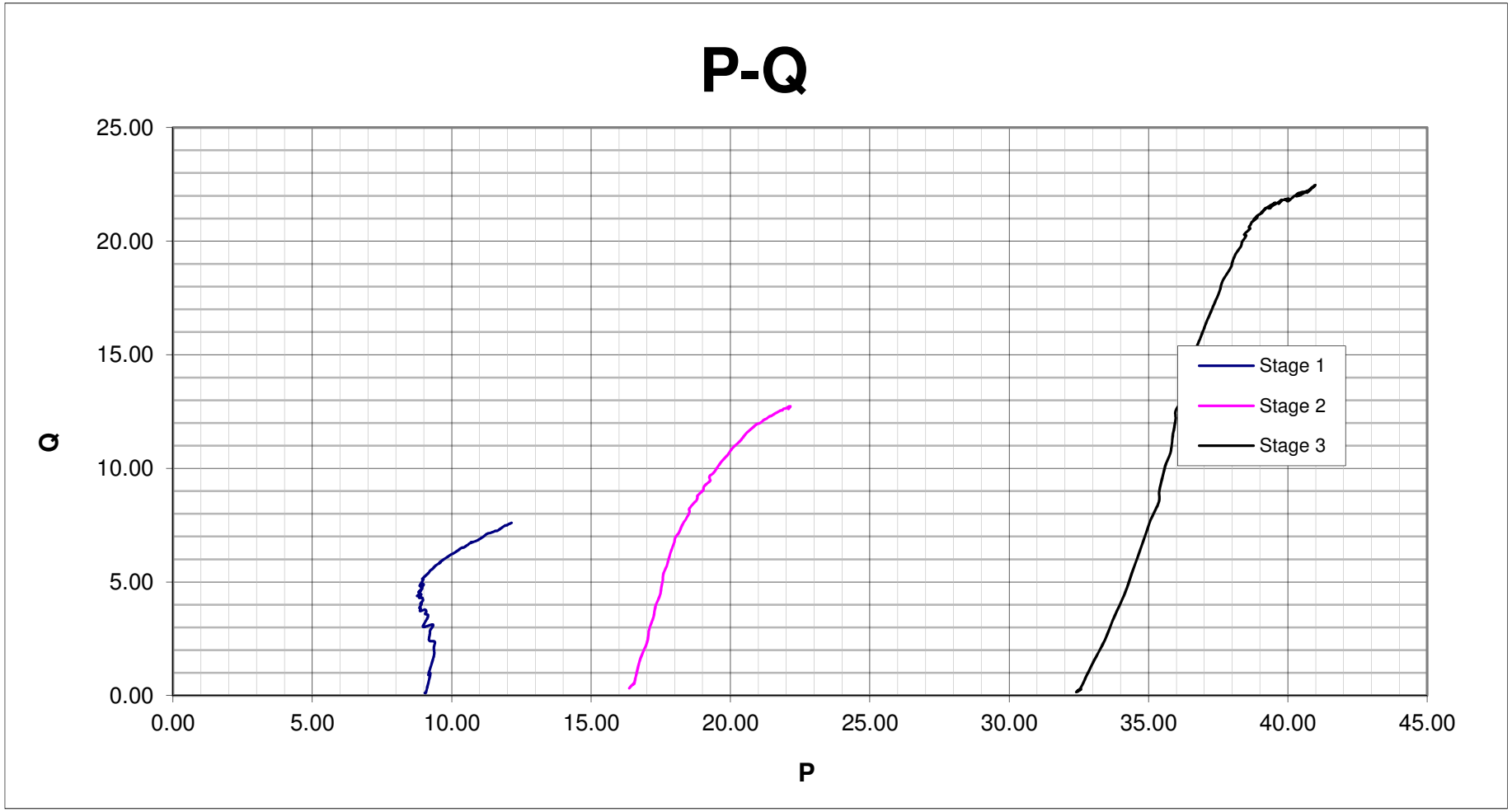
LL = 46 , PL = 18 , PI = 28 ,
Cu = psf,
w_0 = 24.81 %, G = 2.75 ,
Wet γ= 123.8 pcf, Dry γ_d = 99.2 pcf,
γ_w = 62.4 pcf, S = $w_0/(\gamma_w/\gamma_d - 1/G)$ = 93.5 %
e = w_0G/S = 0.730 .

2) Final Condition (after testing)

w_f = 28.55 %,

Stage	Sigma_1'	Sigma_3'	u	Strain	Sigma_1	Sigma_3
	(psi)	(psi)	(psi)	(%)	(psi)	(psi)
1	16.93	3.90	4.93	2.60	21.86	8.83
2	34.07	9.19	6.81	2.50	40.88	16.00
3	60.93	17.80	14.28	3.50	75.21	32.08
Residual					0.00	0.00

	Effective Stresses				Total Stresses	
Stage	Sigma_1'	Sigma_3'	u	Strain	Sigma_1	Sigma_3
	(ksf)	(ksf)	(ksf)	(%)	(ksf)	(ksf)
1	2.44	0.56	0.71	2.60	3.15	1.27
2	4.91	1.32	0.98	2.50	5.89	2.30
3	8.77	2.56	2.06	3.50	10.83	4.62
Residual	0.00	0.00	0.00	0.00	0.00	0.00


P-Q
25.00
20.00
15.00
10.00
5.00
0.00
Q
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
P
Stage 1
Stage 2
Stage 3

Aviles Engineering Corp.

Advanced Testing Assignment Form

Project Number: G149-14

Boring: B-5A

Depth (ft): 14-16

Date Assigned: 4/28/15

Results Deadline:

Type(s) of Testing Required (check all that apply):

- [x] **CU Triaxial**
  - Desired Confining Pressures: 8, 16, 32 psi (multistage)
- [ ] **Consolidation**
- [ ] **Swell**

Any additional testing required for this sample:

- [x] P. I.
- [x] -200 Sieve
- [ ] Sieve Analysis
- [ ] Other: PP = 1.5

Assigned by: Wilber

Aviles Engineering Corporation

Atterberg Limit Determinations (ASTM D-4318)

PROJECT NO: G149-14 DATE: 5/7/15

Boring No:	B-5A						
Depth, ft:	14-16						
Container ID:	~~[illegible]~~ 308						

LIQUID LIMIT DETERMINATION

Tare ID:	3-B	R-22												
Wet Wt. + Tare (g):	25.34	27.48												
Dry Wt. + Tare (g):	21.61	23.74												
Tare Wt (g):	13.54	15.64												
Blow Count:	23	24												
Liquid Limit (LL):	45.76	45.95												
Average LL:	46													

PLASTIC LIMIT DETERMINATION

Tare ID:	T15	Q-13												
Wet Wt + Tare (g):	21.67	22.19												
Dry Wt + Tare (g):	20.72	21.18												
Tare Wt (g):	15.29	15.48												
Plastic Limit (PL):	17.50	17.72												
Average PL:	18													
Plasticity Index (PI):	28													
Technician:	FE													

Computed by: FE

Checked by: _____

Aviles Engineering Corporation

Minus 200 Mesh Sieve / Sieve Analysis Datasheet (ASTM D-1140/D-422)

Project #:	G149-14	Project Name:			
Boring #:	B-5A	Depth (ft):	14-16	Date:	5/19/15
Visual Classification:					

Minus 200 Data:			
Tare ID:	PR2	Wt. of Dry Soil + Tare, before sieving (g):	202.83
Tare Wt. (g):	106.20	Wt of Dry Soil + Tare, after sieving (g):	108.99
Percent Retained:	2.89	Percent Passing:	97.11

Sieve Analysis Data:		Sieve Analysis Done? (y/n):	
Sieve Size	Accumulated Wt. Retained (g)	Percent Passing	Percent Retained
3"			
2"			
1 1/2"			
1"			
3/4"			
3/8"			
#4			
#10			
#20			
#40			
#60			
#100			
#140			
#200			
PAN			

Test Technician: CM

Calculated By: [illegible]

Checked By: [illegible]

S.A.? Y N

C:\Documents and Settings\Soil Lab\My Documents\Forms\M200_SA

Aviles Engineering Corporation
CU PRETEST DATA
ASTM D-4767

Project: G149-14		Date: 5/7/2015	
Boring: B-5A	Depth (ft): 14-16	Cell #: 1	
Soil Description: Tan and Gray Clayey Silt/Silty Clay			
Sample Mass (g): 1068.10	*Scale ID:* 615	Sigma3: 8,16,32	
Sample Dimensions:	Height measurements taken 120 degrees apart, Diameter measurements taken at the quarter points of height.		
Caliper ID: 693			

Height Measurements (in):		**Diameter Measurements (in):**	
Height1:	5.582	Diameter1:	2.769
Height2:	5.569	Diameter2:	2.737
Height3:	5.583	Diameter3:	2.712
Average Height:	5.578	Average Diameter:	2.739
Sample Volume (cu. Ft.)	0.019024551		

Initial Moisture Content:			
Tare ID:	MT-22	*Scale ID:*	615
Tare Wt (g):	65.02	*Oven ID:*	612
Wet Soil + Tare (g):	141.74	*Thermometer ID:*	614
Dry Soil + Tare (g):	126.49		
Moisture Content (%):	24.81		

Sample Density:		**Dial Gauge Data:**	
Wet Density:	123.8	*Dial Gauge ID:*	
Dry Density:	99.2	Initial Reading (in):	0.1520
Test Prep. Technician:	W THOMAS		
Technician Signature:			

Proj. # G149-14 **Boring:** B-5A **Depth (ft):** 14-16

Initial Height Measurements (in.):

Height 1:	5.582		
Height 2:	5.569		
Height 3:	5.583	Average Height (in.):	5.578

Initial Diameter Measurements (in.):

Diam 1:	2.769		
Diam 2:	2.737		
Diam 3:	2.712	Average Diameter (in):	2.739333

Initial Dial Gauge Reading (in):	0.152
End of Saturation Dial Gauge Reading (in.):	0.162

First Consolidation: *(if there is no first stage consolidation, enter '0' for initial and final pipette readings, copy DGs to DGc)*

Initial Pipette Reading (mL):	23
Final Pipette Reading (mL):	19.6
Final Dial Gauge Reading (in.):	0.174

Beginning of First Shear:

Height:	5.556
Diameter:	2.746

End of First Shear:

Dial Gauge Reading at end of shearing (in.):	0.394
Dial Gauge Reading after CV rebound (in):	0.357

Second Stage Consolidation:

Initial Pipette Reading (mL):	23
Final Pipette Reading (mL):	15.2
Final Dial Gauge Reading (in.):	0.357

Beginning of Second Shear:

Height:	5.373
Diameter:	2.772

End of Second Shear:

Dial Gauge Reading at end of shearing (in.):	0.523
Dial Gauge Reading after CV rebound (in):	0.489

Third Stage Consolidation:

Initial Pipette Reading (mL):	23
Final Pipette Reading (mL):	14.5
Final Dial Gauge Reading (in.):	0.486

Beginning of Third Shear:

Height:	5.244
Diameter:	2.783

Aviles Engineering Corporation
CU BACKPRESSURE SATURATION
ASTM D-4767

Project: G149-14	Date: 5/7/15	Sigma3: 8, 16, 32
Boring: B-5A	Depth (ft): 14-16	Cell #: 1

Date: 5/7/15	Time:	Cell Pressure *(psi)*:	~~10~~ 9.25
		Back Pressure *(psi)*:	5.60
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			Ø
B-value: 0.82	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 15		New Back Pressure *(psi)*:	10
Date: 5/7/15	Time: 14:18	Cell Pressure *(psi)*:	14.63
		Back Pressure *(psi)*:	10.00
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			-0.02
B-value: 0.91	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 20		New Back Pressure *(psi)*:	15
Date: 5/7/15	Time: 15:20	Cell Pressure *(psi)*:	20
		Back Pressure *(psi)*:	15.05
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			Ø
B-value: 0.92	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 25		New Back Pressure *(psi)*:	20
Date: 5/7/15	Time: 8:10	Cell Pressure *(psi)*:	24.33
		Back Pressure *(psi)*:	20.01
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			Ø
B-value: 0.93	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 30		New Back Pressure *(psi)*:	25
Technician Signature: N THOMAS			

Aviles Engineering Corporation
CU BACKPRESSURE SATURATION
ASTM D-4767

Project: G149-14	Date: 5/7/15	Sigma3: 8, 16, 32
Boring: B-5A	Depth (ft): 14-16	Cell #: 1

Date: 5/8/15	Time: 10:46	Cell Pressure *(psi)*: 29.96
		Back Pressure *(psi)*: 25.06
Pore Pressure Change *(with backpressure valves closed, after 1 min)*: ~ 0.02 ~		
B-value: 0.95	Increase Pressures? N	Saturation Complete? Y
New Cell Pressure *(psi)*: —		New Back Pressure *(psi)*: —
Date:	Time:	Cell Pressure *(psi)*:
		Back Pressure *(psi)*:
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:		
B-value:	Increase Pressures?	Saturation Complete?
New Cell Pressure *(psi)*:		New Back Pressure *(psi)*:
Date:	Time:	Cell Pressure *(psi)*:
		Back Pressure *(psi)*:
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:		
B-value:	Increase Pressures?	Saturation Complete?
New Cell Pressure *(psi)*:		New Back Pressure *(psi)*:
Date:	Time:	Cell Pressure *(psi)*:
		Back Pressure *(psi)*:
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:		
B-value:	Increase Pressures?	Saturation Complete?
New Cell Pressure *(psi)*:		New Back Pressure *(psi)*:
Technician Signature:		

Triaxial Consolidation Datasheet

Stage: 1 **σ3=** 8 16 32

Cell#: 1

Job No.: G149-14 **Cell Pressure:** 33

Boring No: B-5A **Back Pressure:** 25

Depth: 14-16

Date	Time	Elapsed Time (min)	Pipette Reading (ml)	Dial Gauge Reading (in.)
5/8/15	12:49	0	23.00	0.162
		0.1	22.70	
		0.25	22.50	
		0.5	22.40	
		1	22.10	
		2	21.92	
		4		
		6/~~30~~	20.8	
		130 ~~15~~	20.68	
		222 ~~30~~	20.57	
	6:42	~~60~~	20.20	
5/13/15	7:10	~~120~~	19.60	0.174

Final Height (in): 5.556

Final Diameter (in): 2.746

Triaxial Consolidation Datasheet

Stage: 2 **σ3=** 8 16 32

Cell#: 1

Job No.: G149-14 **Cell Pressure:** 41.6

Boring No: B-5A **Back Pressure:** 25.6

Depth: 14-16

Date	Time	Elapsed Time (min)	Pipette Reading (ml)	Dial Gauge Reading (in.)
5/13/15	13:22	0	23.00	0.374"/0.357"
		0.1	22.00	
		0.25	21.50	
		0.5	21.00	
		1	20.30	
		2	19.53	
		5.5 ~~10~~	18.10	
		9 ~~20~~	17.35	
		18 ~~40~~	16.6	
	15:19	117 ~~30~~	15.7	
	15:55	148 ~~60~~	15.65	EOPC
5/14/15	5:54	992 ~~120~~	15.22	
	11:14	1312	15.20	0.357

Final Height (in): 5.373

Final Diameter (in): 2.772

Triaxial Consolidation Datasheet

Stage: 3 **σ3=** 8 16 (32)

Cell#: 1

Job No.: 149-14 **Cell Pressure:** 58

Boring No: B-5A **Back Pressure:** ~~28~~ 26

Depth: 14-16

Date	Time	Elapsed Time (min)	Pipette Reading (ml)	Dial Gauge Reading (in.)
5/15/15	14:55	0	23.00	0.523/0.489"
		0.1	21.80	
		0.25	21.20	
		0.5	20.80	
		1	20.20	
		2	19.40	
		4	18.42	
		8	17.05	
		15	16.25	
		43 ~~30~~	15.54	
5/16/15	8:37	1062 ~~60~~	14.50	0.486
		120		

Final Height (in): 5.244"

Final Diameter (in): 2.783"

CU Post-Test Datasheet

Project Name: 149-16 **Project Number:** _____

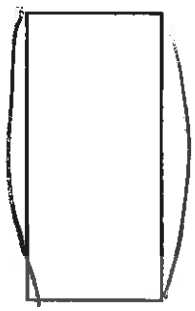
Boring Number: B-5A **Boring Depth (ft):** 14-16 **Cell#:** 1

Date: 5/19/15

Moisture Content:

Tare ID:	MT-17
Tare Weight (g):	85.43
Wet Soil + Tare (g):	170.34
Dry Soil + Tare (g):	151.48
% Moisture:	28.55

Sample Sketch:



Failure Types: (circle all that apply)

