Geotechnical Data Report

Thornton Water Segment F.2 – Issue For Bid

Fort Collins, Colorado

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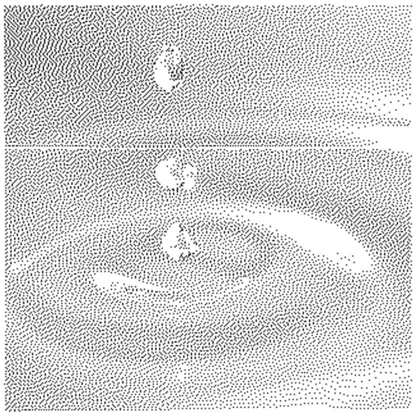
Project No. 2505320



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Project Manager

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Executive Summary

The following report presents the results of the geotechnical investigation in support of the Thornton Raw Water Line, part of the Thornton Water Project, located in Larimer and Weld Counties, Colorado. Specifically, the investigation was conducted for the Segment F.2 alignment. The following summarizes our general conclusions.

- The subsurface conditions encountered do not preclude the proposed construction based on our current understanding of the project.
- Primary materials encountered during the investigation were classified as fill, cohesive soil, non-cohesive soil, and bedrock of the Upper Transition Member of the Pierre Shale.
- Groundwater was encountered at several locations across the project site at depths ranging from 5.8 to 19.0 feet below existing ground surface. Groundwater monitoring wells were installed in several borings during the subsurface investigation for long term groundwater monitoring as detailed in Section 2.3 herein.

1. Introduction & Project Background

The Thornton Raw Waterline – Segment F.2 (Project), part of the Thornton Raw Water Project, owned by City of Thornton (Owner) includes the installation of a water pipeline collocated with the Northern Tier East (NTE) pipeline alignment which is a part of the greater Northern Integrated Supply Project (NISP). The purpose of the project is to construct infrastructure for the City of Thornton (City) to divert water from the Cache La Poudre river to provide to their customers and meet increasing demand (Thornton, City of, 2025). The Thornton Water Project is broken into six sections labeled A, B, C, D, E, and F. Sections A, B, and C are under active construction while section D is complete. Section E is currently under construction, and section F is currently undergoing design (Thornton, City of, 2025). The Segment F.2 alignment can be seen in Figure 1.

HDR Engineering, Inc. (HDR) is the prime engineer for the Thornton F.2 Segment who is teamed with GEI Consultants, Inc. (GEI) for the geotechnical and tunnel portion of the pipeline design. The purpose of this report is to provide the results of the geotechnical investigation for the Thornton Water Pipeline Segment F.2 pipeline alignment and provide geotechnical recommendations for design and construction of the pipelines and associated project components. A Geotechnical Baseline Report (GBR) and Geotechnical Design Memorandum (GDM) has been generated as part of this Project and will be provided under a separate cover to further discuss geotechnical baselines and tunneling means and methods for the trenchless crossings and provide geotechnical recommendations for design and construction of the pipelines and associated project components based on geotechnical data provided herein.

1.1. Site Description and Proposed Construction

The Thornton Segment F.2 alignment currently includes approximately 23,000 feet of 42-inch mortar lined steel pipe that extends generally northwest from the Thornton Segment E termination point at the intersection of County Road 52 and Weld County Road 13 and terminates at the beginning of the Thornton Segment F.1 connection roughly at the intersection of E Douglas Road and a local BNSF railroad track. The Thornton Segment F.2 will be primarily constructed using open-cut methods and will be predominantly located in undeveloped fields. Exceptions to open-cut construction include two tunnel crossings, one extending underneath County Road 52 and one extending underneath I-25. Other major features that will be crossed are the Box Elder Ditch and the Larimer County Canal; however, these are currently proposed to be crossed through open cut methods. Currently, the Thornton Segment F.2 is in the 95 percent design phase and at this time, there are no proposed structures such as larger vaults.

1.2. Geotechnical Investigation

GEI conducted the subsurface investigation for the project intermittently between January 27, 2025, and July 25, 2025. The geotechnical investigation included geotechnical drilling and a subsequent geotechnical laboratory testing program. At the time of writing this report, GEI has completed all 22 planned geotechnical borings to investigate the general subsurface conditions along the pipeline alignment. Boring locations are shown in Figure 1 through Figure 1.5 at the end of this report.

1.3. Subsurface Investigation

Geotechnical borings were advanced to depths between 15 feet and 45 feet below the existing ground surface (bgs). GEI subcontracted Terracon to drill the geotechnical borings utilizing truck-mounted CME 55 and CME 75 drilling rigs. Drilling and sampling procedures were conducted in general accordance with ASTM D1586 – *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* and ASTM D3550 – *Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils*. Continuous-flight, solid-stem and hollow-stem augers were used to advance borings below the existing ground surface. During advance of the augers, Modified California samples (2.0-inch inner diameter) and Split Spoon Samples (1.4-inch inner diameter) were obtained at 5-foot intervals. The number of blows by a 140-pound hammer falling 30 inches required for 12 inches of sampler penetration (recorded in 6-inch increments) are presented on the boring logs. Temporary monitoring wells were constructed in 7 of the borings to measure groundwater levels throughout design. This monitoring will provide valuable information to the team for use during construction. Boring logs are included in Appendix A.

1.4. Geotechnical Laboratory Testing

A geotechnical laboratory testing program was developed by GEI and conducted by Terracon on representative samples collected during the subsurface investigation. A laboratory summary table and graphical testing results are provided in Appendix B. Due to overlap between some borings on the NISP project and the Thornton Segment F.2 project some graphical testing results for borings that were not completed for the Thornton Segment F.2 project are included. The only results to be considered for the subject project are for the borings presented in Appendix A. Laboratory tests conducted in general accordance with associated AASHTO and ASTM standards are presented in Table 1-1 below.

Table 1-1. Geotechnical Laboratory Testing

Test	Standard
Grain Size Distribution	ASTM D422/ASTM C136
#200 Sieve Wash	ASTM D1140
Unconfined Compressive Strength	ASTM D2166
Atterberg Limits	ASTM D4318
Sulfates – Water Soluble	ASTM C1580
Moisture Content & Dry Density	ASTM D2216 & D2937

If field characterized soil and bedrock descriptions differed from results indicated by laboratory classification testing, the boring logs presented in Appendix A were amended to reflect the laboratory testing results.

1.5. Corrosion Laboratory Testing

Laboratory testing both in the field and laboratory setting was performed. Field corrosion potential testing was gathered through in-situ soil resistivity measurements gathered along the alignment at locations identified on Figure 1.1 through 1.4. Soil resistivity measurements were conducted in general accordance with ASTM G57-06 *Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method.* Resistivity measurements were collected to a maximum depth of 20 feet at intervals of

5-feet. Field resistivity measurements were compared to soil samples selected at similar locations and depths submitted for laboratory corrosivity testing.