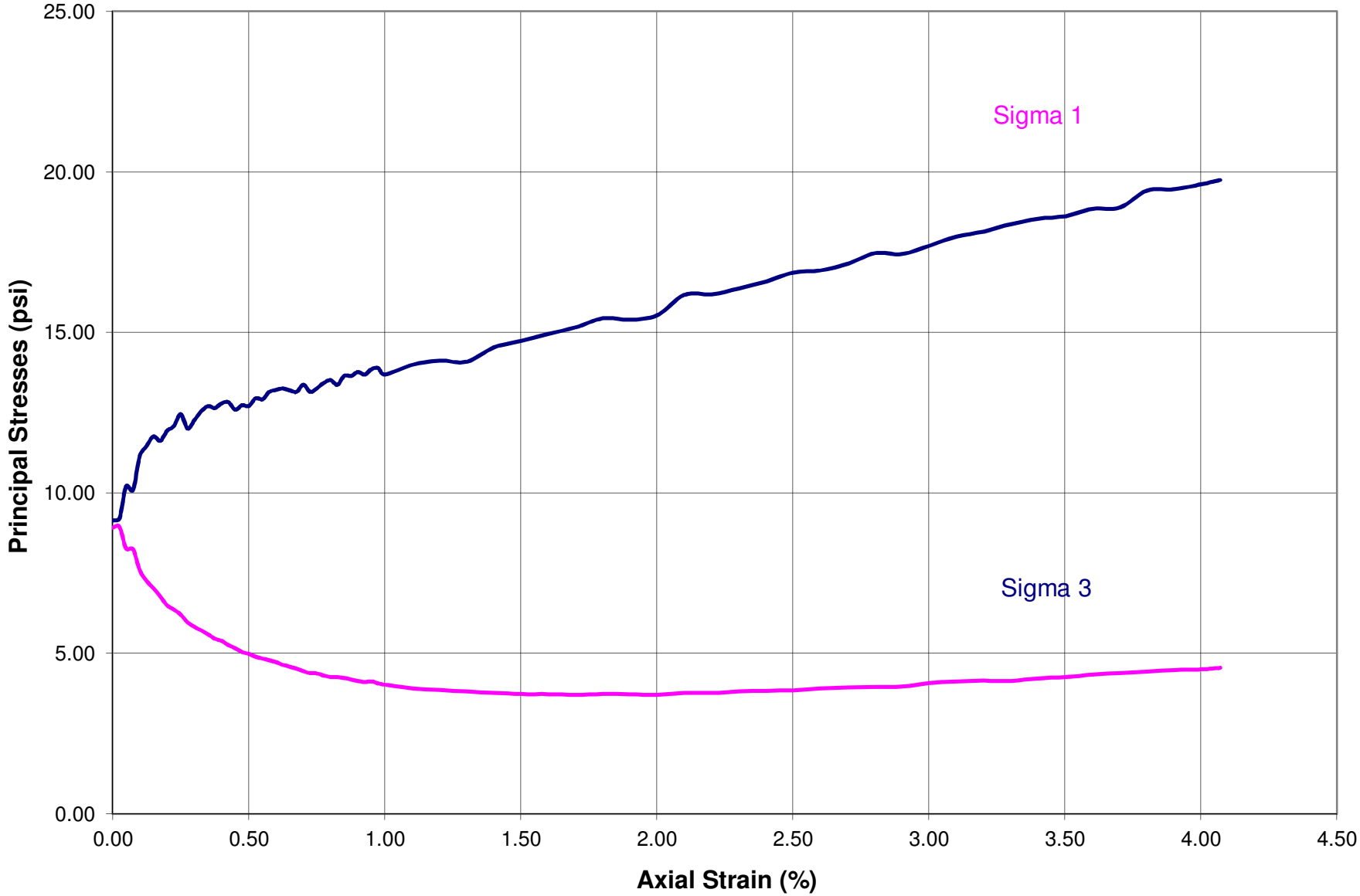
Bulge Single Shear Multiple Shear Vertical Fracture SLS

Technician: WTE

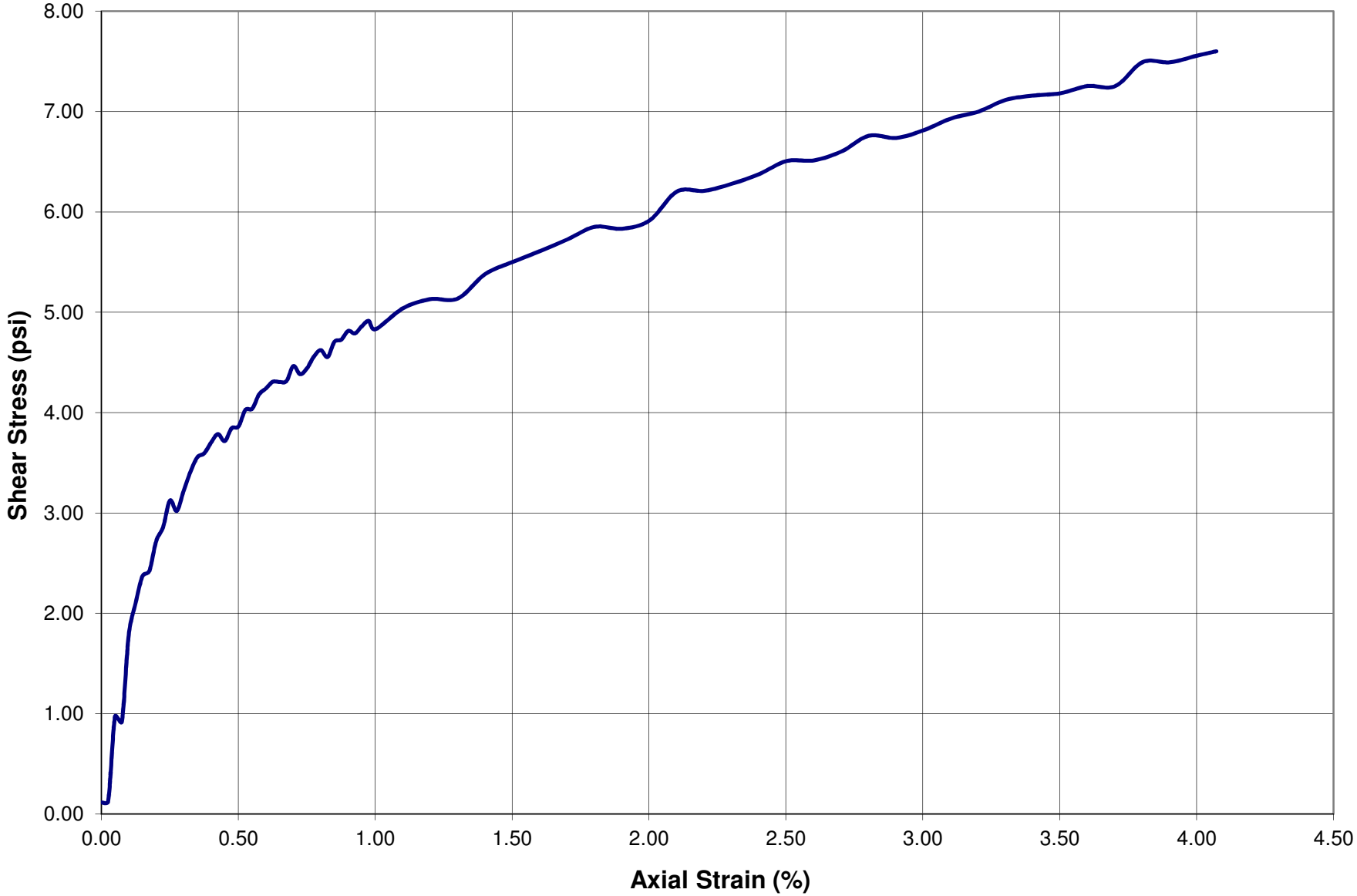
CU TEST RESULTS

B-5A, 14’-16’, STAGE 1 @ 8 PSI

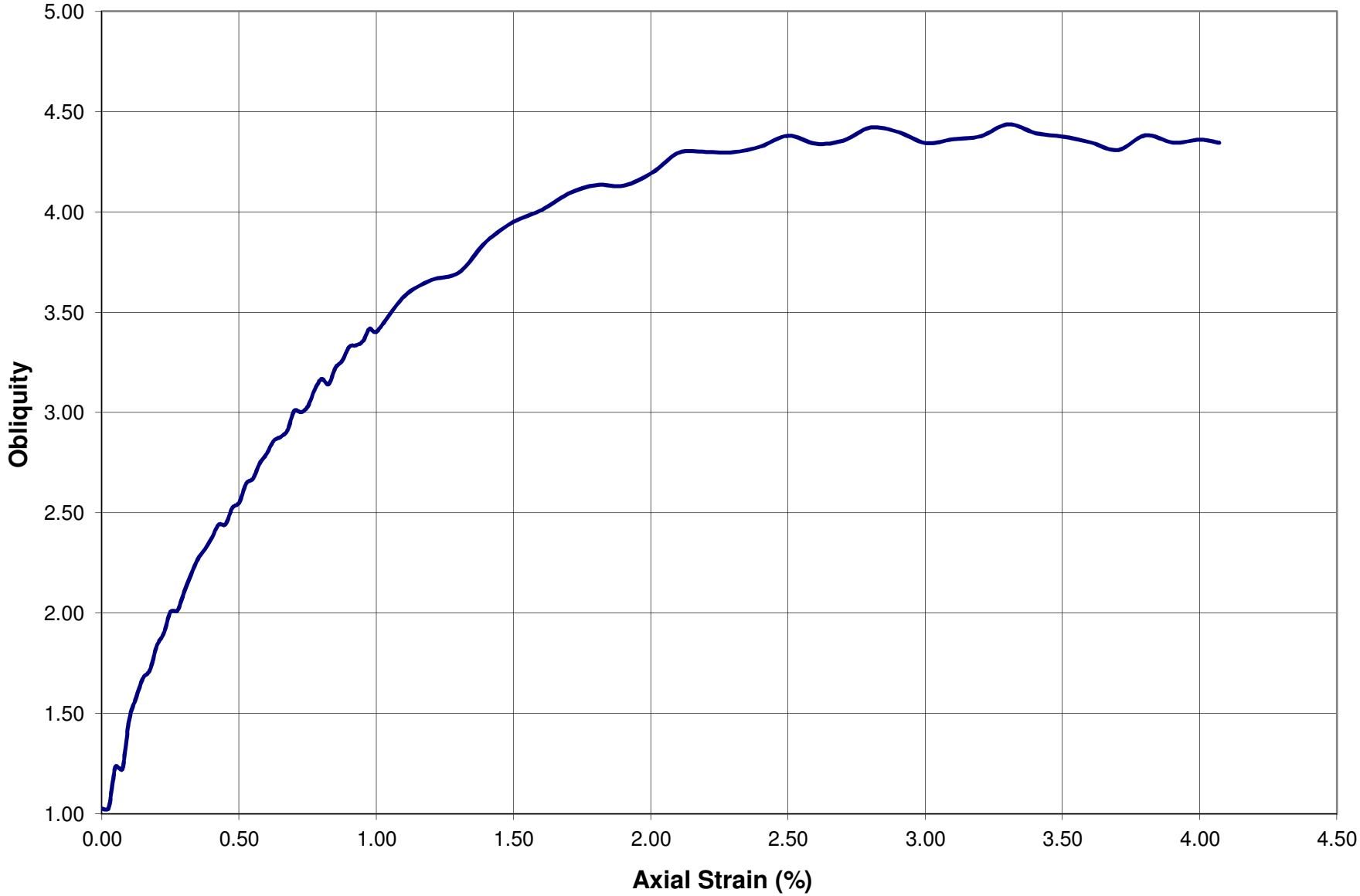
G149-14 B-5A-14-16 STAGE1.xls



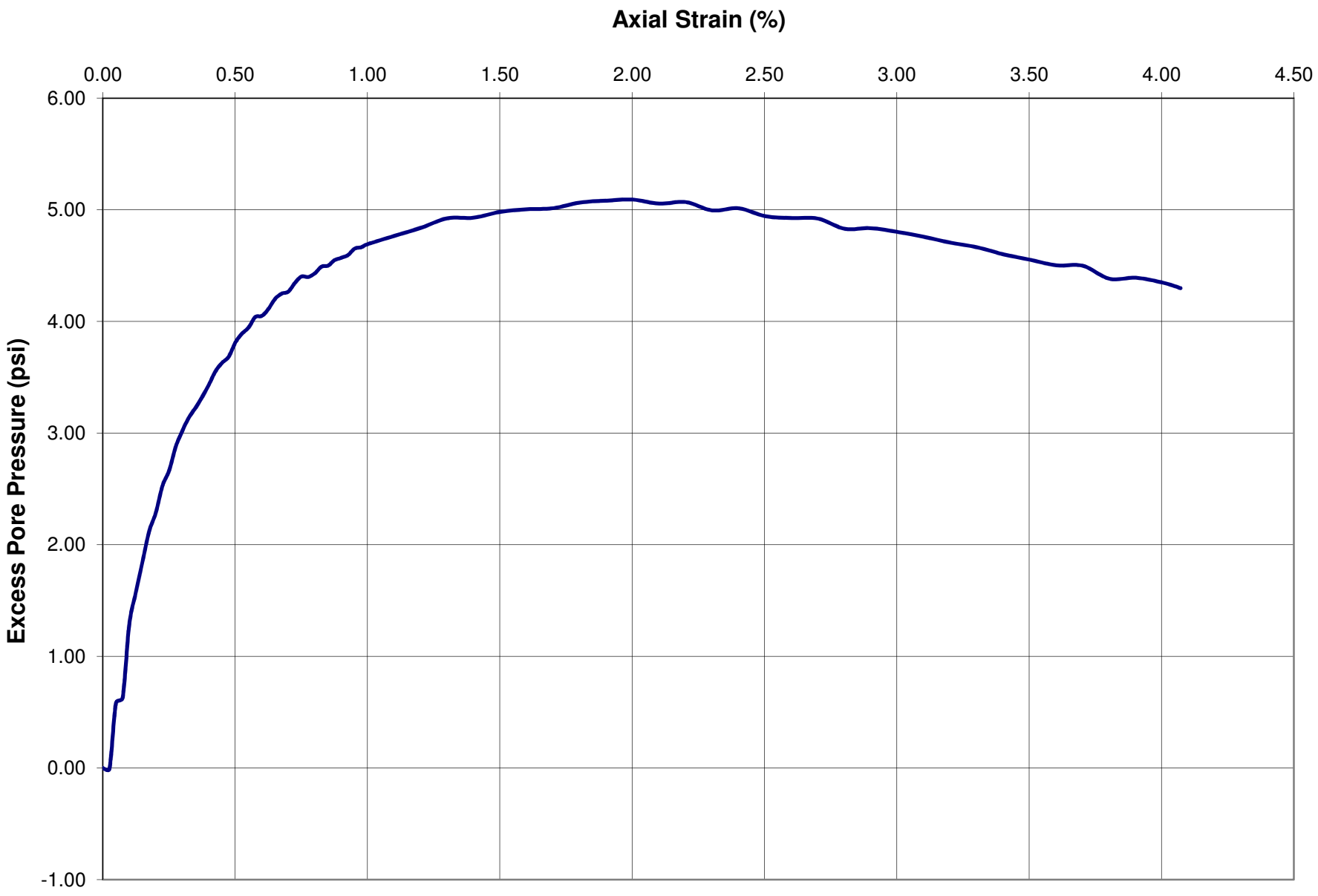
G149-14 B-5A-14-16 STAGE1.xls



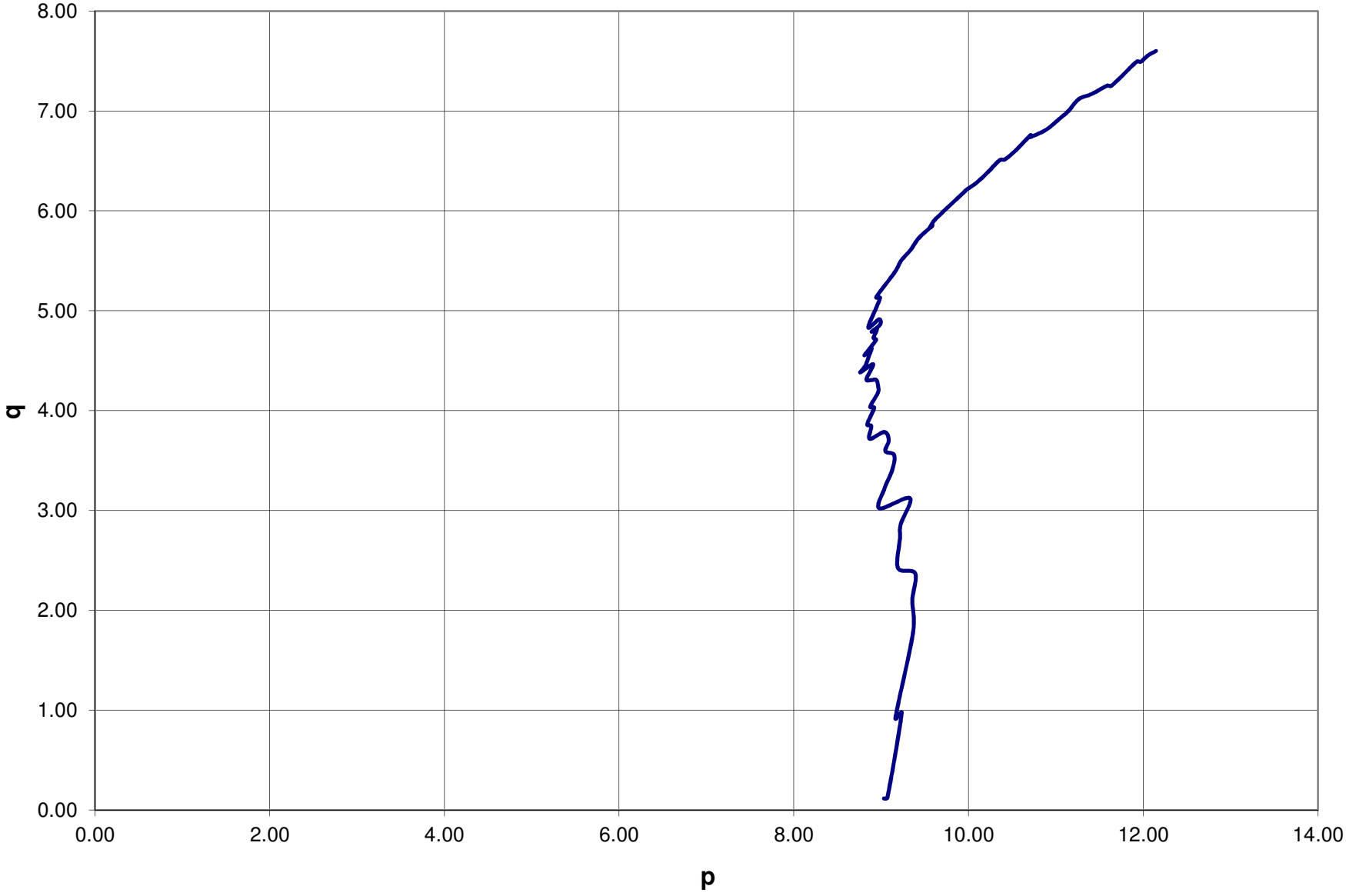
G149-14 B-5A-14-16 STAGE1.xls



G149-14 B-5A-14-16 STAGE1.xls



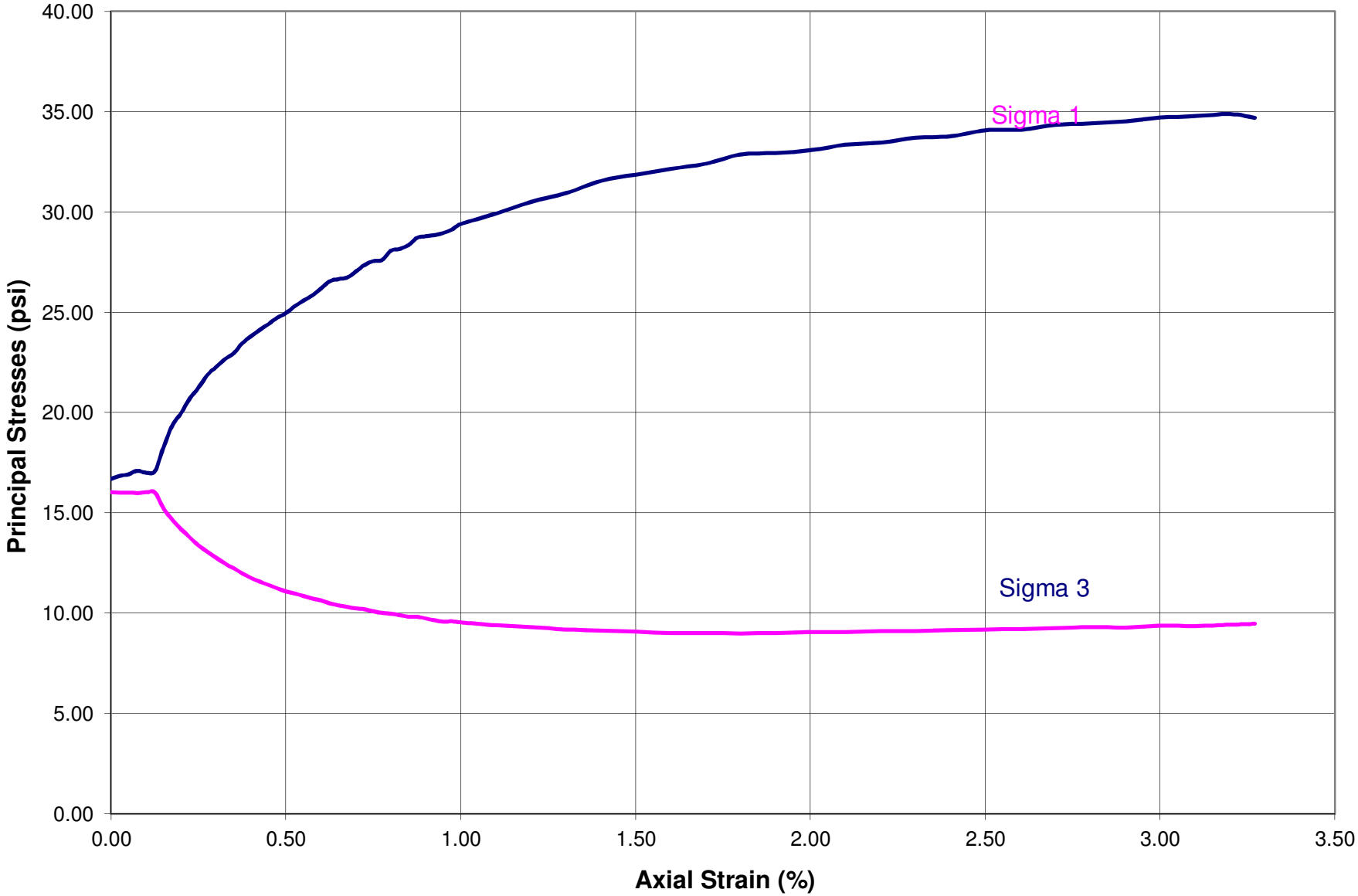
G149-14 B-5A-14-16 STAGE1.xls



CU TEST RESULTS

B-5A, 14’-16’, STAGE 2 @ 16 PSI

G149-14 B-5A-14-16 STAGE2.xls



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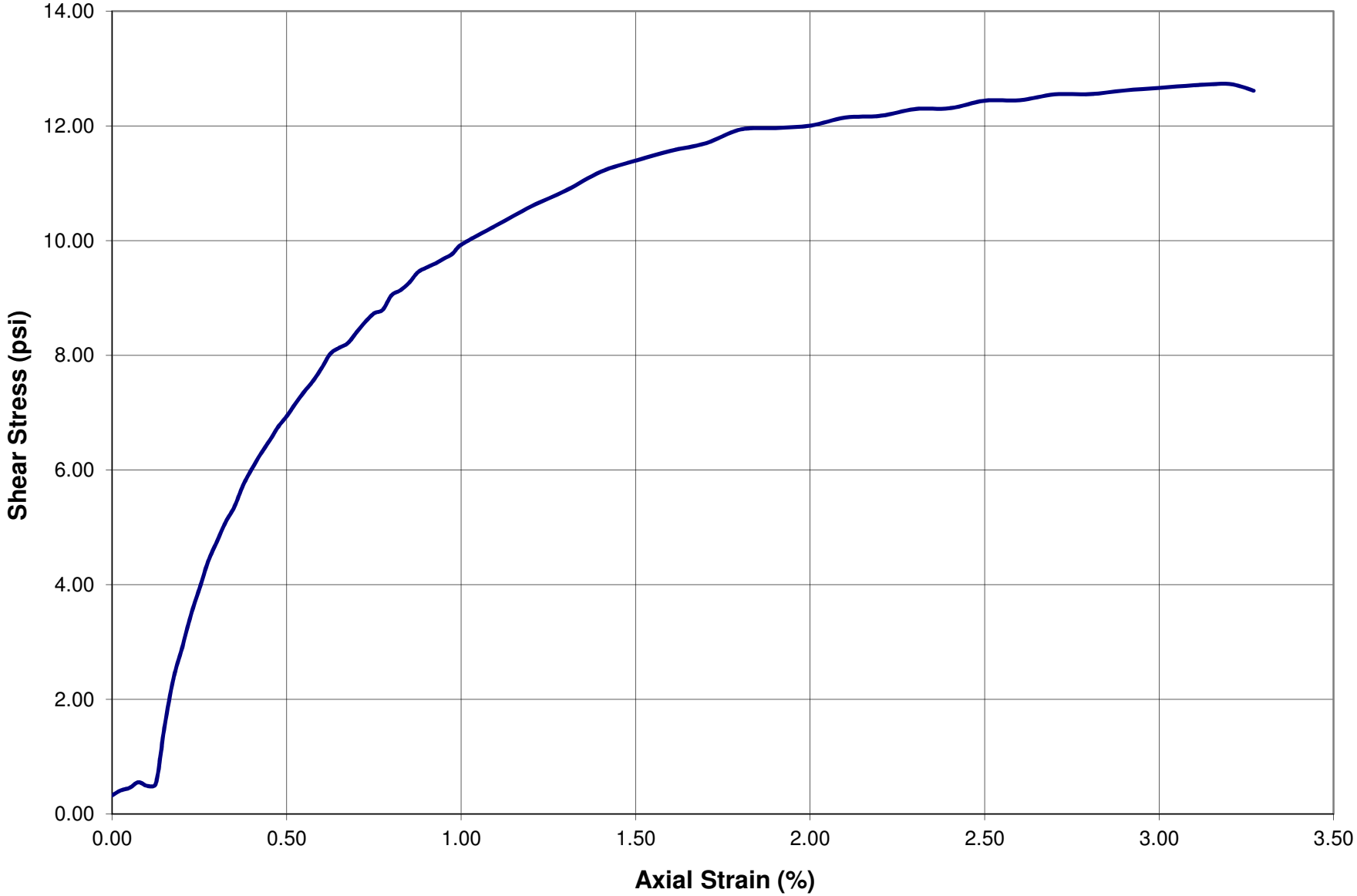

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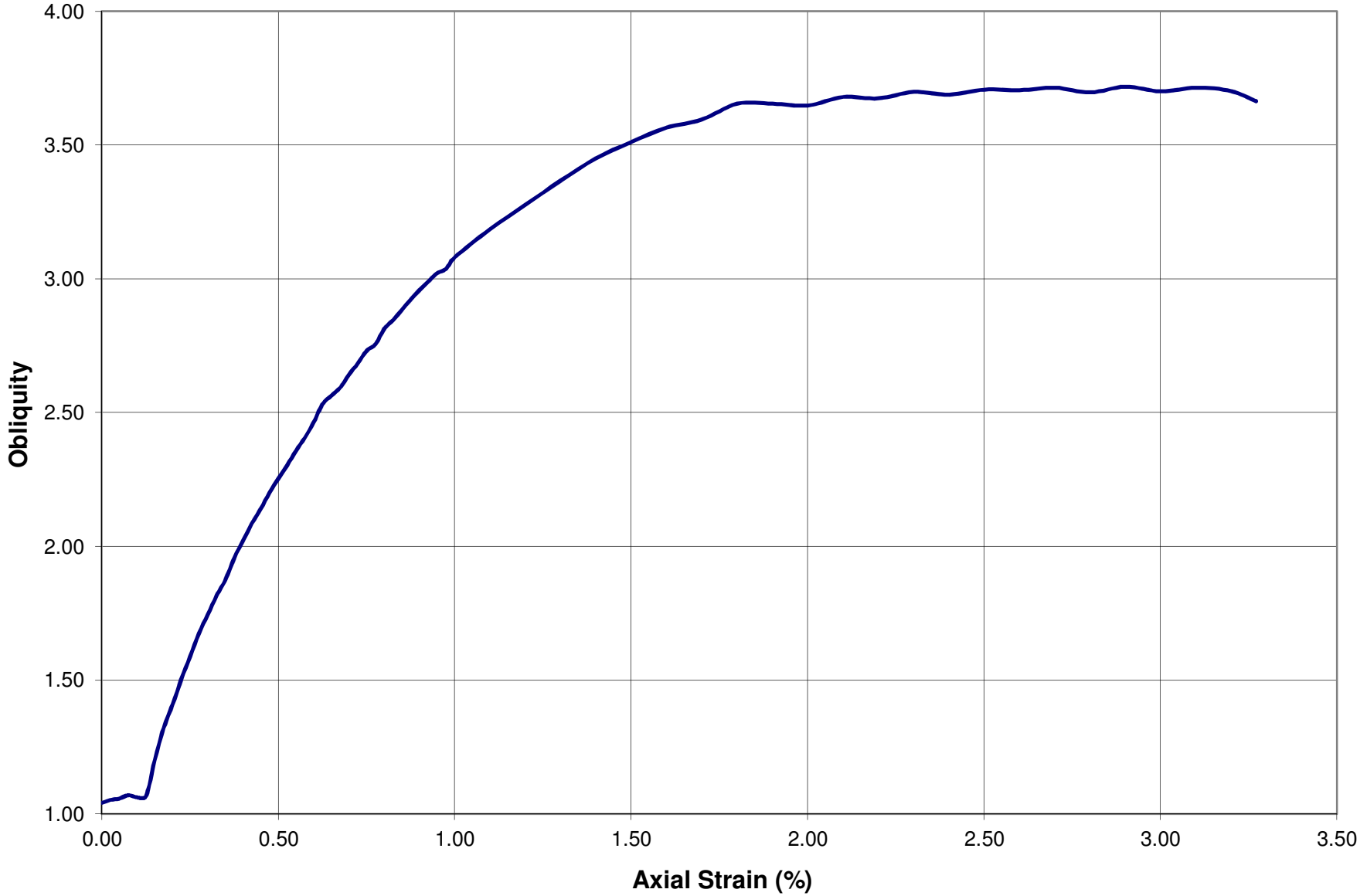

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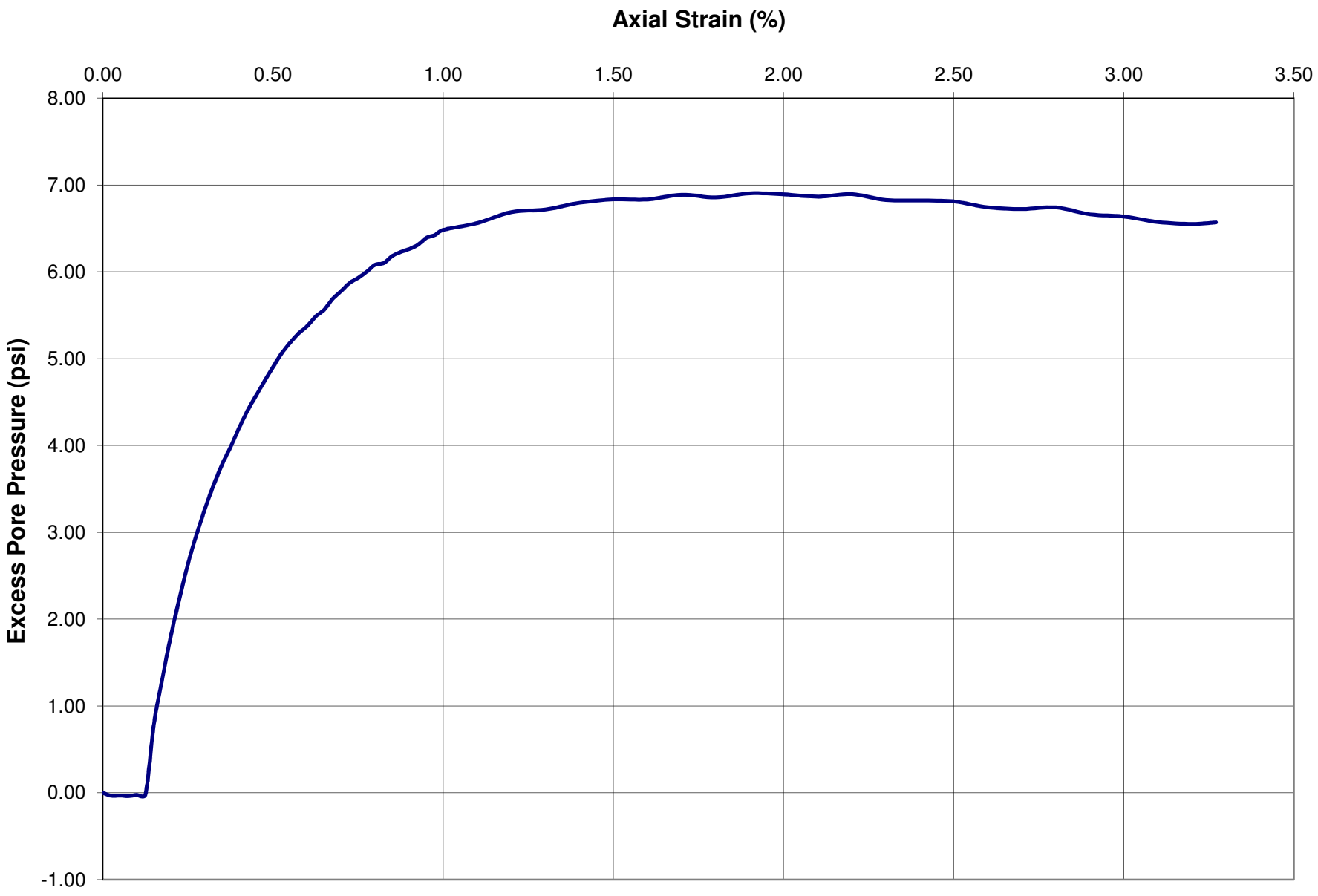