Corrosion laboratory testing was conducted by Terracon on representative samples collected in the field. Results of the corrosion laboratory testing are presented in Appendix C. Tests conducted in general accordance with associated ASTM, AASHTO, and AWWA standards are presented in Table 1-2 below.

Table 1-2. Corrosion Laboratory Testing

Test	Standard
Chloride	ASTM D512
pH	AASHTO T289
Redox Potential	ASTM G200
Sulfate-Water Soluble	ASTM C1580
Sulfide	AWWA 4500-S D
Resistivity	ASTM G57
Total Salts	AWWA 2520 B

2. Subsurface Conditions

Subsurface conditions were assessed based on the findings of the geotechnical investigation described in the previous section. Soil and rock descriptions noted on the boring logs and below are in general accordance with ASTM D 2487 – *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)* and D 2488 – *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*.

2.1. Regional Geology

Geologic mapping of the Boulder-Fort Collins-Greeley area (Colton, 1978) indicates the site is underlain primarily by upper Holocene-aged eolian clay, silt, and sand with some local channel deposits consisting of upper Holocene-aged Piney Creek alluvium. The eolian deposits are described as light-brown, reddish-brown, and olive-gray clay, silt (loess), and fine sand. Eolian deposits in the vicinity of the Project site likely consist primarily of loess with a thickness of between 3 and 15 feet. The Piney Creek alluvium is described as dark gray sandy to gravelly alluvium that underlies terraces whose surfaces are 10 to 20 feet above the nearby flood plain. The thickness of the alluvium is described as 0 to 20 feet.

Bedrock in the vicinity of the project site is mapped as the Upper Transition Member of Cretaceous-aged Pierre Shale consisting of friable sandstone and soft shaly sandstone containing thin-bedded sandy shale and calcareous sandstone concretions. The thickness of the unit is approximately 2,000 feet.

2.2. Subsurface Materials

Soil encountered during the subsurface investigation was classified as Fill, Cohesive Soil, and Non-Cohesive Soil based primarily on soil behavior rather than grain size distribution. Bedrock encountered during the subsurface investigation consisted of sandstone and claystone of the Upper Transition Member of the Pierre Shale. Boring logs and a supplementary boring log key explaining boring log details are provided in Appendix A.

2.2.1. Fill

Fill was encountered in boring NTE-23 at ground surface and extended to a depth of 9 feet bgs. Encountered Fill was described as the following in accordance with the Unified Soil Classification System (USCS):

- Lean Clay (CL)

The encountered fill material contained primarily clay with little sand and fragments of asphaltic concrete. Blow counts of 15 blows per foot (bpf) were measured in the fill indicating a relative density of very stiff.

2.2.2. Cohesive Soil

Cohesive Soil was encountered in all borings. Encountered Cohesive Soil was described as the following in accordance with USCS:

- Lean Clay (CL)
- Lean Clay with Sand (CL)
- Sandy Lean Clay (CL)
- Clayey Sand (SC)

Cohesive Soil was primarily comprised clay with varying silt and sand content. Clayey Sands were included in this classification on account of their cohesive behavior despite consisting of greater than 50 percent coarse material. Blow counts in Cohesive Soil ranged from 0 to 26 bpf indicating a relative consistency of very soft to very stiff for soils with fines contents greater than 30 percent and very loose to medium dense for soils with less than 30 percent fines.

2.2.3. Non-Cohesive Soil

Non-Cohesive Soil was encountered in 14 of the 22 borings conducted. Encountered Non-Cohesive Soil was described as the following in accordance with USCS:

- Silty Sand (SM)
- Silt with Sand (ML)
- Sandy Silt (ML)
- Poorly Graded Sand with Gravel (SP)
- Poorly Graded Sand with Clay (SP-SC)
- Poorly Graded Sand with Clay and Gravel (SP-SC)
- Poorly Graded Sand with Silt (SP-SM)
- Poorly Graded Sand (SP)
- Well Graded Sand with Clay (SW-SC)
- Well Graded Sand with Clay and Gravel (SW-SC)
- Well Graded Sand with Gravel (SW)
- Well Graded Sand (SW)Clayey Sand with Gravel (SC)

Non-Cohesive Soil was primarily comprised of sand and gravel with varying clay and silt content. Silt with Sand and Sandy Silt were included in this classification on account of their non-cohesive behavior despite consisting of greater than 50 percent fine material. Blow counts in Non-Cohesive Soil ranged from 2 to 58 bpf indicating a relative density of very loose to very dense for materials with less than 30 percent fines and stiff for materials with greater than 30 percent fines.

2.2.4. Upper Transition Member, Pierre Shale Bedrock

Sandstone, shale, and claystone bedrock of the Upper Transition Member of the Pierre Shale were encountered in 14 of the 22 conducted borings at depths ranging from the ground surface to 44 feet below the existing ground surface. The bedrock was completely weathered to fresh with blow counts of 7 bpf to 50 blows per 2 inches of sampler penetration (50/2”). Eight unconfined compressive strength tests were conducted on the bedrock with results ranging from 931 to 18,421 psf.

2.3. Groundwater

Groundwater was encountered in all but 3 of the borings during the subsurface investigation from 4.5 to 19 feet bgs. Temporary monitoring wells were installed in 7 of the 22 borings for future monitoring. Fluctuations in the groundwater level may occur due to variations in rainfall, temperature, site development, and other factors not evident at the time that these measurements were made. Table 2-1 presents initial groundwater levels in all borings as measured during drilling, and Table 2-2 presents groundwater level fluctuations in the monitoring wells as measured after drilling.

Table 2-1. Initial Groundwater Levels During Drilling

Boring	Borehole Elevation	Groundwater Level (feet[1])	Groundwater Elevation (feet)
NTBH-1	5155	9.6	5145.4
NTBH-2	5157	7.0	5150
NTBH-3-MW	5152	18.0	5134
NTBH-4	5167	DNE	DNE
NTE-6-MW	5133	5.8	5127.2
NTE-7	5135	10.0	5125
NTE-8	5133	7.5	5125.5
NTE-9	5105	11.5	5093.5
NTE-10-MW	5104	12.5	5091.5
NTE-11	5090	14.0	5076
NTE-12	5090	13.0	5077
NTE-13	5095	19.0	5076
NTE-14-MW	5064	14.0	5050
NTE-15	5038	4.5	5033.5
NTE-16	5038	DNE	DNE
NTE-17-MW	5044	14.5	5029.5
NTE-18-MW	5043	15.6	5027.4
NTE-19	5041	16.0	5025
NTE-20	5047	17.2	5029.8
NTE-21	5055	DNE	DNE
NTE-22-MW	5060	14.7	5045.3
NTE-23	5060	16.2	5043.8

Notes:
1. Below existing ground surface.

Table 2-2. Groundwater Fluctuations in Monitoring Wells After Drilling

Date	Groundwater Level (feet[1])						
	NTBH-3-MW[2]	NTE-6-MW[5]	NTE-10-MW[4]	NTE-14-MW[6]	NTE-17-MW[4]	NTE-18-MW[3]	NTE-22-MW[3]
04/01/2025	-	-	14.6	-	14.9	14.7	13.4
05/08/2025	-	5.9	3.1	14.5	14.3	15.1	13.1
06/05/2025	-	5.5	12.0	15.3	14.3	15.2	14.0
07/03/2025	-	5.1	10.4	15.6	15.3	16.7	14.9
08/08/2025	-	3.6	10.3	14.4	17.0	18.3	17.6

Date	**Groundwater Level (feet[1])**						
	NTBH-3-MW[2]	**NTE-6-MW[5]**	**NTE-10-MW[4]**	**NTE-14-MW[6]**	**NTE-17-MW[4]**	**NTE-18-MW[3]**	**NTE-22-MW[3]**
09/10/2025	-	4.5	10.3	13.0	17.6	18.8	19.0
10/10/2025	-	4.3	12.8	11.9	16.7	17.7	18.6
11/7/2025	-	5.1	13.6	14.9	16.0	-	-
12/05/2025	-	6.0	14.2	13.2	15.2	-	-
01/05/2026	-	5.8	14.5	12.9	14.1	-	-
02/06/2026	-	5.7	-	12.2	-	-	-
03/04/2026	-	6.2	-	12.6	-	-	-
04/13/2026	-	6.5	-	-	-	-	-
04/20/2026[7]	14.8	-	-	-	-	-	-
07/29/2026	16.3						

Notes:

1. Below existing ground surface.
2. Unable to take groundwater level readings due to expired Right of Entry permit.
3. Abandoned on October 10th, 2025 due to expired Right of Entry permit.
4. Abandoned on January 5th. 2026.
5. Abandoned on April 13th, 2026.
6. Abandoned on March 4th, 2026.
7. Regained access in April, 2026

3. Limitations

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principles; no warranty, express or implied is made. The subsurface conditions described in this report were based on data obtained from widely spaced exploratory borings, geotechnical laboratory testing, information provided by the client, engineering judgement, and our experience with similar subsurface conditions and projects. The boring logs presented in this report only depict the subsurface conditions at the actual boring locations. Subsurface conditions are typically variable, both laterally and vertically, and the nature and extent of the subsurface variations across the site may not become evident until construction. The boundaries between different soil types and bedrock presented in this report are approximate and, in some cases, may be more abrupt or gradational than described herein. Groundwater levels may vary with time, adjacent surface water levels, precipitation, and changes to the hydrogeological conditions at or surrounding the project site.

This report has been prepared exclusively for our client for design purposes for the subject project. GEI Consultants is not responsible for technical interpretations by others of the data presented in this report or use of this report by others for the subject project or other projects. If differing site conditions are encountered during further evaluation of the subsurface conditions by others or during construction, GEI Consultants should be notified immediately to determine if any changes to our recommendations presented in this report are warranted.

The recommendations presented in this report are only intended for the proposed design and construction as understood by GEI Consultants at the time of issuing this report. If the proposed design and construction changes, GEI Consultants should be notified immediately and given the opportunity to review the proposed changes and if necessary, modify our recommendations presented herein.

An environmental assessment was not included in GEI Consultants scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for informational purposes. If the client is concerned about the environmental conditions at the site, GEI Consultants recommends the client and/or owner retain a qualified environmental firm to conduct an environmental site assessment.

4. References

American Association of State Highway and Transportation Officials. (n.d.). AASHTO Standards. Washington, D.C.

American Society for Testing and Materials. (n.d.). ASTM Standards. West Conshohocken, Pennsylvania: ASTM International.

Colton, R. B. (1978). *Geologic Map of the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colorado.* Retrieved from USGS National Geologic Map Database: https://ngmdb.usgs.gov/Prodesc/proddesc_9734.htm

Thornton, City of. (2025). *Thornton Water Project - Project Overview.* Thornton, Colorado.

Figures

LEGEND:

—	PROPOSED THORNTON WATER PIPELINE - SEGMENT F.2 ALIGNMENT
- - -	FUTURE THORNTON WATER PIPELINE - SEGMENT F.1 ALIGNMENT

NOTES:

1. PROPOSED STRUCTURE LOCATIONS ARE APPROXIMATE AND INCLUDED FOR INFORMATIONAL PURPOSES ONLY. SEE CONTRACT DRAWINGS FOR EXACT LOCATIONS.
2. BORING LOCATIONS ARE APPROXIMATE

Thornton Raw Waterline Segment F.2

HDR Engineers, Inc. Denver. CO

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Site Vicinity Map Segment F.2 Alignment

Project 2505320

July 2026

Fig. 1

HITCHENS, LUKE B:\Working\HDR\2505320 Thornton Segment F\06_DESIGN\Drawings\Segment_F.2_Boring_Location_Map.dwg - 7/1/2026

LEGEND:

- ◕ BORING LOCATION (DRILLED)
- ⌖ MONITORING WELL LOCATION (DRILLED)
- — PROPOSED SEGMENT F.2 PIPELINE ALIGNMENT
- ▲ WENNER 4-PIN SOIL RESISTIVITY TEST SITE

NOTES:

1. BORING LOCATIONS ARE APPROXIMATE.

Thornton Raw Waterline Segment F.2	GEI Consultants	BORING LOCATION MAP SEGMENT F.2 ALIGNMENT (CONT.)
HDR Engineers, Inc. Denver, CO	Project 2505320	July 2026 Fig. 1.1

HITCHENS, LUKE B:\Working\HDR\2505320 Thornton Segment F\06_DESIGN\Drawings\Segment_F.2_Boring_Location_Map.dwg - 7/1/2026

LEGEND:

◑	BORING LOCATION (DRILLED)
—	PROPOSED SEGMENT F.2 PIPELINE ALIGNMENT
▲	WENNER 4-PIN SOIL RESISTIVITY TEST SITE

NOTES:

1. BORING LOCATIONS ARE APPROXIMATE

Thornton Raw Waterline Segment F.2

HDR Engineers, Inc. Denver, Coloado

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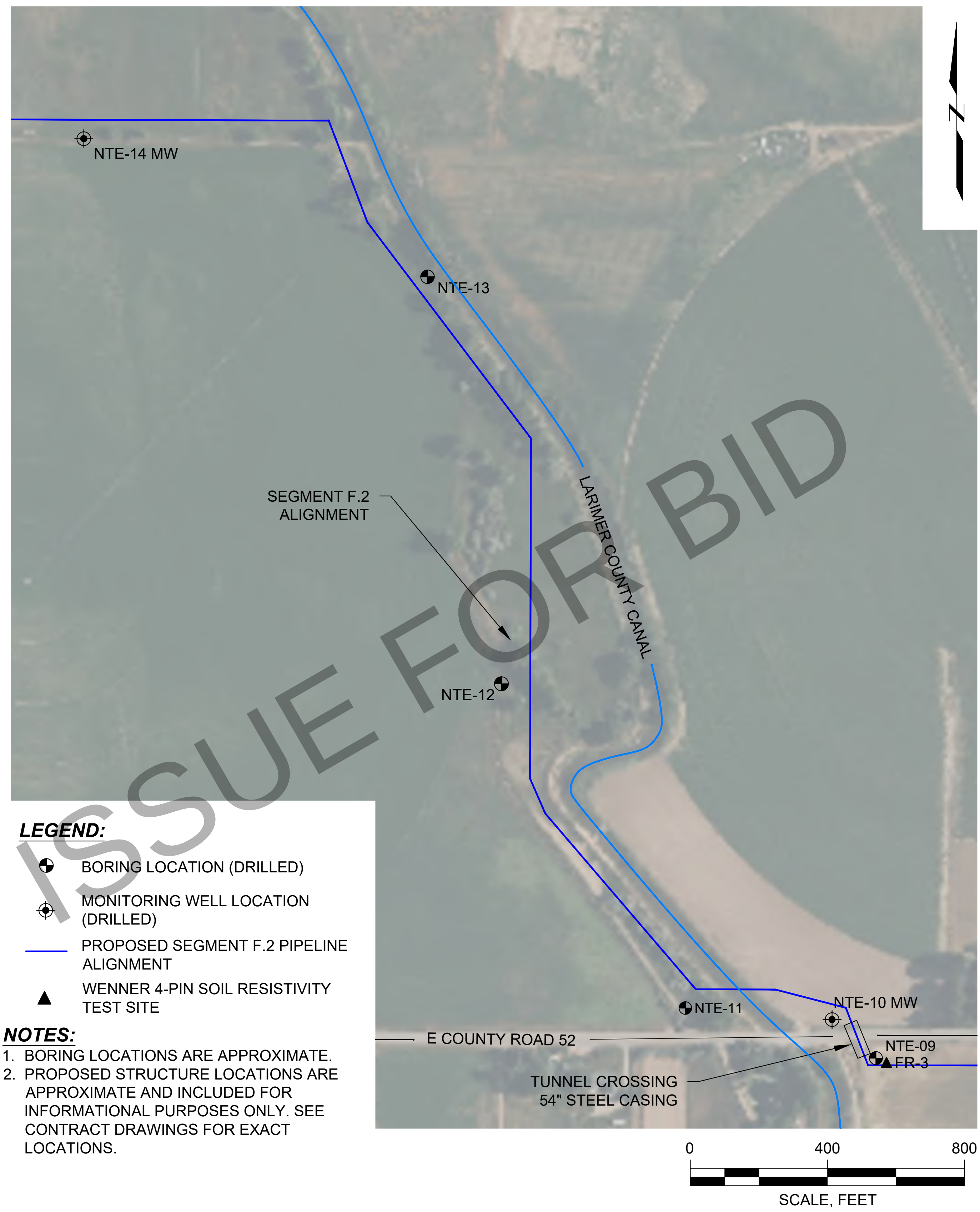
Project 2505320

BORING LOCATION MAP
SEGMENT F.2 ALIGNMENT
(CONT.)

July 2026

Fig. 1.2



LEGEND:

◈	BORING LOCATION (DRILLED)
⌖	MONITORING WELL LOCATION (DRILLED)
—	PROPOSED SEGMENT F.2 PIPELINE ALIGNMENT
▲	WENNER 4-PIN SOIL RESISTIVITY TEST SITE

NOTES:

1. BORING LOCATIONS ARE APPROXIMATE.
2. PROPOSED STRUCTURE LOCATIONS ARE APPROXIMATE AND INCLUDED FOR INFORMATIONAL PURPOSES ONLY. SEE CONTRACT DRAWINGS FOR EXACT LOCATIONS.

Thornton Raw Waterline Segment F.2

HDR Engineers, Inc. Denver, Colorado

GEI Consultants

Project 2505320

BORING LOCATION MAP
SEGMENT F.2 ALIGNMENT
(CONT.)

July 2026

Fig. 1.3

LEGEND:

◒	BORING LOCATION (DRILLED)
⌖	MONITORING WELL LOCATION (DRILLED)
—	PROPOSED SEGMENT F.2 PIPELINE ALIGNMENT
▲	WENNER 4-PIN SOIL RESISTIVITY TEST SITE

NOTES:

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Thornton Raw Waterline Segment F.2

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Project 2505320

BORING LOCATION MAP
SEGMENT F.2 ALIGNMENT
(CONT.)

July 2026

Fig. 1.4

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LEGEND:

●	BORING LOCATION (DRILLED)
⌖	MONITORING WELL LOCATION (DRILLED)
—	PROPOSED SEGMENT F.2 PIPELINE ALIGNMENT
- - - -	FUTURE SEGMENT F.1 PIPELINE ALIGNMENT

NOTES:

1. BORING LOCATIONS ARE APPROXIMATE.

Thornton Raw Waterline Segment F.2

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Project 2505320

BORING LOCATION MAP
THORNTON SEGMENT F.2
ALIGNMENT (CONT.)

May 2026

Fig. 1.5

HITCHENS, LUKE B:\Working\HDR\2505320 Thornton Segment F\06_DESIGN\Drawings\Segment_F.2_Boring_Location_Map.dwg - 7/1/2026

Appendix A Boring Logs

A.1. Standard Geotechnical Drilling Key

A.2. Boring Logs

A.1. Standard Geotechnical Drilling Key

Appendix A Boring Logs

A.1. Standard Geotechnical Drilling Key

A.2. Boring Logs

A.1. Standard Geotechnical Drilling Key

BORING LOG KEY

STANDARD GEOTECHNICAL DRILLING

Soil Classifications:

Clear Square Sieve Openings — U.S. Standard Series Sieve Sizes

12"		3"		3/4"		4		10		40		200	

Boulders	Cobbles	Gravel		Sand			Silts and Clays
		Coarse	Fine	Coarse	Medium	Fine	

300mm 75mm 19mm 4.75mm 2.0mm 0.42mm 0.075mm

Color: Sample colors are in general accordance with basic brown, red, yellow, and gray combinations

Description of Moisture	
Description	**Criteria**
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil below the groundwater table

Description of Odor	
Description	**Criteria**
No Organic Odor	Organic odor is not present
Trace Organic Odor	Mild organic odor; mixture of soil and organics
Strong Organic Odor	Prominent organic odor; sample is primarily organic

Gradation Estimates by Field Observation	
Description	**Quantity (%)**
Trace	<5
Few	5 to 10
Little	15 to 25
Some	30 to 45
Mostly	> 50

Relative Density or Consistency of Non-cohesive and Cohesive Soils			
Non-cohesive Soils		**Cohesive Soils**	
Classification	**Blows per 12 in**	**Classification**	**Blows per 12 in**
Very Loose	0 to 4	Very Soft	0 to 2
Loose	5 to 10	Soft	3 to 4
Medium Dense	11-30	Medium Stiff	5 to 8
		Stiff	9 to 15
Dense	31 to 50	Very Stiff	16 to 30
Very Dense	>50	Hard	>30