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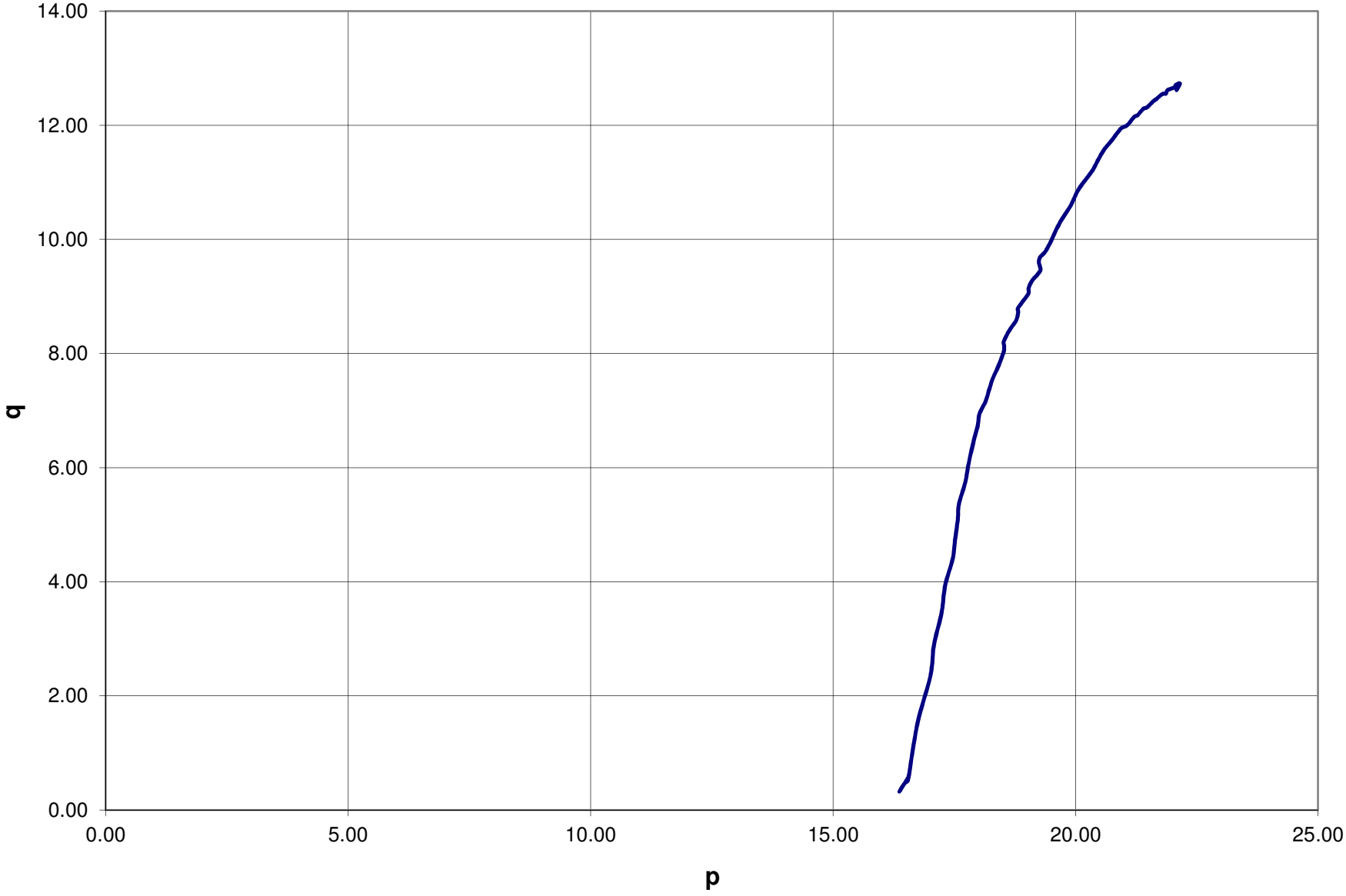
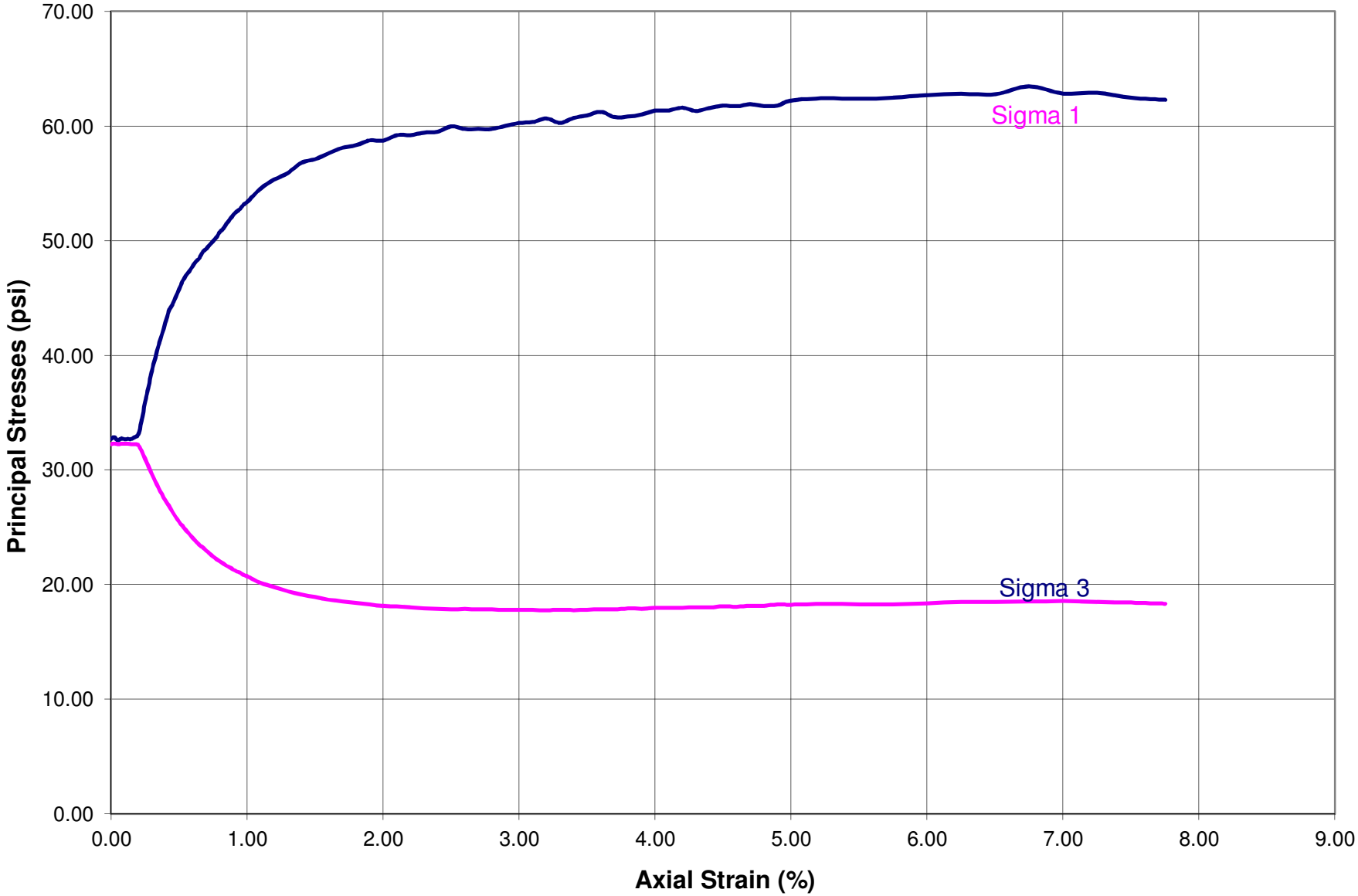


CU TEST RESULTS

B-5A, 14’-16’, STAGE 3 @ 32 PSI

G149-14 B-5A-14-16 STAGE3.xls



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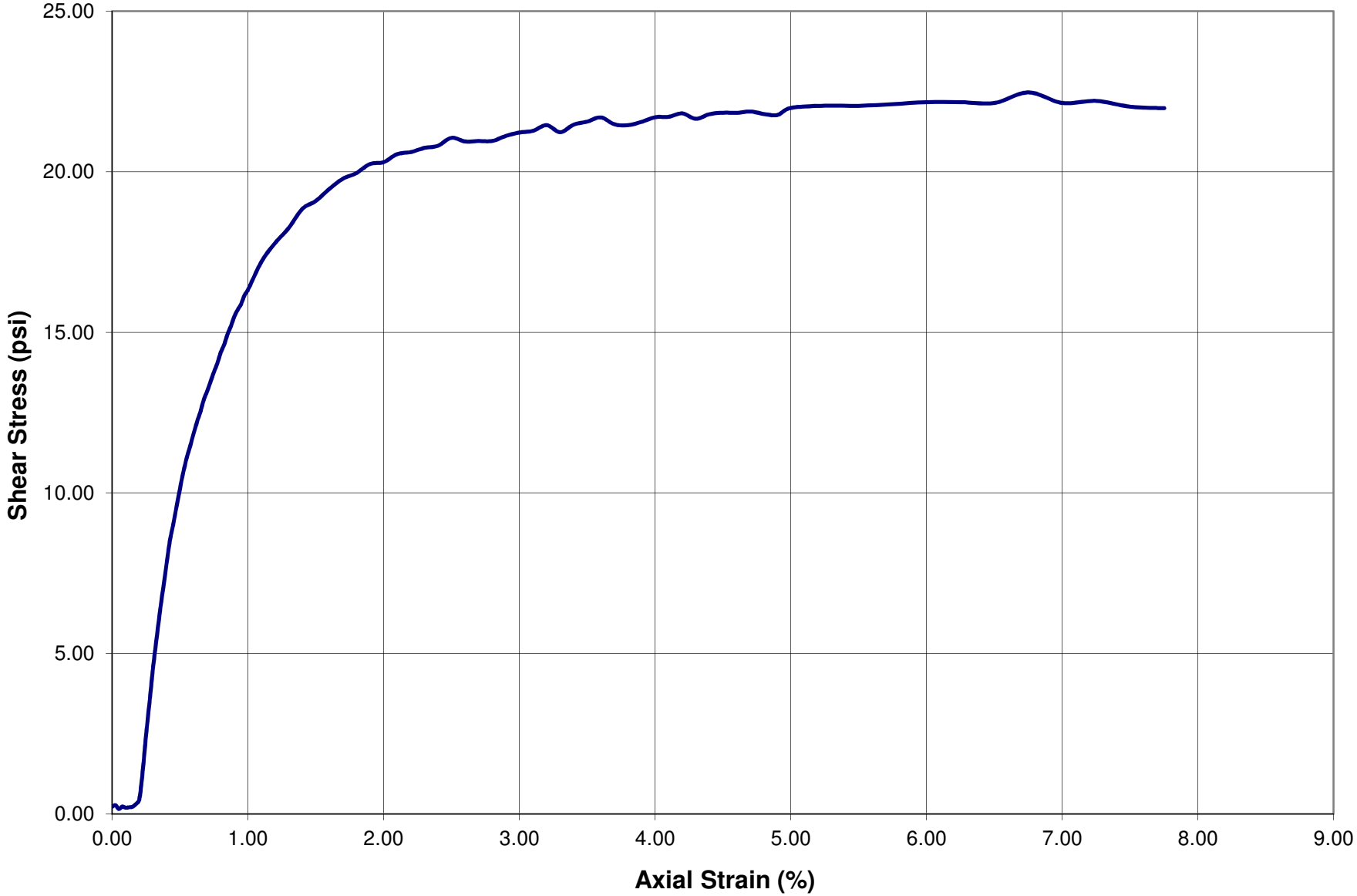

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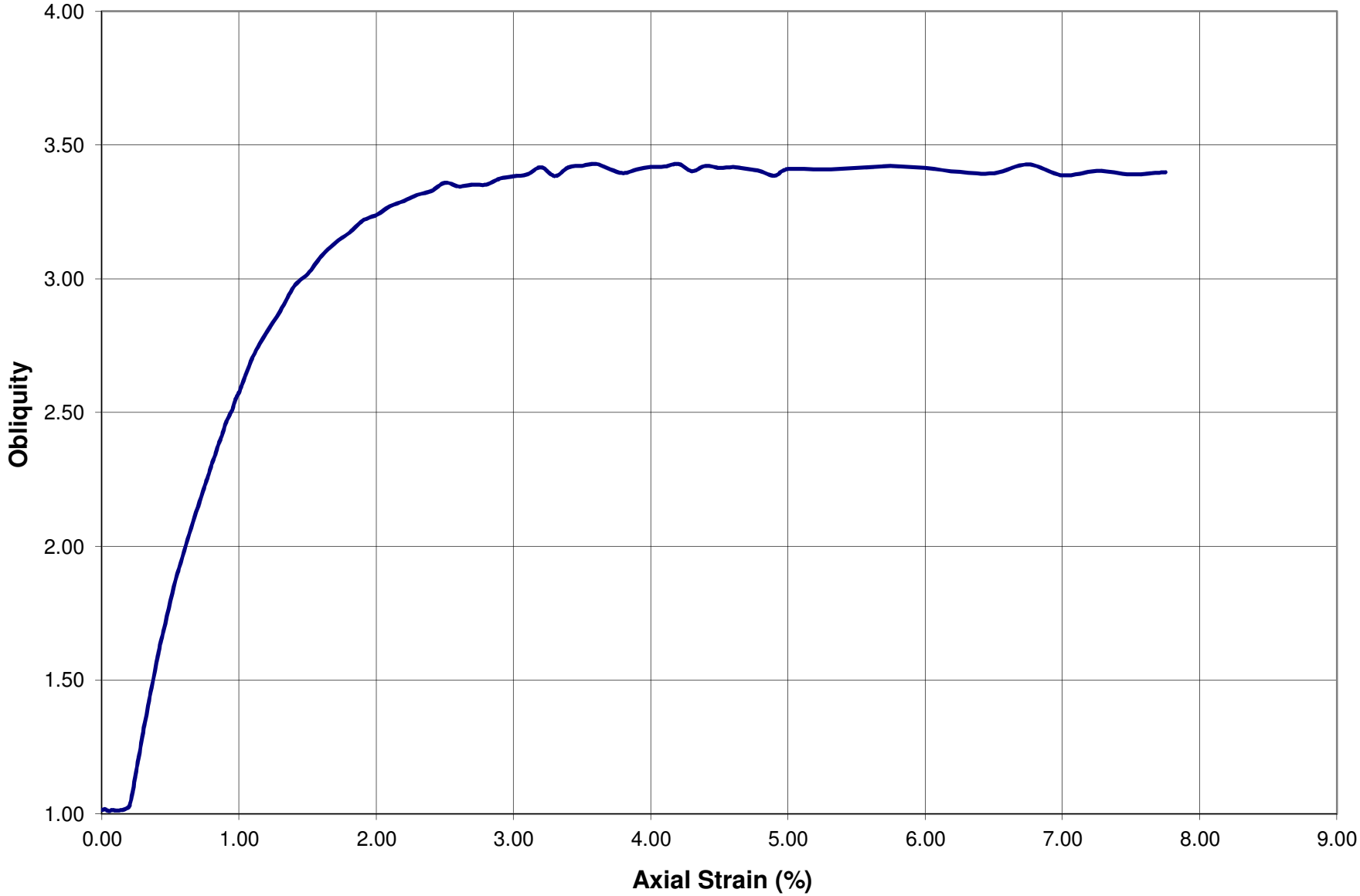

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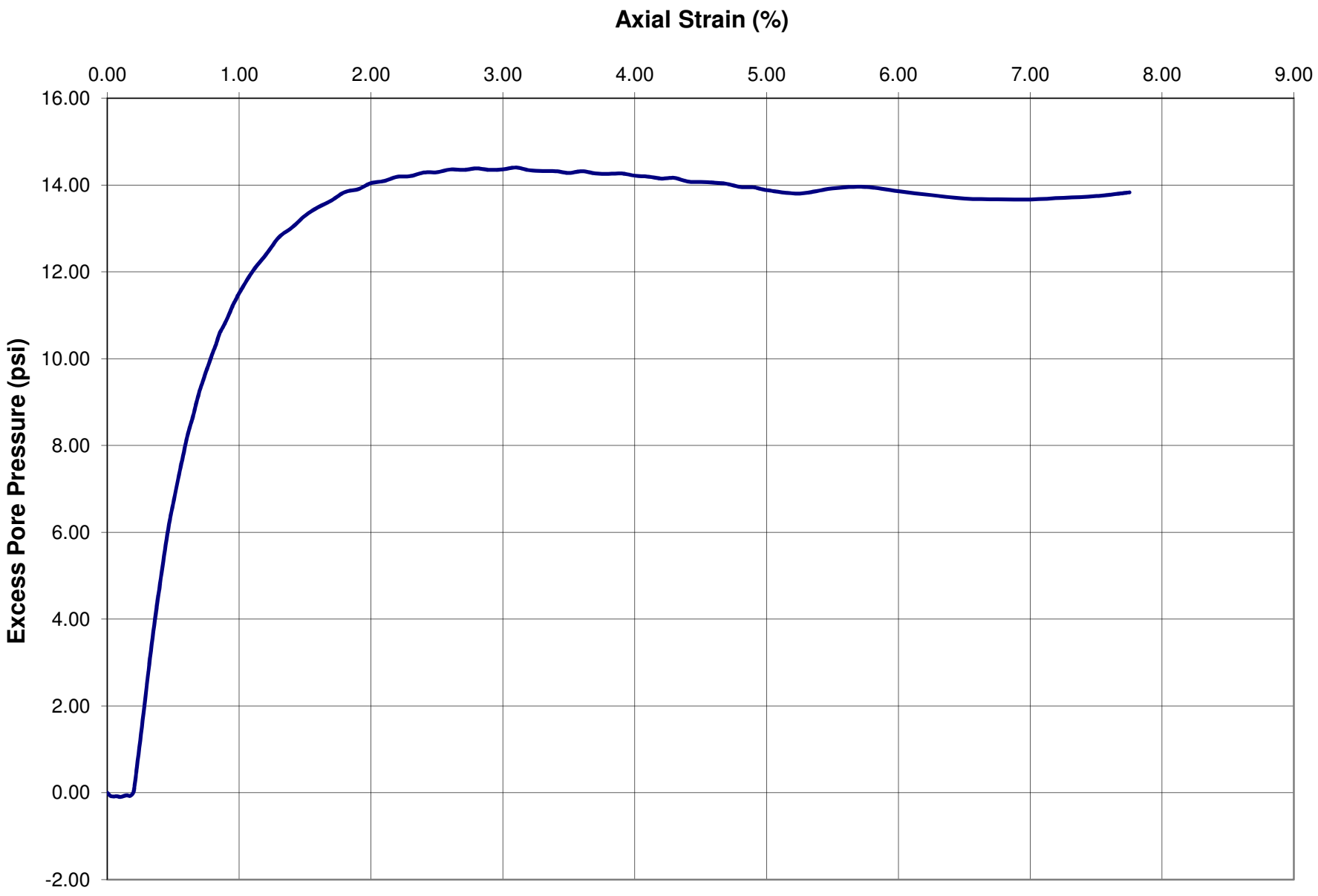

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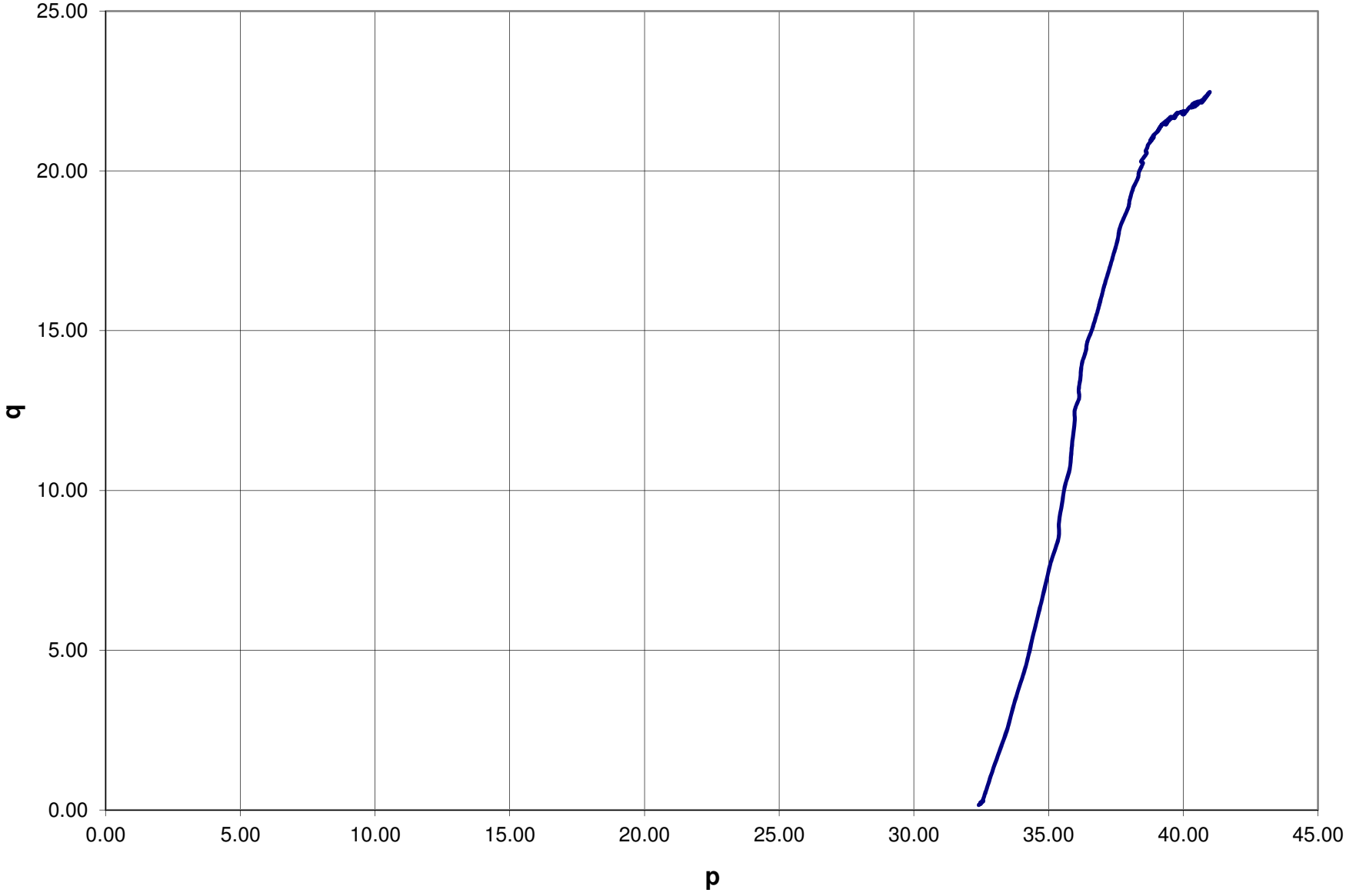


AVILES ENGINEERING CORP.