Plasticity	
Description	**Criteria**
Nonplastic	A $\frac{1}{8}$" diameter thread cannot be rolled
Low	A $\frac{1}{8}$" in diameter thread can be rolled with difficulty; a lump cannot be formed at a moisture lower than the plastic limit
Medium	A $\frac{1}{8}$" in diameter thread can be rolled easily; a crumbly lump can be formed at a moisture lower than the plastic limit
High	A $\frac{1}{8}$" in diameter thread can be rolled very easily; a lump can be formed at a moisture lower than the plastic limit

Cementation	
Description	Criteria
Weak	Crumbles with light finger pressure
Moderate	Crumbles with considerable finger pressure
Strong	Will not crumble with finger pressure

Rock Descriptions:

Weathering	
Description	**Criteria**
Fresh	No visible sign of rock material weathering: perhaps slight discoloration on major discontinuity surfaces.
Slightly Weathered	Discoloration of rock material on discontinuity surfaces.
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as corestones.
Highly Weathered	More than half of the rock material is decompsed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.

Texture	
Description	**Criteria**
Very Fine Grained	Grains not individually visible to the unaided eye
Fine Grained	Grains barely visible to the unaided eye, up to $\frac{1}{16}$" diameter
Medium Grained	Grain diameter between $\frac{1}{16}$" and $\frac{3}{16}$"
Coarse Grained	Grains diameter between $\frac{3}{16}$" and $\frac{1}{4}$"
Very Coarse Grained	Grains larger than $\frac{1}{4}$" in diameter

Field Hardness	
Description	**Criteria**
Very Hard	Cannot be scratched with a knife or sharp pick.
Hard	Can be scratched with a knife or pick only with difficulty
Medium	Can be gouged $\frac{1}{16}$" deep by firm pressure on knife or pick point
Soft	Can be grooved or gouged readily with knife or pick point
Very Soft	Can be carved with knife and scratched readily by fingernail

Geologic Interpretation:

A ***Geologic Interpretation*** of encountered soil and bedrock units is provided for each specific ***Visual Material Description***. Examples of geologic interpretations for soil that may be presented include: FILL, ALLUVIUM, AEOLIAN, AND GLACIAL TILL, AND RESIDUUM. Rock geologic interpretations are referenced based on a combination of field classifications and applicable geologic maps.

Sample Graphics and Descriptions:

- ⧗ California Barrel Sampler: Barrel sampler loaded with sample liners and driven to collect a relatively representative and intact specimen of soil or weak rock.
- ◩ Split-Spoon Sampler: Split-barrel sampler driven in accordance with ASTM D1586 used to provide visual material descriptions and collect a disturbed specimen.
- ▯ Shelby Tube Sampler: Thin wall tube hydraulically pushed into the subsurface to collect a representative and intact specimen of soil.
- ◣ Bulk Sample: Bulk or bagged sample taken from auger cuttings.
- ▯ Rock Core

Groundwater Monitoring Well Graphics:

- ▨ Riser Pipe with Auger Cuttings
- ▦ Well Screen with Silica Sand
- ⁝ Riser Pipe with Silica Sand
- ▤ Riser Pipe with Bentonite Chips
- ▩ Auger Cuttings
- ⊠ Stick-Up Well
- ⊠ Flush Mounted Cap
- ▽ First Groundwater Reading
- ▽ Second Groundwater Reading
- ▽ Third Groundwater Reading

Boring Graphics:

Below are the primary boring log graphics. Any classification combinations will result in a combination of graphics.

- ⊠ Fill
- ▨ Lean Clay
- ▥ Silt
- ▧ Fat Clay
- ▥ Elastic Silt
- ▩ Well Graded Gravel
- ⁘ Poorly Graded Gravel
- ░ Well Graded Sand
- ░ Poorly Graded Sand
- ⁙ Sandstone
- ▤ Claystone
- ▤ Siltstone

GEI Consultants

A.2. Boring Logs

BORING: NTBH-1

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 22JULY2024

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25 in. HSA
Hammer Weight (lbs)/Fall (in): 140lb/30-inch
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inch OD

GEI Consultants

Boring Location: 40.624038, -104.962585
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States		INDEX DATA						Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**NON-COHESIVE SOIL**												
		⧗	6 8	12			Silty SAND (SM), mostly fine sand, little silt, medium dense, olive brown to olive gray, moist, little calcareous material.												
5		⧗	5 2	10			Poorly Graded SAND with Silt (SP-SM), mostly fine sand, few silt, loose, brown, moist.												
							6.5 ft.												
		⧗	2 3	12			**COHESIVE SOIL** LEAN CLAY with Sand (CL), little fine sand, medium stiff, brown, moist.												
10		⧗	2 2	12			Clayey SAND (SC), mostly fine sand, some clay, few fine gravel, loose, brown, moist	(9.6 ft.) ▼	16		0.0015			44					
							14.0 ft.												
15		⧗	2 2	4			**NON-COHESIVE SOIL** Poorly Graded SAND with Clay (SP-SC), mostly fine to medium sand, few clay, few fine gravel, very loose, brown, wet.												
							15.0 ft.												
							END OF EXPLORATION												
20																			
25																			
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	22July24	1 hr	9.6'
▼			
▼			

BORING: NTBH-2

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 22JULY2024

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25 in. HSA
Hammer Weight (lbs)/Fall (in): 140lb/30-inch
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inch OD

GEI Consultants

Boring Location: 40.623828, -104.957970
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results											
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0						▨	**COHESIVE SOIL**												
		⧗	3 4	6		▨	LEAN CLAY with Sand (CL), little fine sand, medium stiff, brown, moist.												
5		⧗	2 2	8		▨	As above except soft		19					72					
		⧗	2 2	12		▨	As above except wet.	(7.0 ft.) ▼	26					81	30	11			
10		⧗	2 1	12		▨	As above except trace calcareous material.		24					84					
15		⧗	2 4	12		▨	Clayey SAND (SC), mostly fine sand, some clay, loose, brown, wet. 15.0 ft. **END OF EXPLORATION**												
20																			
25																			
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	22July24	0.5 hr	7.0'
▼			
▼			

BORING: NTBH-3-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 22JULY2024

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lb/30-inch
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inch OD

GEI Consultants

Boring Location: 40.624025, -105.953611
Boring Elevation:
Notes: Location from handheld GPS unit.

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
							Laboratory Testing Results		In-Situ States			INDEX DATA					Strength & Compressibility		
0							**COHESIVE SOIL**												
		⧗	5 8	10			Clayey SAND (SC), mostly fine sand, little clay, medium dense, brown, moist, trace calcareous material.												
5		⧗	4 5	10			LEAN CLAY with Sand (CL), little fine sand, stiff, brown, moist.		11		0.0550			77	36	19			
		⧗	3 5	6			As above except olive brown.												
10		⧗	4 7	6			Lean CLAY (CL), mostly clay, few fine sand, stiff, brown, moist.		17					89					
15		⧗	2 5	10			As above except medium stiff.												
								(18.0 ft.)											
20		⧗	5 9	12			As above except stiff, yellowish brown, wet. 20.0 ft. **END OF EXPLORATION**												
25																			
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	22July24	1 hr	18.0'
▼			
▼			

BORING: NTBH-4

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 25JULY2024

Drilling and Sampling Methods

Drill Make and Model: CME-55
Drilling Method: Hollow Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lb/30-inch
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inch OD

GEI Consultants

Boring Location: 40.624278, -104.948684
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
							Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions		In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic		Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧓	6 7	12			LEAN CLAY with Sand (CL), stiff, olive brown, moist.												
5		⧓	6 9	12			Sandy LEAN CLAY (CL), some coarse sand, trace fine gravel, stiff, brown, moist.		17					51	34	15			
		⧓	6 5	10			As above												
10		⧓	6 6	12			As above except few fine gravel, few calcareous content.												
							14.0 ft.												
15		⧓	16 24	12			**PIERRE SHALE, UPPER MEMBER** Sandy CLAYSTONE, very soft, highly to moderately weathered, yellowish brown to light brown gray, very fine-grained with fine sand, laminar bedding, moist.												
							15.0 ft.												
							END OF EXPLORATION												
20																			
25																			
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
▼ 25July24	0 min	DNE
▼		
▼		

BORING: NTE-6-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 07APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.624128, -104.966401
Boring Elevation:
Notes: Location from handheld GPS device.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States		INDEX DATA						Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧓	3 4	12			LEAN CLAY with Sand (CL), little fine sand, medium stiff, brown, moist.												
		⧓	3 3	12			As above.		23					73	40	25			
5								(5.8 ft.) ▼											
		⧓	2 2	12			LEAN CLAY (CL), mostly clay, few fine sand, soft, dark brown, moist.		25	99		0	11	89			2,469		
		⧓	3 5	12			As above except medium stiff, olive, wet.	(10.0 ft.) ▼	24	102					44	29	2,672		
10																			
		⧓	2 2	12			Clayey SAND (SC), mostly fine sand, some clay, soft, brown, wet.		20					46	29	16			
		⧓	3 3	12			Sandy LEAN CLAY (CL), some fine sand medium stiff, olive, wet.		19					55					
15																			
		⧓	3 3	12			As above			1									
		⧓	3 3	12			As above.		18	116				51	26	10	1,658		
20																			
		⧓	5 9	12			As above except stiff.												
25							25.0 ft.												
							PIERRE SHALE, UPPER MEMBER SHALE, very soft, moderately weathered, tan, very fine-grained, thin laminations, wet.												
		⧓	22 47	12			As above except olive grey to yellowish brown.												
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	07APR25	0.5 hr	10'
▼	07APR25	3.5 hr	5.8'
▼			

BORING: NTE-6-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 07APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

Boring Location: 40.624128, -104.966401
Boring Elevation:
Notes: Location from handheld GPS device.

Visual Material Description

Soil:
-GEOLOGIC INTERPRETATION-
USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock:
-GEOLOGIC INTERPRETATION-
Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions

Sampling Data										Laboratory Testing Results											
										In-Situ States			INDEX DATA					Strength & Compressibility			
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)		
		⧓	50/6"	8		▤	As above.														
35							35.0 ft. **END OF EXPLORATION**														
40																					
45																					
50																					
55																					
60																					

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	07APR25	0.5 hr	10'
▼	07APR25	3.5 hr	5.8'
▼			

BORING: NTE-7

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 07APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.624263, -104.970459
Boring Elevation:
Notes: Location from handheld GPS device.

Visual Material Description

Soil:
-GEOLOGIC INTERPRETATION-
USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock:
-GEOLOGIC INTERPRETATION-
Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States		INDEX DATA						Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic		Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0						▨	**COHESIVE SOIL**												
		⧗	2 3	12		▨	Sandy LEAN CLAY (CL), some fine sand, medium stiff, olive brown, moist.												
5		⧗	3 3	12		▨	As above.		16	112				67	26	13	2,590		
		⧗	I 1	12		▨	As above except very soft.		25					66	27	14			
10		⧗	1 1	12		▨	As above except wet.	(10.0 ft.) ▼	21					57					
						▨	14.0 ft.												
15		⧗	2 1	12		▨	**NON-COHESIVE SOIL** Well-Graded SAND with Clay (SW-SC), mostly fine to coarse sand, few clay, very loose, brown, wet.												
20		⧗	4 7	12		▨	As above except medium dense.												
25		⧗	5 6	12		▨	As above.												
							25.0 ft. **END OF EXPLORATION**												
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	07APR25	0.5 hr	10'
▼			
▼			

BORING: NTE-8

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 07APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.624323, -104.974373
Boring Elevation:
Notes: Location from handheld GPS device.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**NON-COHESIVE SOIL**												
		⧗	3 3	12			Poorly-Graded SAND (SP), fine sand, loose, brown, moist, little organics.												
							4.0 ft.												
5		⧗	2 2	12			**COHESIVE SOIL** Sandy LEAN CLAY (CL), some fine sand, soft, brown, moist.		15					53	28	13			
		⧗	1 2	12			As above except little sand and more moist.	(7.5 ft.) ▼	24			0	24	76					
10		⧗	2 1	12			As above except some sand and wet.		26	102				54	31	16			
15		⧗	6 7	12			Clayey SAND (SC). mostly fine to coarse sand, some clay, few fine gravel, medium dense, brown, wet.		16					36					
							19.0 ft.												
20		⧗	5 3	12			**NON-COHESIVE SOIL** Poorly-Graded SAND (SP), coarse sand, loose, orange, wet, iron oxidation.												
							20.0 ft.												
							PIERRE SHALE, UPPER MEMBER SHALE, very soft, completely weathered, very fine-grained, grey to yellowish brown, wet. At 22-feet, auger contact of hard bedrock.												
25		⧗	29 50/2"	10			As above except moderately weathered.												
							25.0 ft.												
							END OF EXPLORATION												
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	07APR25	0.5 hr	7.5'
▼			
▼			

BORING: NTE-9

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 07APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.624274, -104.977926
Boring Elevation:
Notes: Location from handheld GPS device.