APPENDIX J-2

CU Test Results - B-7A, 6’-8’

CALCULATION OF TRIAXIAL CU TESTING RESULTS

Job Name: SWTP Contract 70B Waterline
Client: Kuo & Associates
Location: B-7A-6-8

Job No.: G149-14
5/20/2015
File @: Z:\Engineering\Reports\2014\149-14

Three Staged Consolidated-Undrained Triaxial Tests

Tan and Gray Fat Clay (CH)

1) Initial Condition (before testing) [6 to 8 ft]

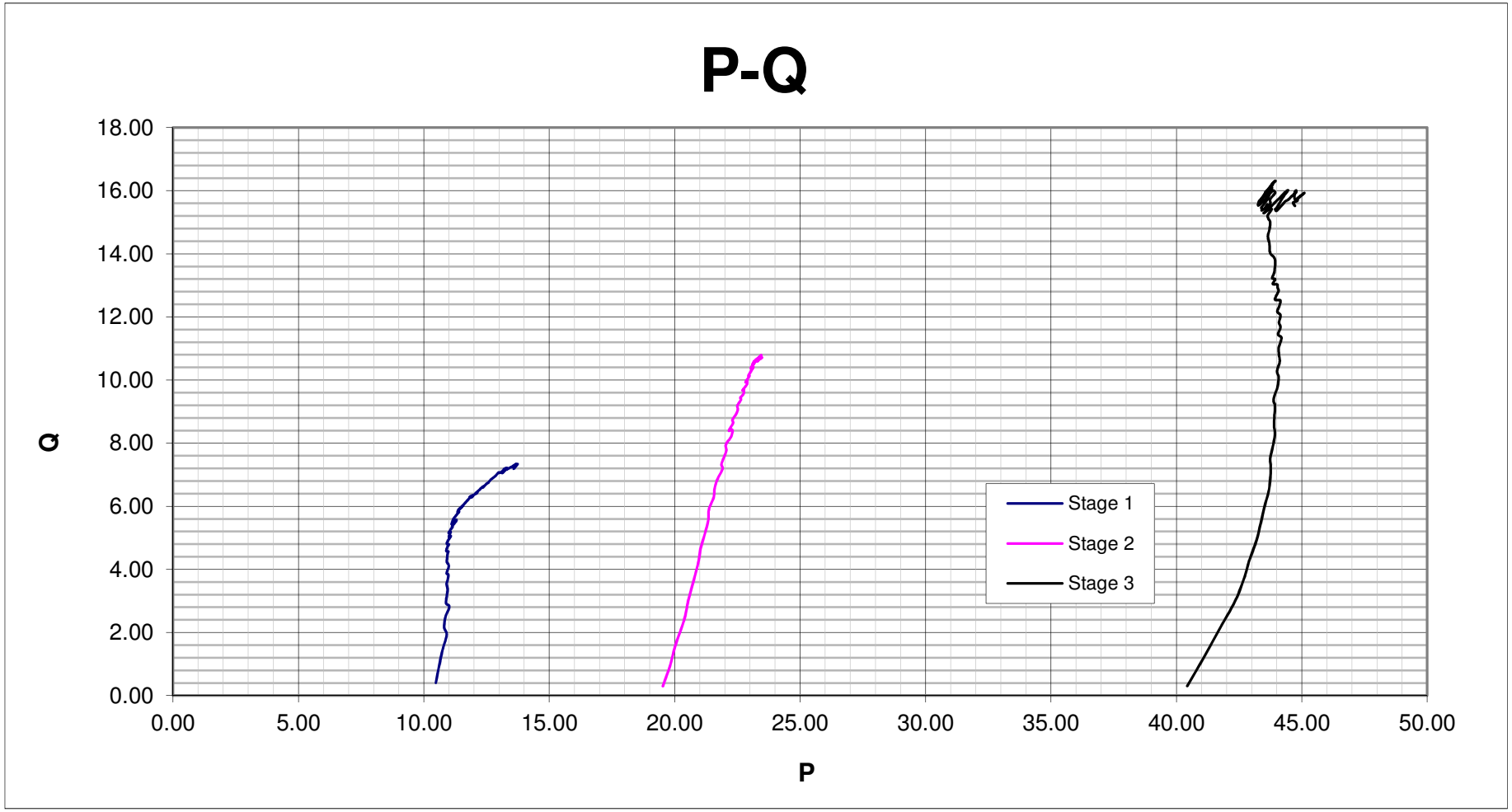
LL =	64	, PL =	22	, PI =	42 ,
Cu =		psf,			
w_0 =	26.96	%,		G =	2.7 ,
Wet γ=	123.0	pcf,		Dry γ =	96.9 pcf,
γ_w =	62.4	pcf,		S = $w_0/(\gamma_w/\gamma_d - 1/G)$ =	98.5 %
e = w_0G/S =	0.739	.			

2) Final Condition (after testing)

w_f = 19.51 %,

Stage	Sigma_1'	Sigma_3'	u	Strain	Sigma_1	Sigma_3
	(psi)	(psi)	(psi)	(%)	(psi)	(psi)
1	19.76	5.88	4.18	3.40	23.94	10.06
2	32.66	13.02	6.21	0.83	38.87	19.23
3	59.22	28.38	11.55	1.90	70.77	39.93
Residual					0.00	0.00

	Effective Stresses				Total Stresses	
Stage	Sigma_1'	Sigma_3'	u	Strain	Sigma_1	Sigma_3
	(ksf)	(ksf)	(ksf)	(%)	(ksf)	(ksf)
1	2.85	0.85	0.60	3.40	3.45	1.45
2	4.70	1.87	0.89	0.83	5.60	2.77
3	8.53	4.09	1.66	1.90	10.19	5.75
Residual	0.00	0.00	0.00	0.00	0.00	0.00


P-Q
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Q
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
P
Stage 1
Stage 2
Stage 3

Aviles Engineering Corp.

Advanced Testing Assignment Form

Project Number: 6149-14

Boring: B-7A

Depth (ft): 6-8

Date Assigned: 4/28/15

Results Deadline:

Type(s) of Testing Required (check all that apply):

- [x] **CU Triaxial**
  - Desired Confining Pressures: 5, 10, 20 psi MULTI-STAGE
- [ ] **Consolidation**
- [ ] **Swell**

Any additional testing required for this sample:

- [x] P. I.
- [x] -200 Sieve
- [ ] Sieve Analysis
- [ ] Other: PP = 1.75

Assigned by: Wilber

Aviles Engineering Corporation
CU BACKPRESSURE SATURATION
ASTM D-4767

Project: 149-14	Date: 5/7/15	Sigma3: 5 10 20
Boring: B-7A	Depth (ft): 6-8	Cell #: 6

Date: 5/7/15	Time: 13:40	Cell Pressure *(psi)*: 9.24
		Back Pressure *(psi)*: 5.57
Pore Pressure Change *(with backpressure valves closed, after 1 min)*: −0.05 ✓		
B-value: 0.48	Increase Pressures? Y	Saturation Complete? N
New Cell Pressure *(psi)*: 15		New Back Pressure *(psi)*: 10
Date: 5/7/15	Time: 13:48	Cell Pressure *(psi)*: 15.00
		Back Pressure *(psi)*: 10.08
Pore Pressure Change *(with backpressure valves closed, after 1 min)*: −0.12 ✓		
B-value: 0.48	Increase Pressures? Y	Saturation Complete? N
New Cell Pressure *(psi)*: 20		New Back Pressure *(psi)*: 15
Date: 5/7/15	Time: 14:33	Cell Pressure *(psi)*: 19.96
		Back Pressure *(psi)*: 15.03
Pore Pressure Change *(with backpressure valves closed, after 1 min)*: −0.15 ✓		
B-value: 0.63	Increase Pressures? Y	Saturation Complete? N
New Cell Pressure *(psi)*: 25		New Back Pressure *(psi)*: 20
Date: 5/7/15	Time: 15:36 ~~15:49~~	Cell Pressure *(psi)*: ~~29.07~~ 25.00
		Back Pressure *(psi)*: ~~15.05~~ 20.07
Pore Pressure Change *(with backpressure valves closed, after 1 min)*: −0.15 ✓		
B-value: 0.66	Increase Pressures? Y	Saturation Complete? N
New Cell Pressure *(psi)*: 30		New Back Pressure *(psi)*: 25
Technician Signature: VVT		

Aviles Engineering Corporation
CU BACKPRESSURE SATURATION
ASTM D-4767

Project: 149-14	Date: 5/7/15	Sigma3: 5 10 20
Boring: B-7A	Depth (ft): 6-8	Cell #: 6

Date: 5/8/15	Time: 7:10	Cell Pressure *(psi)*:	30.01
		Back Pressure *(psi)*:	25.10
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			-0.03
B-value: 0.83	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 35		New Back Pressure *(psi)*:	30
Date: 5/8/15	Time: 7:29	Cell Pressure *(psi)*:	34.98
		Back Pressure *(psi)*:	29.98
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			-0.08
B-value: 0.87	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 40		New Back Pressure *(psi)*:	35
Date: 5/8/15	Time: 11:13	Cell Pressure *(psi)*:	40.17
		Back Pressure *(psi)*:	34.97
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			-0.11
B-value: 0.89	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 45		New Back Pressure *(psi)*:	40
Date: 5/11/15	Time: 6:42	Cell Pressure *(psi)*:	46.08
		Back Pressure *(psi)*:	40.77
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:			0.05
B-value: 0.93	Increase Pressures? y	Saturation Complete? N	
New Cell Pressure *(psi)*: 50		New Back Pressure *(psi)*:	45
Technician Signature:			

Aviles Engineering Corporation
CU BACKPRESSURE SATURATION
ASTM D-4767

Project: 149-14	Date: 5/7/15	Sigma3: 5 10 20
Boring: B-7A	Depth (ft): 6-8	Cell #: 6

Date: 5/12/15	Time: 10:44	Cell Pressure *(psi)*: 50.85
		Back Pressure *(psi)*: 45.02
Pore Pressure Change *(with backpressure valves closed, after 1 min)*: -0.02 ✓		
B-value: 0.96	Increase Pressures? N	Saturation Complete? Y
New Cell Pressure *(psi)*: —		New Back Pressure *(psi)*: —
Date:	Time:	Cell Pressure *(psi)*:
		Back Pressure *(psi)*:
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:		
B-value:	Increase Pressures?	Saturation Complete?
New Cell Pressure *(psi)*:		New Back Pressure *(psi)*:
Date:	Time:	Cell Pressure *(psi)*:
		Back Pressure *(psi)*:
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:		
B-value:	Increase Pressures?	Saturation Complete?
New Cell Pressure *(psi)*:		New Back Pressure *(psi)*:
Date:	Time:	Cell Pressure *(psi)*:
		Back Pressure *(psi)*:
Pore Pressure Change *(with backpressure valves closed, after 1 min)*:		
B-value:	Increase Pressures?	Saturation Complete?
New Cell Pressure *(psi)*:		New Back Pressure *(psi)*:
Technician Signature:		

H = 5.569

DG = 0.276"

D = 2.770

Triaxial Consolidation Datasheet

Stage: 2 **σ3=** ~~[illegible]~~ 20

Cell#: 6

Job No.: 149-14 **Cell Pressure:** 65

Boring No: B-7A **Back Pressure:** 45

Depth: 6-8

Date	Time	Elapsed Time (min)	Pipette Reading (ml)	Dial Gauge Reading (in.)
5/14/15	15:38	0	23.00	0.530/0.527
		0.1	22.50	
		0.25	22.20	
		0.5	22.0	
		1	21.30	
		2	21.45	
		14	20.1	
5/15/15	7:00	~~8~~	14.43	
5/15/15	14:46	~~15~~	14.08	
5/18/15	8:09	~~30~~	13.70	0.535"
		60		
		120		

Final Height (in): 5.310

Final Diameter (in): 2.813

Triaxial Consolidation Datasheet

Stage: 3 **σ3=** 40

Cell#: 6

Job No.: 149-14 **Cell Pressure:** 85

Boring No: P-7A **Back Pressure:** 45

Depth: 6-8

Date	Time	Elapsed Time (min)	Pipette Reading (ml)	Dial Gauge Reading (in.)	
5/18/15	11:32	0	23.00	0.653/0.653	
		0.1	22.5		
		0.25	22.35		
		0.5	22.18		
		1	21.85		
		3 ~~2~~	21.30		
		4	21.10		
		10 ~~8~~	20.30		
		94 ~~15~~	16.86		
		136 ~~30~~	16.00		
	15:01	209 ~~88~~	14.97		LEAK
5/19/15	6:52	1160 ~~120~~	6.2		
	7:52	1220	5.68		

Final Height (in): 5.174

Final Diameter (in): 2.818

CONSOL R500

Triaxial Consolidation Datasheet

Stage: **σ3=**

Cell#:

Job No.: **Cell Pressure:**

Boring No: **Back Pressure:**

Depth:

Date	Time	Elapsed Time (min)	Pipette Reading (ml)	Dial Gauge Reading (in.)
5/19/15	8:10	0	20.00	
	8:20	~~0.5~~	19.72	
	8:30	~~0.25~~	19.44	
	9:10	~~0.5~~	19.04	
	9:50	100	18.86	
	11:45	215	18.66	
	14:20	373	18.57	0.671
		8		
		15		
		30		
		60		
		120		

Final Height (in):

Final Diameter (in):

CU Post-Test Datasheet

Project Name: 149-14 **Project Number:** _____

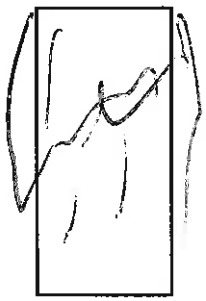
Boring Number: B-7A **Boring Depth (ft):** 6-8 **Cell#:** 6

Date: 5/20/15

Moisture Content:

Tare ID:	B2
Tare Weight (g):	116.32
Wet Soil + Tare (g):	210.73
Dry Soil + Tare (g):	195.32
% Moisture:	19.51

Sample Sketch:



Failure Types: (circle all that apply)

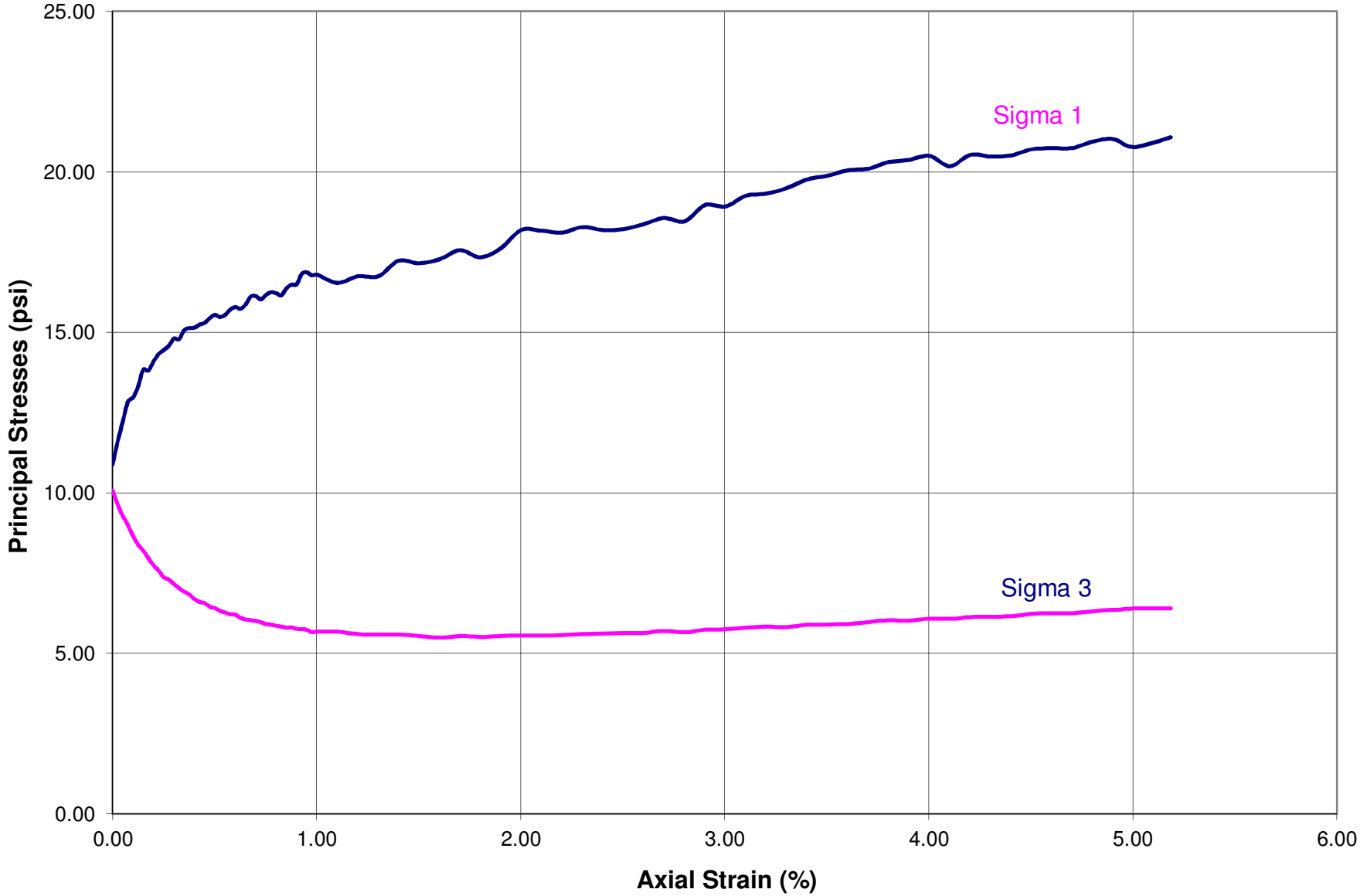
Bulge Single Shear Multiple Shear Vertical Fracture SLS