	Sampling Data						Visual Material Description		Laboratory Testing Results										
							Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions		In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic		Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0						▨	**COHESIVE SOIL**												
		⧗	3 4	12		▨	Clayey SAND (SC), mostly fine sand, little clay, medium stiff, olive brown, moist.												
5		⧗	3 4	12		▨	Sandy LEAN CLAY (CL), some fine to coarse sand, medium stiff, olive brown moist.		9					53	29	14			
		⧗	2 2	12		▨	As above except soft and little sand.		19					73					
10		⧗	1 1	6		▨	As above except very soft.		21					67	32	17			
		⧗	1 1	12		▨	Clayey SAND (SC), mostly fine sand, some clay, very loose, brown, wet.	(11.5 ft.) ▼	19			1	57	42					
							14.0 ft.												
15		⧗	29 25	12		░	**PIERRE SHALE, UPPER MEMBER** SANDSTONE with Silt, soft, moderately weathered, tan to yellowish brown, fine-grained, wet.		5					8	NP	NP			
		⧗	28 50/5"	6		░	Silty SANDSTONE, soft, moderately weathered, tan to yellowish brown, fine- grained, wet.		17					35					
20		⧗	50/6"	10		░	As above.		16					38					
25		⧗	50/6"	10		░	As above except slightly weathered.		17	112				37	28	5	3,145		
30		⧗	50/3"	5		░	As above.												
							30.0 ft.												
							END OF EXPLORATION												

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	07APR25	0.5 hr	11.5'
▼			
▼			

BORING: NTE-10-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 27JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

Boring Location: 40.624598, -104.978345
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results: In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧗	5 5	6			Clayey SAND (SC), mostly fine sand, little clay, stiff, brown, moist.												
5		⧗	3 4	7			Sandy LEAN CLAY (CL), some fine sand, medium stiff, olive brown, moist.				0.0402								
		⧗	3 2	5			As above.							51	28	13			
10		⧗	1 1	11			As above except very soft.		20	109				67	28	13			
		⧗	WOH	12			As above.	(12.5 ft.)	25	106				56	28	13			
							14.0 ft.												
15		⧗	3 4	12			**PIERRE SHALE, FOX HILLS MEMBER** Sandy CLAYSTONE, very soft, completely weathered, yellowish brown, fine- to medium-grained, wet.		16					68					
		⧗	14 19	12			As above except highly to moderately weathered, thin layers.												
20		⧗	16 28	12			As above.		18	111				54			1,531		
		⧗	34 50/5"	11			As above except slightly weathered.												
25		⧗	29 39	10			As above except fresh.		11	124				53			10,081		
30		⧗	50/6"	11			As above.												

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	27JAN25	1 hr	12.5'
▽			
▽			

BORING: NTE-10-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 27JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.624598, -104.978345
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results											
									In-Situ States			INDEX DATA					Strength & Compressibility			
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
		⧗	50/4"	4		▨	As above.												
35							35.0 ft. **END OF EXPLORATION**												
40																			
45																			
50																			
55																			
60																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▽	27JAN25	1 hr	12.5'
▽			
▽			

BORING: NTE-11

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 07APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

Boring Location: 40.624694, -104.979897
Boring Elevation:
Notes: Location from handheld GPS device.

Sampling Data							Visual Material Description		Laboratory Testing Results											
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0						▨	**COHESIVE SOIL**												
		⧓	1 2	12		▨	Clayey SAND (SC), mostly fine sand, some clay, soft, brown, moist.												
5		⧓	1 2	6		▨	Sandy LEAN CLAY (CL), some fine sand, soft, brown, moist.		16					62					
		⧓	4 6	12		▦	6.5 ft. **PIERRE SHALE, UPPER MEMBER** Clayey SANDSTONE, soft, moderately weathered, grey to yellowish brown, fine-grained, moist.		18	109				26	29	7	931		
10		⧓	11 50/6"	12		▦	As above except more clay and grey.		11					40					
15		⧓	27 50/5"	12		▦	As above except dark grey to yellowish brown, wet.	(14.0 ft.) ▼	15					38					
20		⧓	50/6"	6		▦	As above except slightly weathered.												
25		⧓	50/5"	6		▦	As above. 25.0 ft.												
							END OF EXPLORATION												
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	07APR25	0.5 hr	14'
▼			
▼			

BORING: NTE-12

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 08APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.627300, -104.981732
Boring Elevation:
Notes: Location from handheld GPS device.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧓	4 4	12			Clayey SAND (SC), mostly fine sand, little clay, loose, brown, moist.												
5		⧓	3 4	12			As above except dark brown.		12		0.087								
		⧓	2 3	12			Sandy LEAN CLAY (CL), some fine to coarse sand, medium stiff, brown, moist.		19					61	27	9			
10		⧓	2 3	12			As above except fine sand, more moist.		18					39					
								(13.0 ft.) ▽											
							14.0 ft.												
15		⧓	6 13	12			**PIERRE SHALE, UPPER MEMBER** SANDSTONE, very soft, completely weathered, brown to yellowish brown, fine-grained, wet.												
20		⧓	50/6"	6			As above exept soft, moderately weathered, brown to grey.												
25		⧓	50/6"	6			As above.												
							25.0 ft. **END OF EXPLORATION**												
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▽	08APR25	0.5 hr	13'
▽			
▽			

BORING: NTE-13

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 08APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.630574, -104.982533
Boring Elevation:
Notes: Location from handheld GPS device.

Sampling Data							Visual Material Description		Laboratory Testing Results											
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧓	4 5	12			Lean Clay with Sand, mostly fine sand, little clay, stiff, brown, moist.												
5		⧓	2 2	12			As above except soft.		15					72	25	12			
		⧓	2 2	12			Sandy LEAN CLAY, some fine sand, soft, olive brown, moist.							55	23	9			
10		⧓	1 2	12			As above except fine to coarse sand.		18					54					
							13.0 ft.												
15		⧓	22 42	12			**PIERRE SHALE, UPPER MEMBER** Clayey SANDSTONE, very soft, moderately weathered, tan to brown, very fine- to fine-grained, moist.												
								(19.0 ft.) ▼											
20		⧓	35 50/4"	12			Sandy SHALE, very soft, moderately weathered, dark grey to yellowish brown, very fine- to fine-grained, thin laminations, wet.												
25		⧓	46 50/3"	6			SANDSTONE, very soft, moderately weathered, grey to tan, fine-grained, wet. 25.0 ft. **END OF EXPLORATION**												
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	08APR25	0.5 hr	19'
▼			
▼			

BORING: NTE-14-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 08APR2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.631669, -104.986151
Boring Elevation:
Notes: Location from handheld GPS device.