Technician: _____

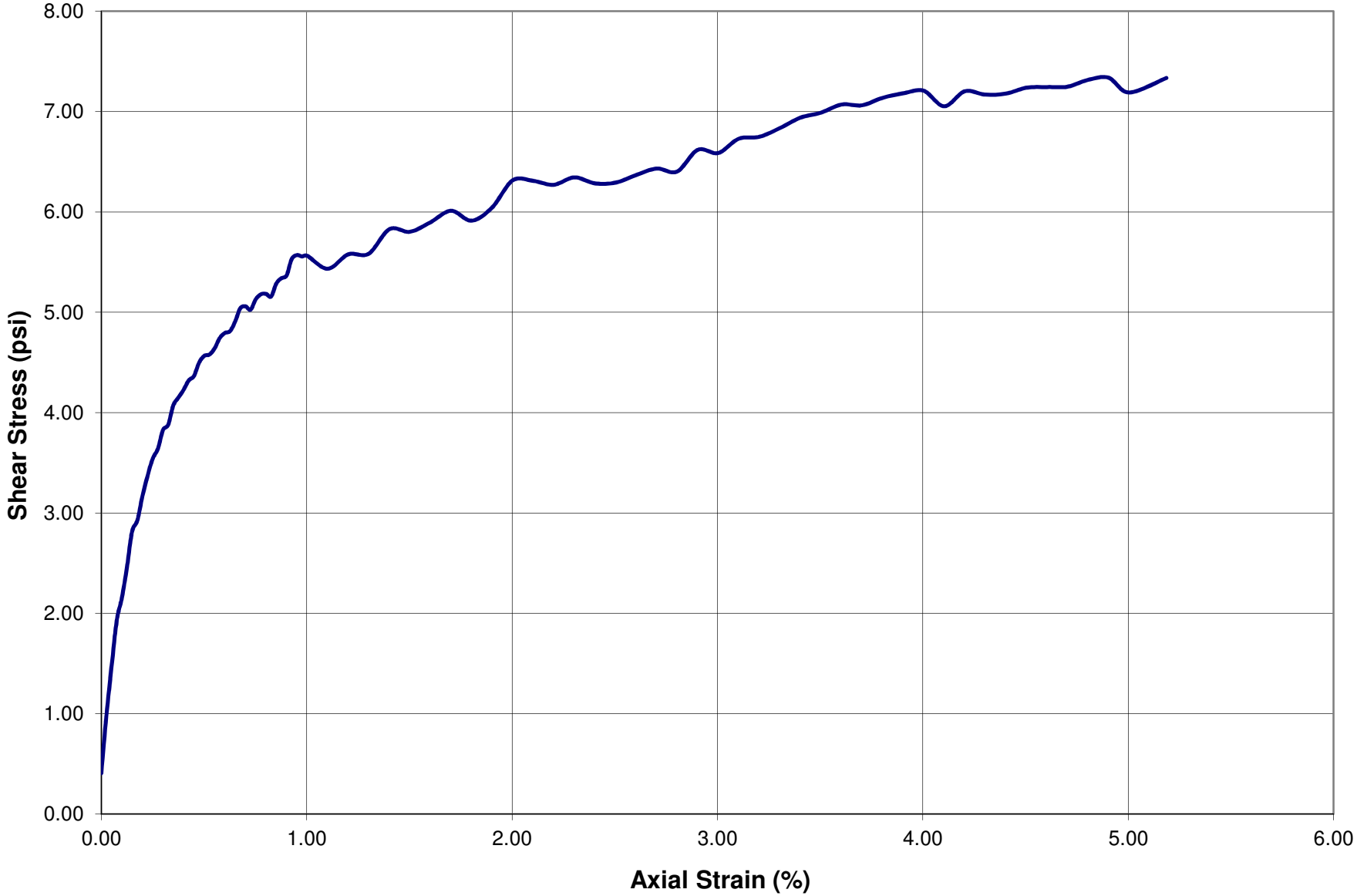
CU TEST RESULTS

B-7A, 6’-8’, STAGE 1 @ 5 PSI

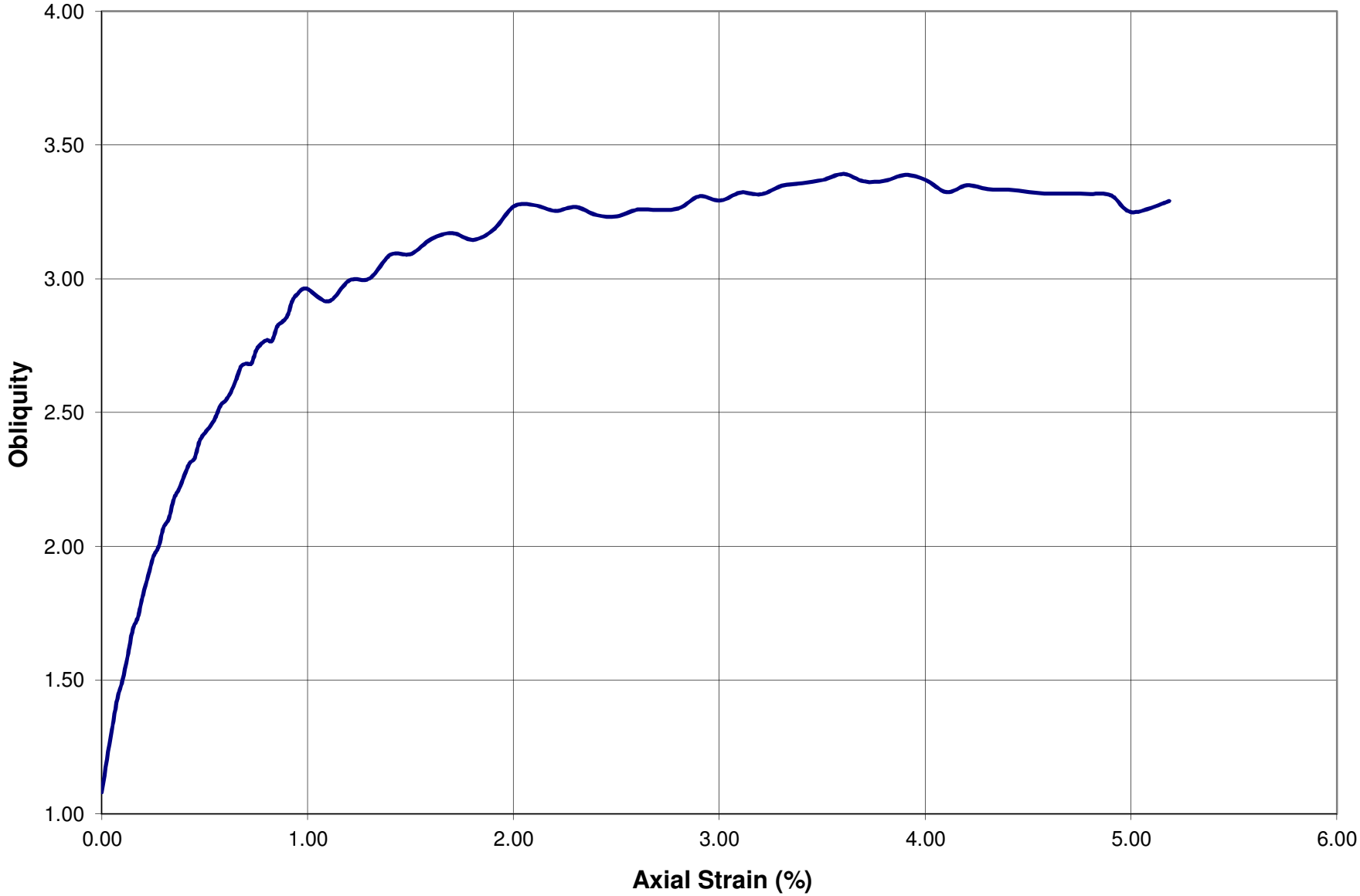
G149-14 B-7A-6-8 STAGE1.xls



G149-14 B-7A-6-8 STAGE1.xls



G149-14 B-7A-6-8 STAGE1.xls



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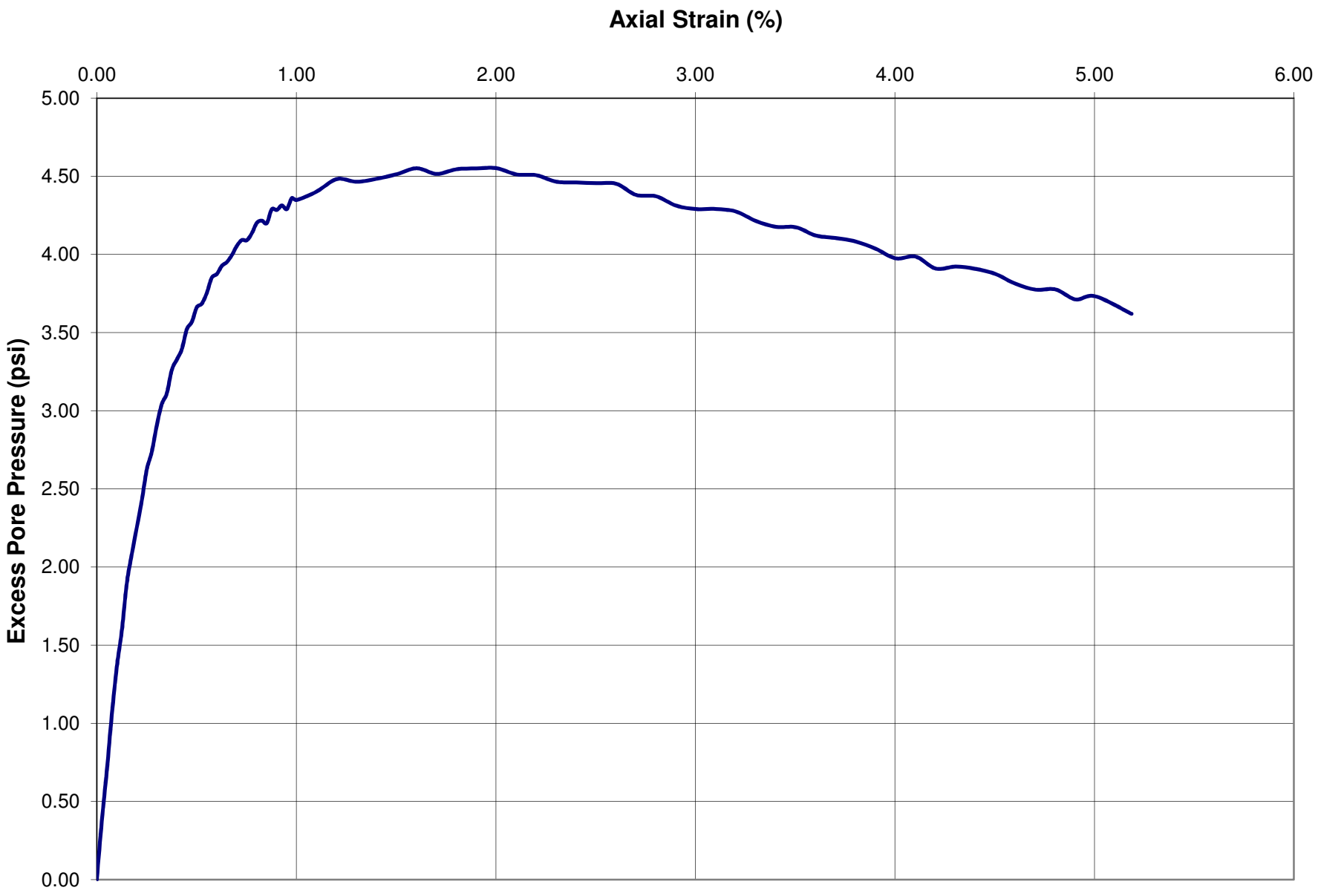
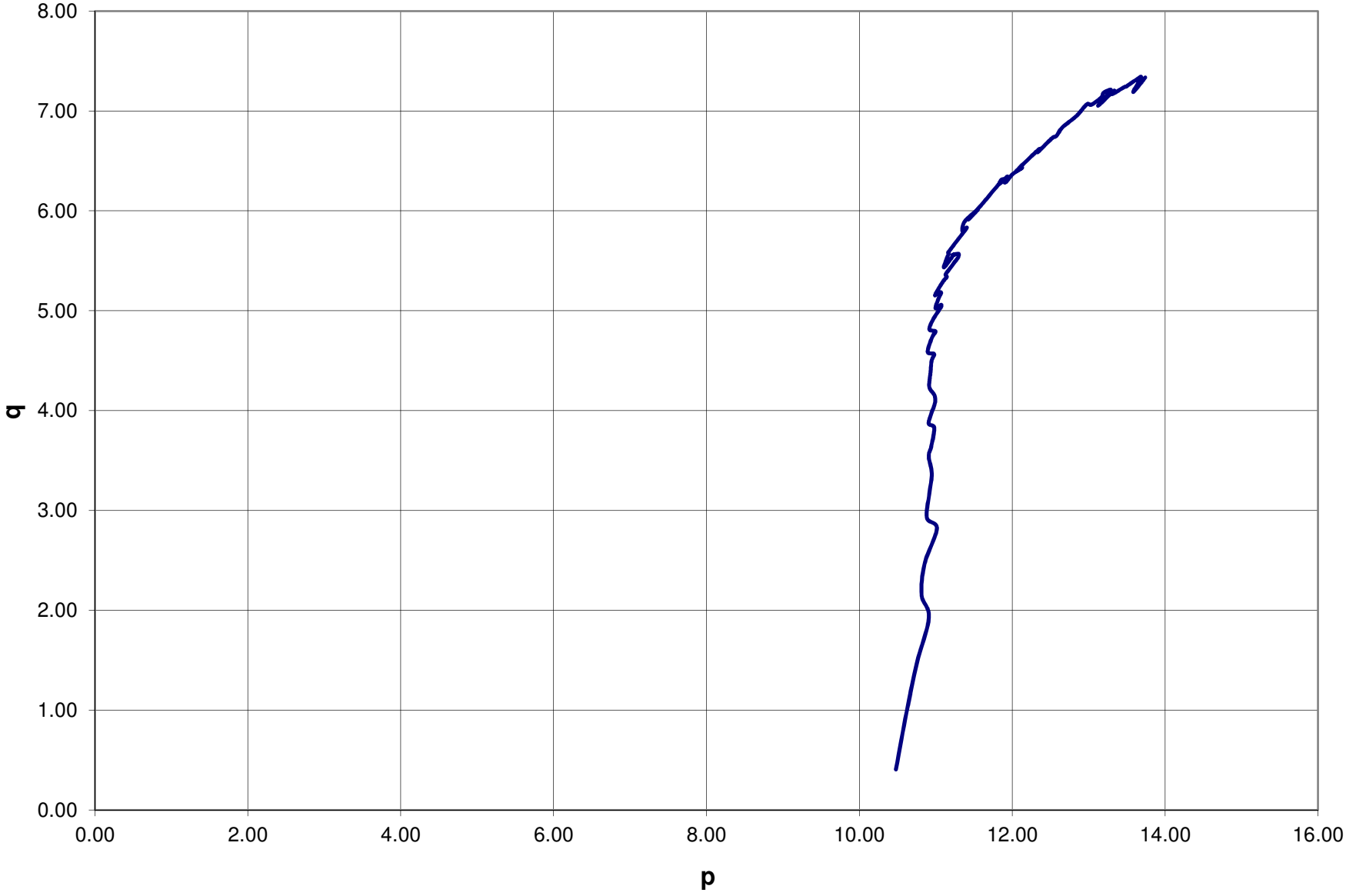


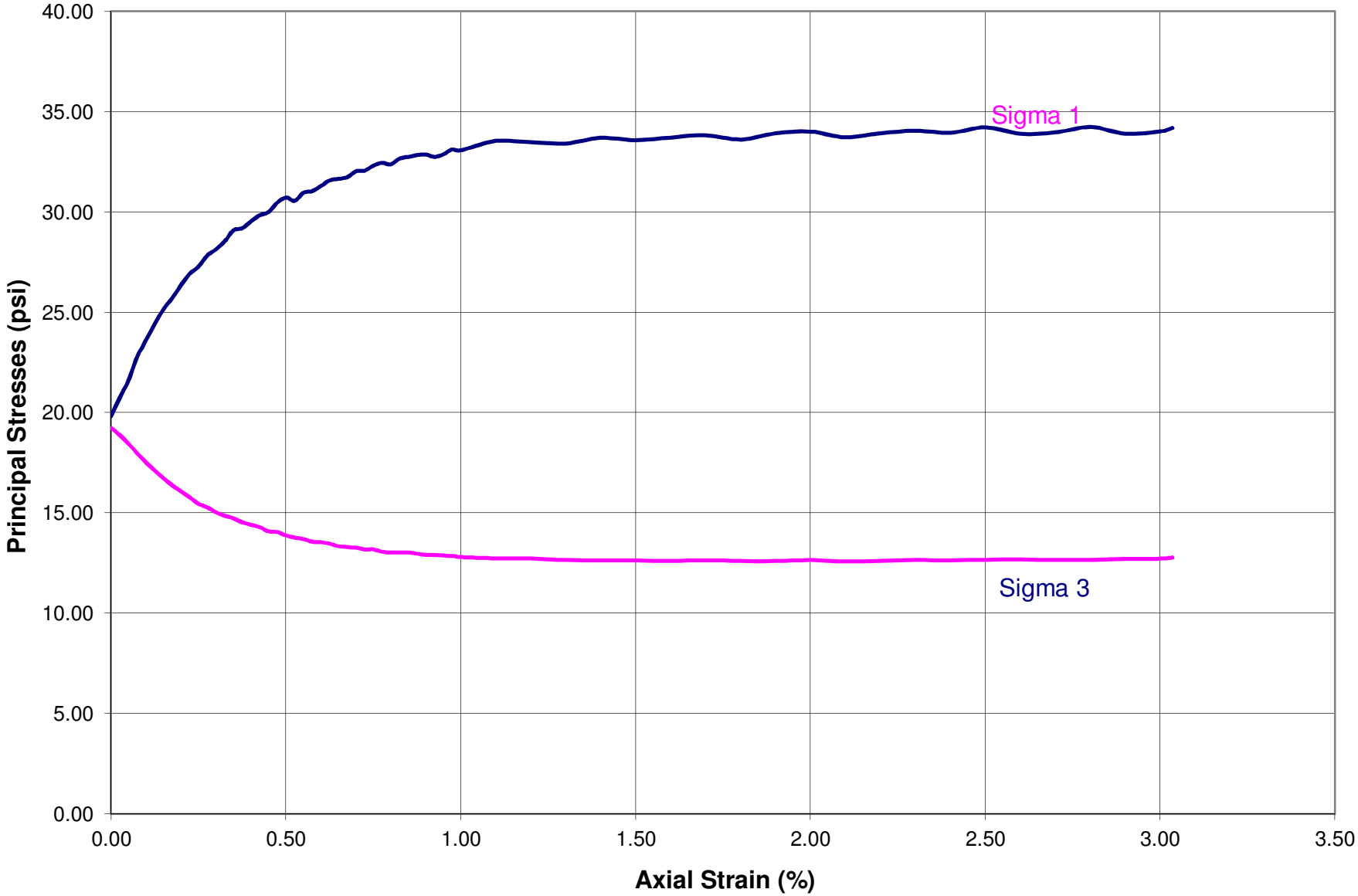
G149-14 B-7A-6-8 STAGE1.xls



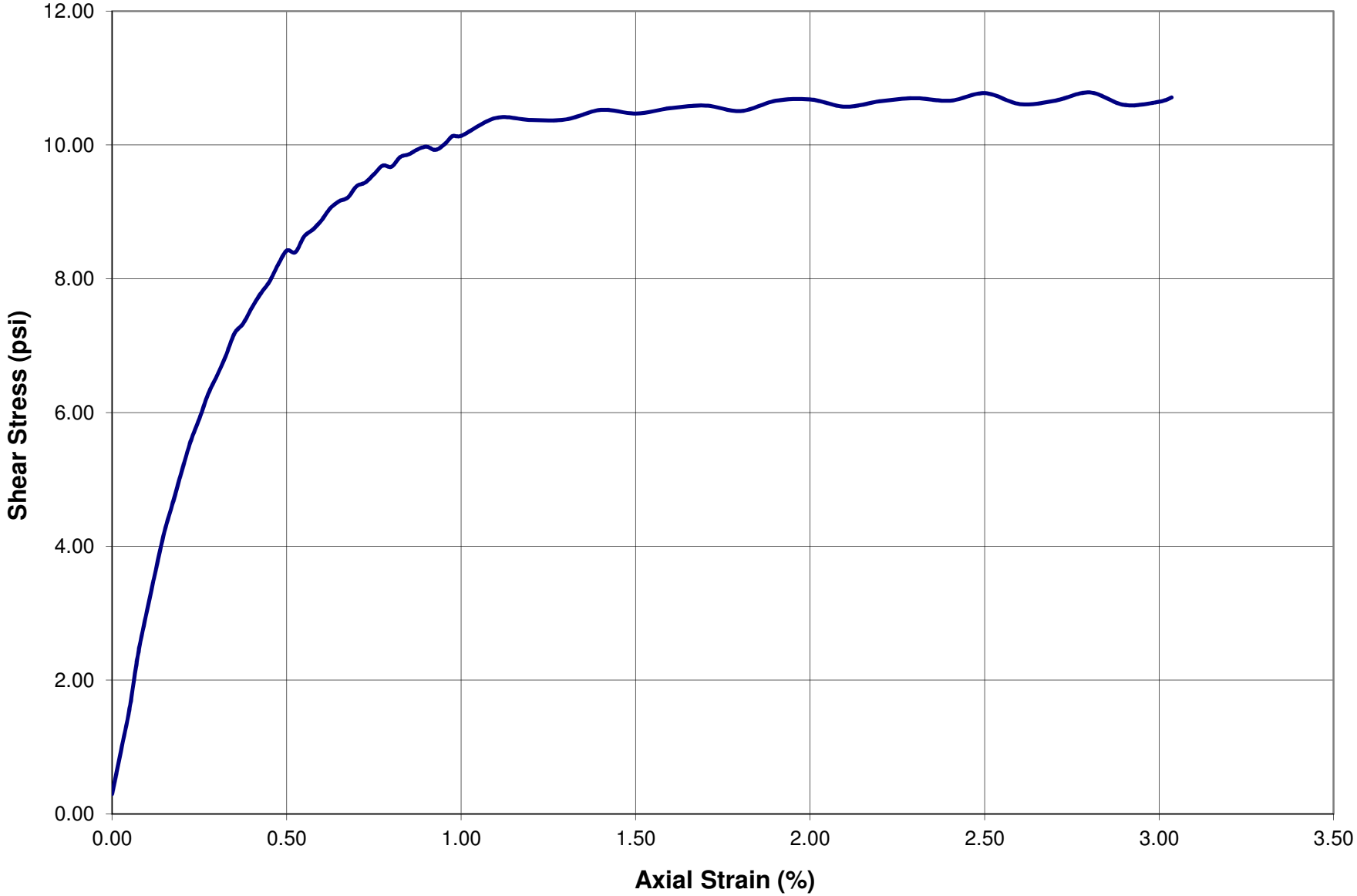
CU TEST RESULTS

B-7A, 6’-8’, STAGE 2 @ 10 PSI

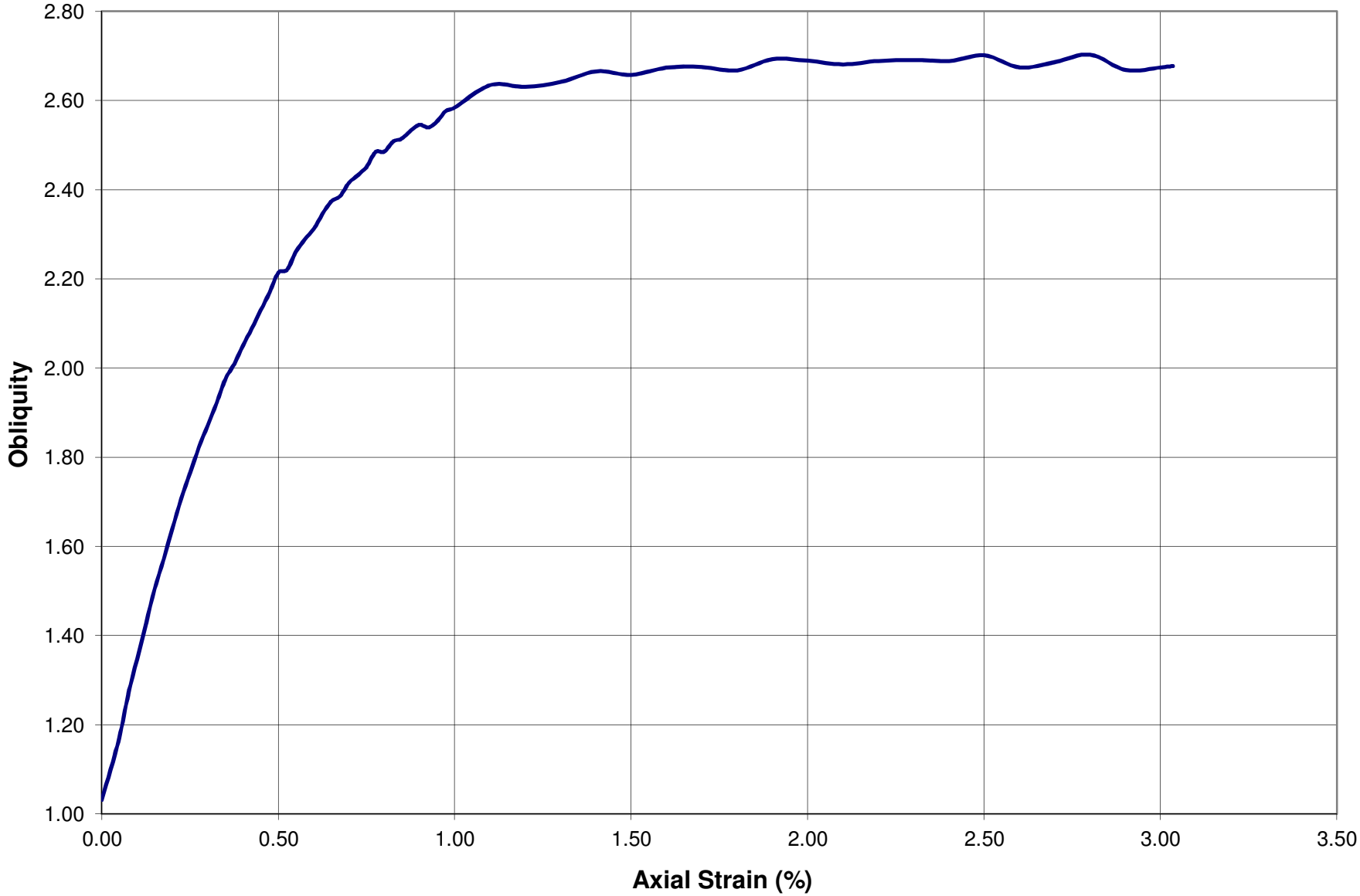
G149-14 B-7A-6-8 STAGE2.xls



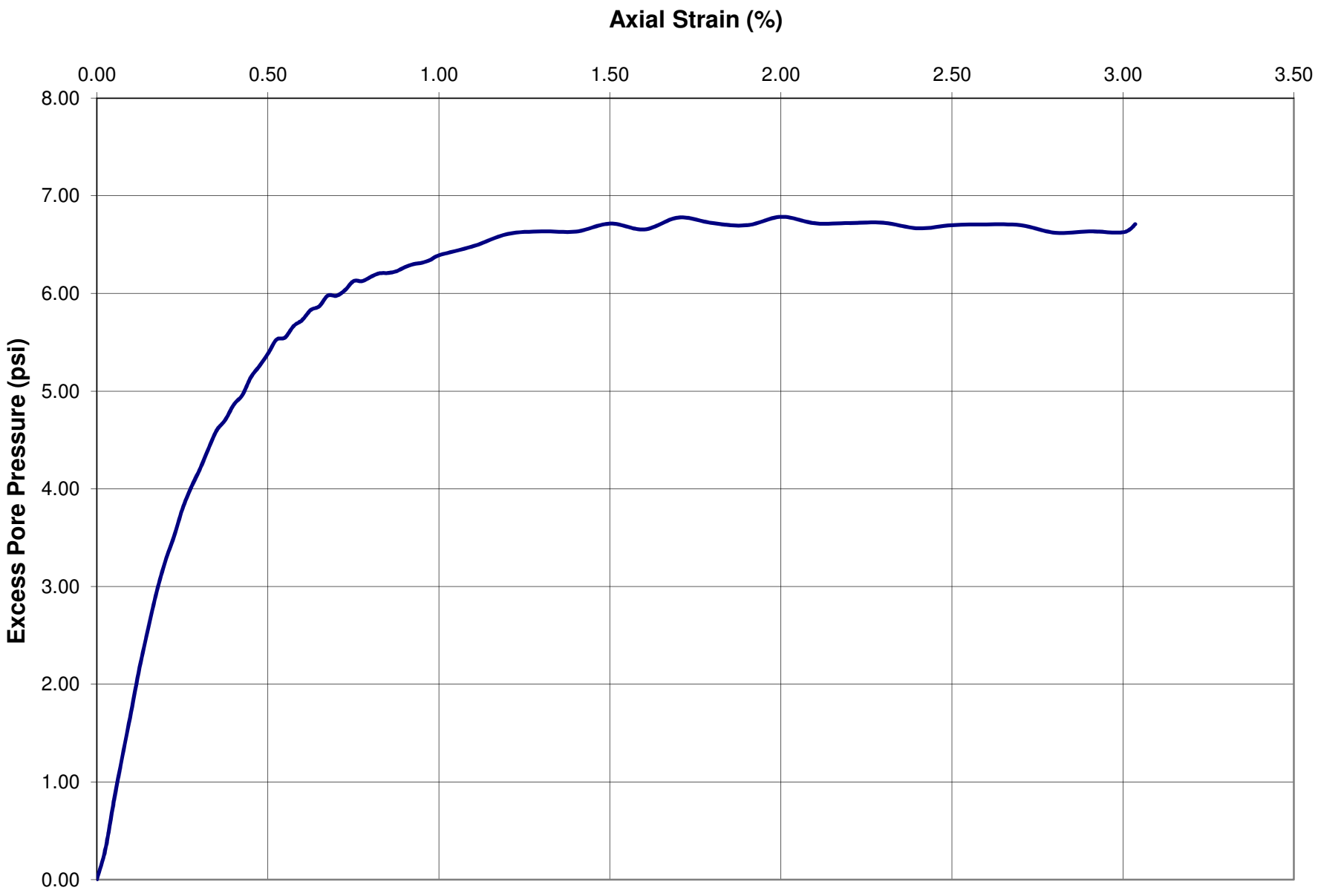
G149-14 B-7A-6-8 STAGE2.xls



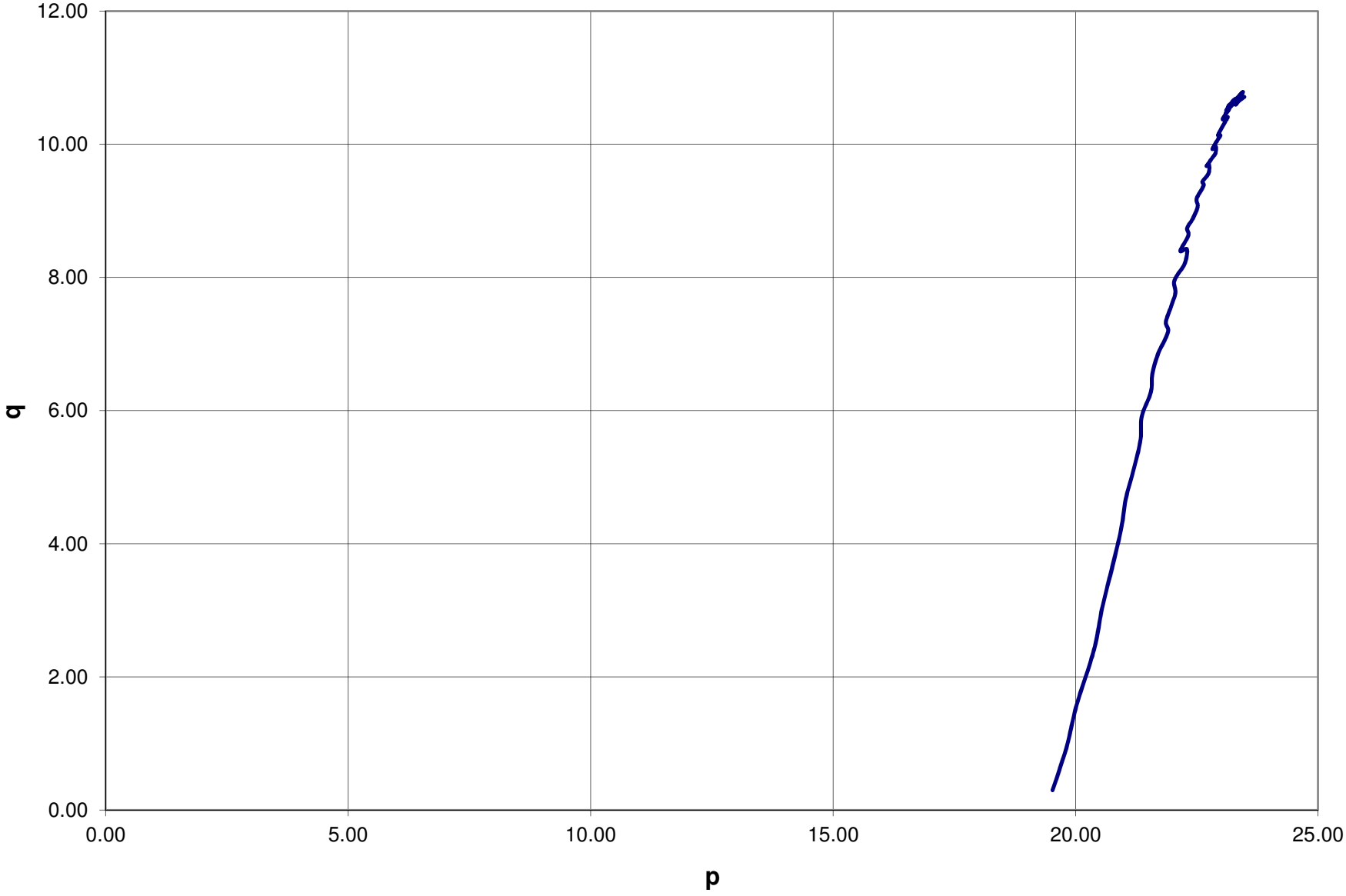
G149-14 B-7A-6-8 STAGE2.xls



G149-14 B-7A-6-8 STAGE2.xls



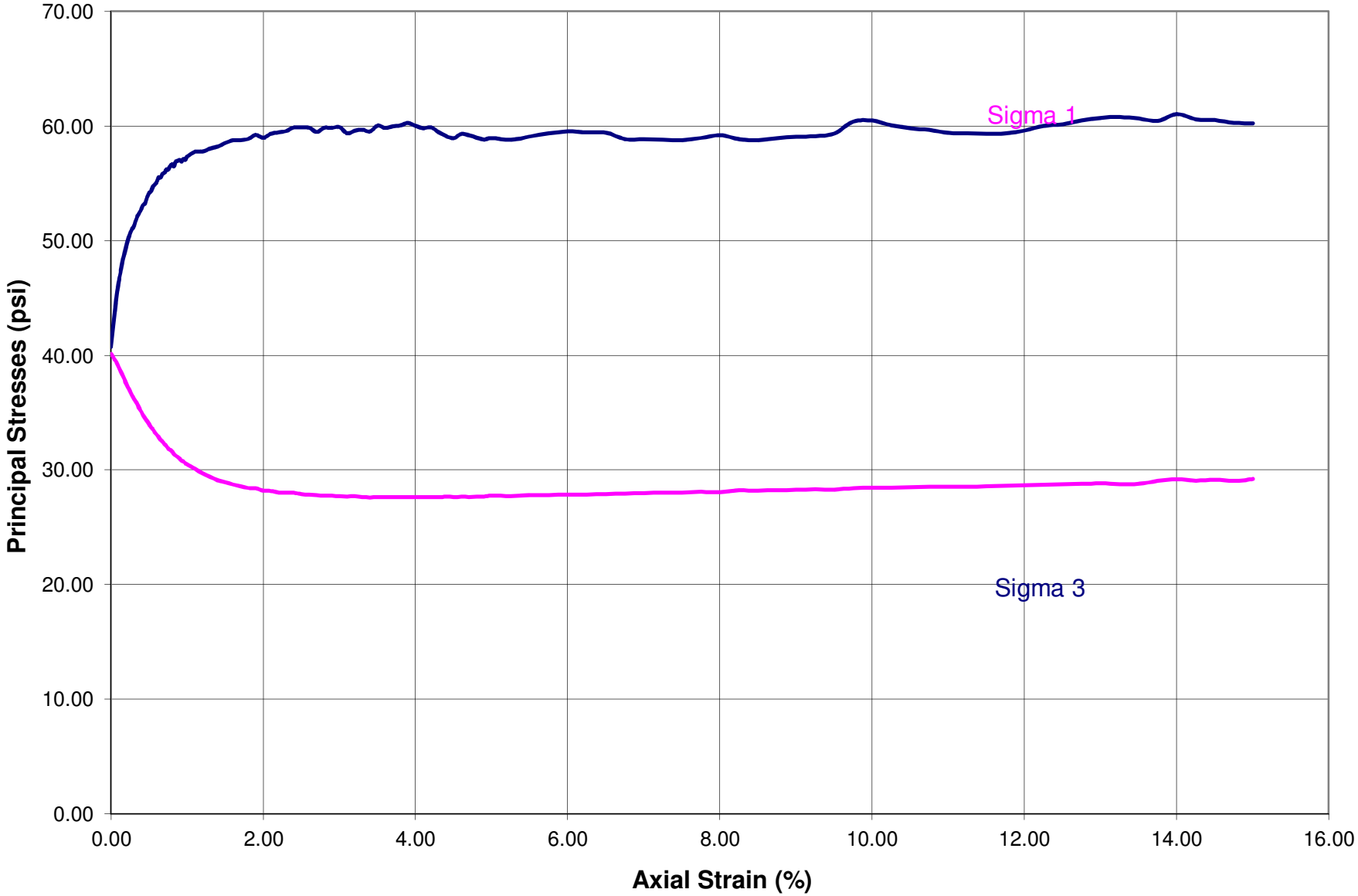
G149-14 B-7A-6-8 STAGE2.xls



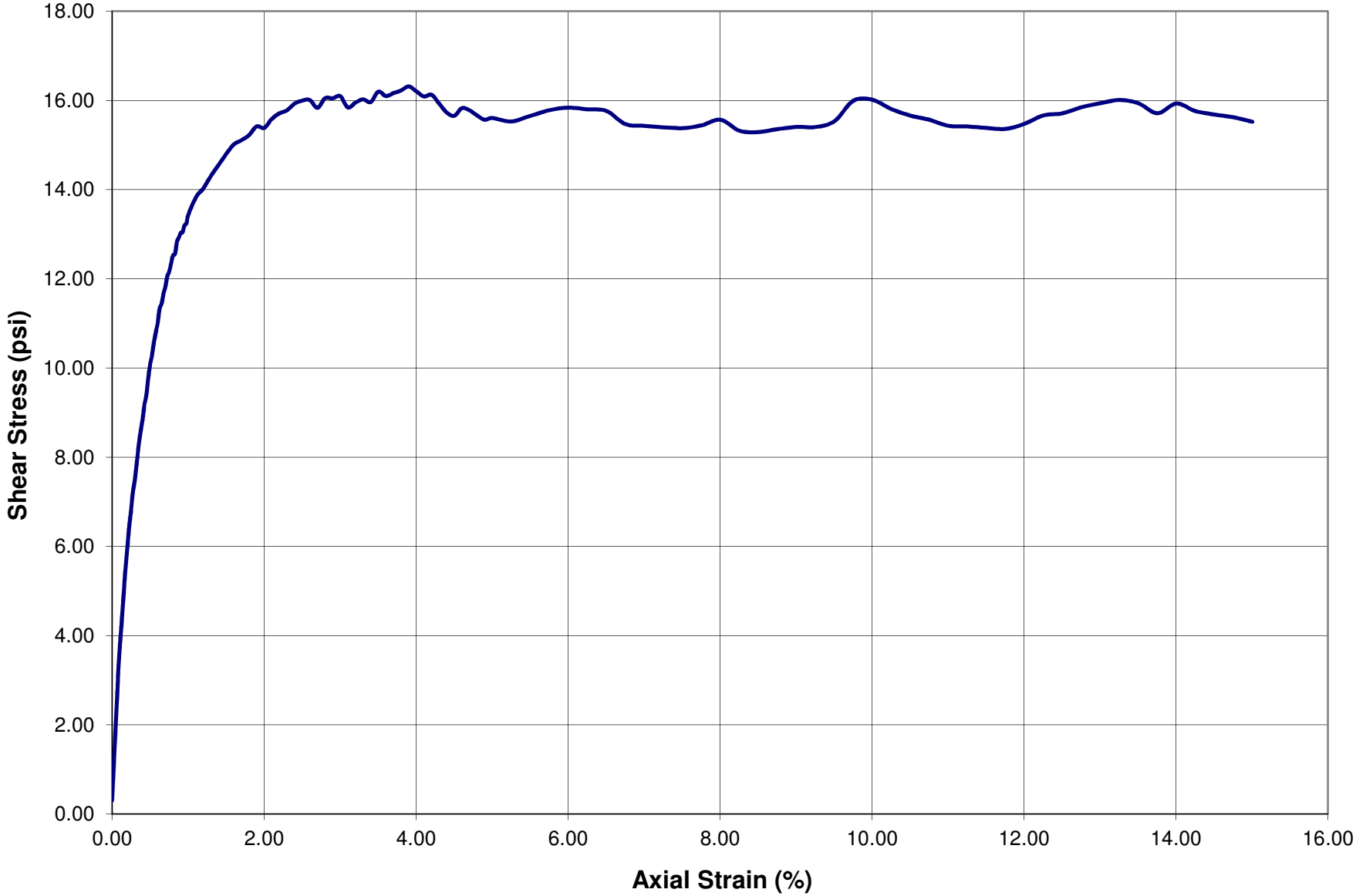
CU TEST RESULTS

B-7A, 6’-8’, STAGE 3 @ 20 PSI

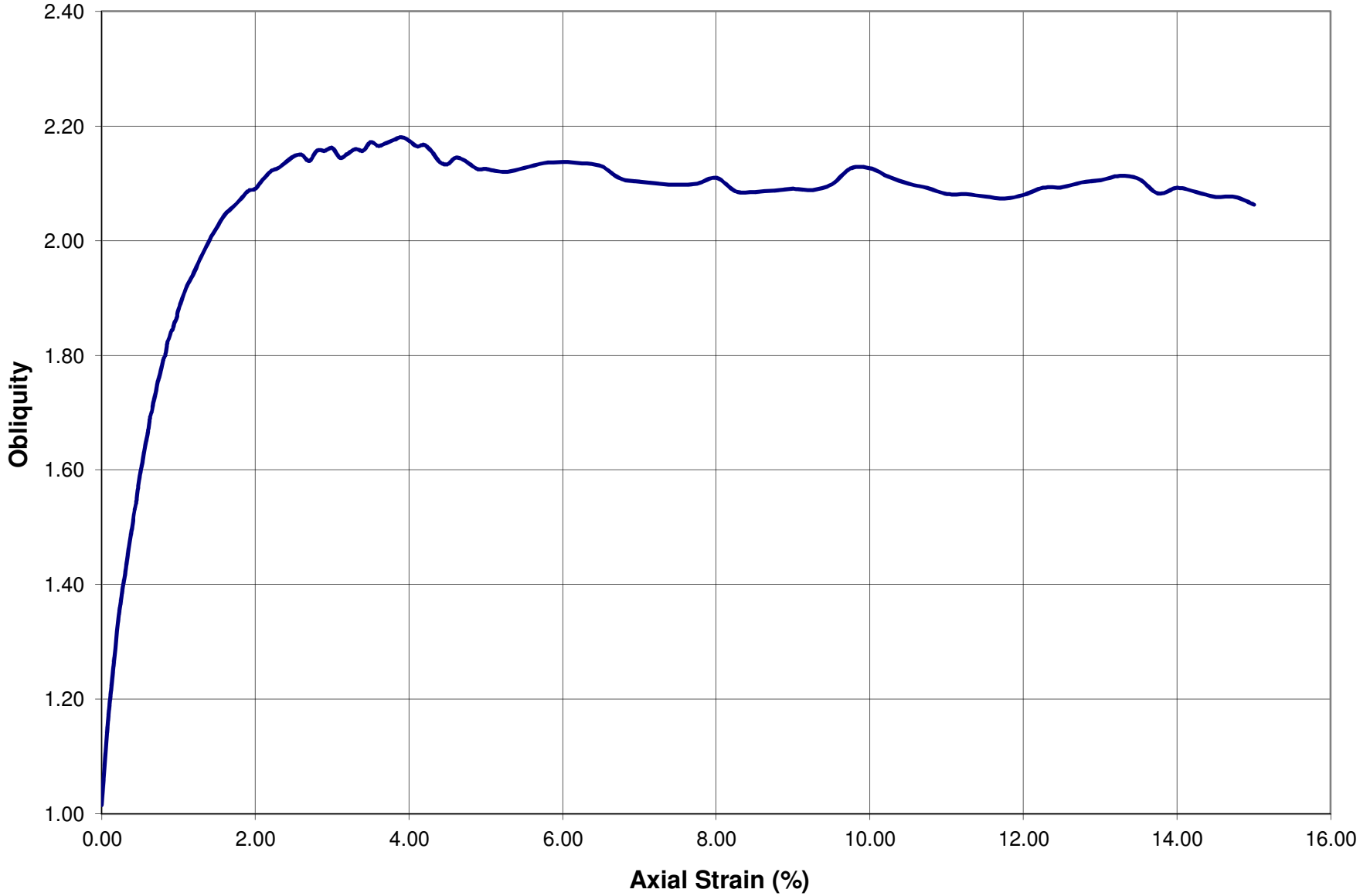
G149-14 B-7A-6-8 STAGE3.xls



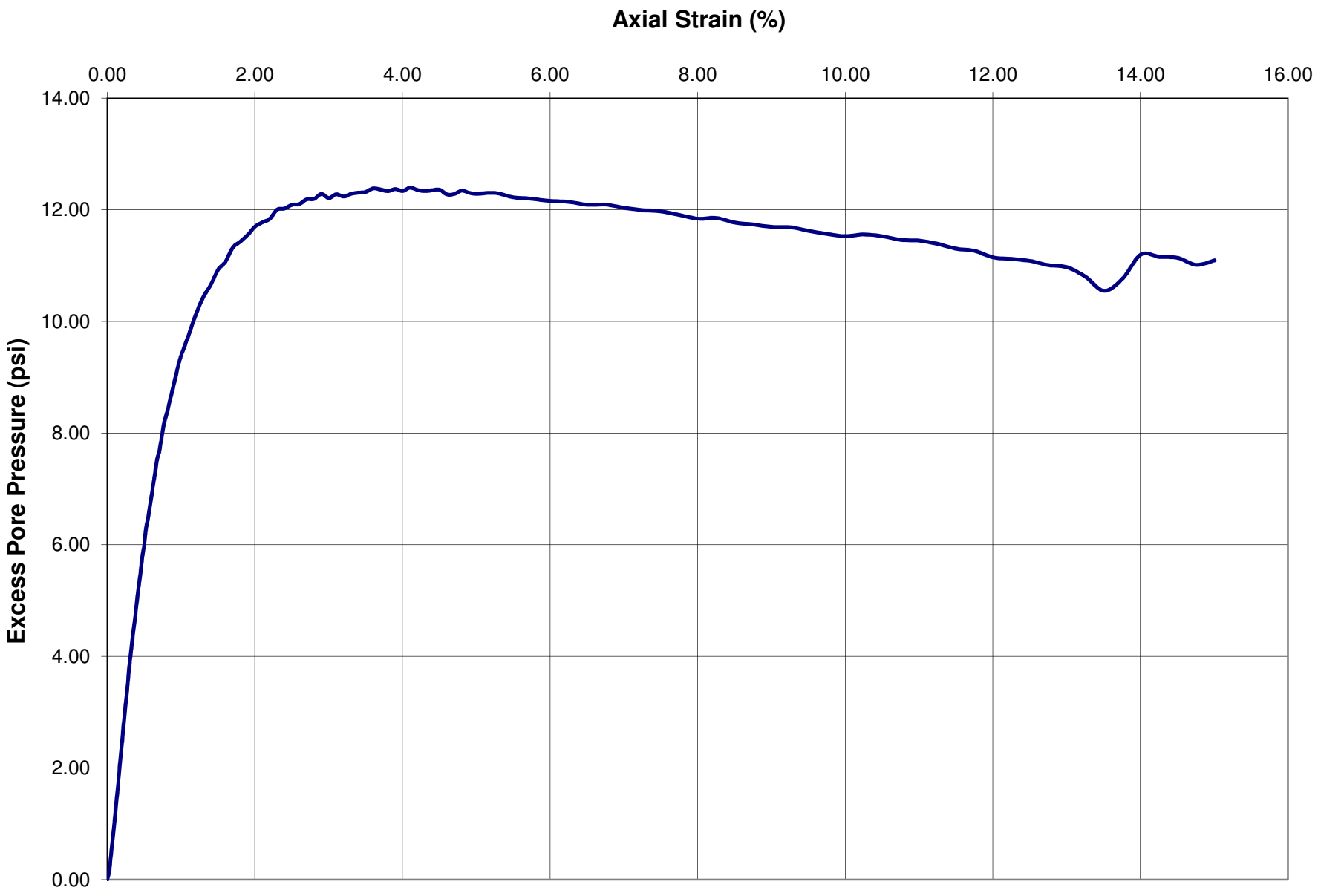
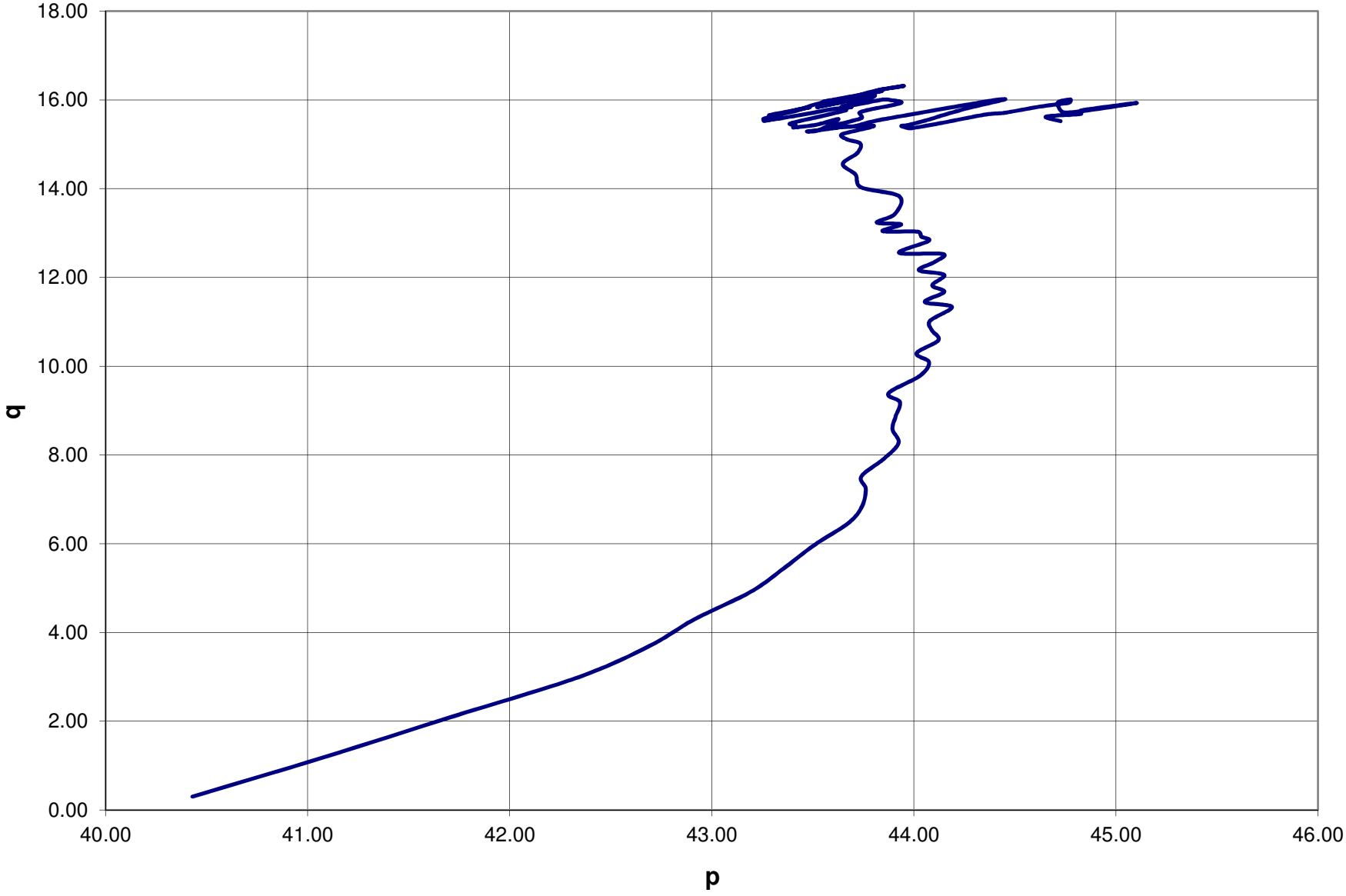
G149-14 B-7A-6-8 STAGE3.xls



G149-14 B-7A-6-8 STAGE3.xls



G149-14 B-7A-6-8 STAGE3.xls



G149-14 B-7A-6-8 STAGE3.xls