Sampling Data							Visual Material Description Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Laboratory Testing Results: In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic			Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**NON-COHESIVE SOIL**												
		⧓	6 5	12			Silty SAND (SM), mostly fine sand, some silt, medium dense, brown, moist.												
5		⧓	3 2	12			As above except loose, few sulfates.		8	102									
		⧓	1 2	12			As above except very loose, olive brown, no sulfates.		12					45	NP	NP			
10		⧓	2 2	12			Sandy SILT (ML), some fine sand, soft, olive brown, moist		16					59					
							14.0 ft.	(14.0 ft.) (14.0 ft.)											
15		⧓	1 3	12			**COHESIVE SOIL** Sandy LEAN CLAY (CL), some fine to medium sand, soft, brown, wet.		20			1	30	69					
							16.5 ft. **PIERRE SHALE, UPPER MEMBER**												
20		⧓	32 50/4"	12			Clayey SANDSTONE, very soft, moderately weathered, brown, very fine- to fine-grained, wet.												
25		⧓	50/6"	6			As above.												
							25.0 ft. **END OF EXPLORATION**												
30																			

General Notes:

1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	08APR25	0.5 hr	14'
▼	08APR25	2 hr	14'
▼			

BORING: NTE-15

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 30JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal., Split-Spoon
Sampler Diameter(s): 2.5-, 2.0-inches

GEI Consultants

Boring Location: 40.631755, -104.991306
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results											
									In-Situ States			INDEX DATA					Strength & Compressibility			
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧗	5 5	12			LEAN CLAY with Sand (CL), few fine sand, soft, olive brown, moist.		20					85	40	23			
5		⧗	1 1	11				(4.5 ft.) ▼											
							4.5 ft. **NON-COHESIVE SOIL** Poorly-Graded SAND with Clay (SP-SC), mostly fine sand, few clay, very loose, brown, wet.												
		⧗	1 0	12			6.5 ft. **COHESIVE SOIL** LEAN CLAY with Sand (CL), mostly clay, little fine sand, very soft, pale olive, wet.		31			0	22	78					
10		⧗	2 2	12			LEAN CLAY (CL), few fine sand, soft, olive to olive brown, wet.		28					90					
15		⧗	8 12	12			14.0 ft. **NON-COHESIVE SOIL** Well-Graded SAND with Clay and Gravel (SW-SC), mostly medium to coarse sand, some fine gravel, few clay, medium dense, brown, wet.		10			33	57	10					
20		◤	22 26	17			19.0 ft. **PIERRE SHALE, UPPER SHALE MEMBER** SHALE, very soft, moderately to slightly weathered, grey to brown, very fine- to fine-grained, thin laminations, wet.												
							20.5 ft. **END OF EXPLORATION**												
25																			
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	30JAN25	1 hr	4.5'
▼			
▼			

BORING: NTE-16

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 29JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.631788, -104.994882
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Laboratory Testing Results											
									In-Situ States		INDEX DATA						Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic			Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0						▨	**COHESIVE SOIL**												
		⧓	6 7	12		▨	Sandy LEAN CLAY (CL), some fine sand, stiff, brown, moist.												
5		⧓	4 3	12		▨	As above except medium stiff, dark brown.		22					62	36	19			
		⧓	2 4	5		▨	As above.												
10		⧓	3 4	12		▨	Clayey SAND (SC), mostly fine sand, some clay, loose, olive yellow, moist.		17					48	32	15			
							14.0 ft.												
15		⧓	22 50/6"	12		▤	**PIERRE SHALE, UPPER SHALE MEMBER** SHALE, very soft, moderately weathered, brown, very fine- to fine-grained, thin laminations, moist.		17	115				100	43	26	18,421		
20		⧓	20 50/3"	6		▤	As above except slightly weathered, yellowish brown to dark brown.												
							20.0 ft.												
							END OF EXPLORATION												
25																			
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▽	29JAN25	0.5 hr	Not Observed
▽			
▽			

BORING: NTE-17-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 28JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal., Split-Spoon
Sampler Diameter(s): 2.5-, 2.0-inches

Boring Location: 40.631856, -104.999086
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
			8 6	6			LEAN CLAY (CL), few fine sand, stiff, pale olive, moist.												
5			5 6	12			As above except little sulfates.												
			5 7	6			As above except olive.				0.21								
10			9 7	12			9.0 ft. **NON-COHESIVE SOIL** Well-Graded SAND with Clay and Gravel (SW-SC), mostly fine to coarse sand, some fine gravel, few clay, medium dense, brown, moist.		2			30	64	6					
			12 17 13	14			As above.		2			30	64	6					
15			10 20 27	11			As above except dense, wet.	(14.0 ft.) (14.5 ft.)											
			6 10 10	16			As above except little fine gravel, medium dense.		10			21	71	8					
20			13 6	11			As above.		10			21	71	8					
			3 4	8			20.5 ft. **COHESIVE SOIL** LEAN CLAY with Sand (CL), little fine to coarse sand, medium stiff, olive, wet.												
25			13 15	12			24.0 ft. **NON-COHESIVE SOIL** Well-Graded SAND with Gravel (SW), mostly fine to coarse sand, little to few fine gravel, medium dense, brown, wet.												
30			6 22 34	15			Well-Graded SAND with Clay and Gravel (SW-SC), mostly fine to coarse sand, little fine gravel, few clay, very dense, brown, wet.		12			16	73	11					

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	28JAN25	1 hr	14.0'
▽	28JAN25	2 hr	14.5'
▽			

BORING: NTE-17-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 28JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal., Split-Spoon
Sampler Diameter(s): 2.5-, 2.0-inches

GEI Consultants

Boring Location: 40.631856, -104.999086
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results											
									In-Situ States		INDEX DATA						Strength & Compressibility			
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)	
35			7 22 36	16			As above. Note: Heaving sands.													
							38.5 ft. **PIERRE SHALE, UPPER SHALE MEMBER** SHALE, very soft, moderately weathered, grey to yellowish brown, very fine-grained, thin laminations, wet.													
40			22 50/5"	12			40.0 ft. **END OF EXPLORATION**		17	116				100	50	31	14,610			
45																				
50																				
55																				
60																				

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
▼ 28JAN25	1 hr	14.0'
▼ 28JAN25	2 hr	14.5'
▼		

BORING: NTE-18-MW

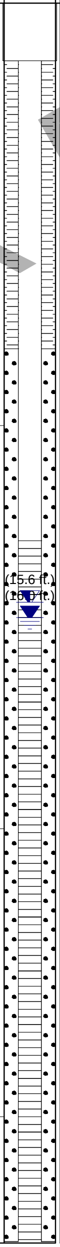
Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 28JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal., Split-Spoon
Sampler Diameter(s): 2.5-, 2.0-inches

GEI Consultants

Boring Location: 40.631926, -105.001741
Boring Elevation:
Notes: Location from handheld GPS unit. Well abandoned on 10/10/2025



Sampling Data							Visual Material Description Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Laboratory Testing Results										
									In-Situ States		INDEX DATA						Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic			Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
			8 11	12			Clayey SAND (SC), mostly fine sand, some clay, very stiff, pale olive, moist, little sulfates.												
5			6 7	9			LEAN CLAY with Sand (CL), little fine sand, stiff, olive, moist.		14	114									
			3 5	12			As above except medium stiff.												
10			2 3	12			As above.		21	106				77	32	16			
							11.0 ft.												
			7 14	11			**NON-COHESIVE SOIL** Poorly-Graded SAND with Clay and Gravel (SP-SC), mostly medium to coarse sand, little fine gravel, few clay, medium dense, brown, moist.		4			26	69	5					
15			15 9	12			As above.		4			26	69	5					
			8 11 12	16			As above except wet.		9			24	71	5					
20			10 17 15	14			As above except dense.		9			24	71	5					
							21.5 ft.												
			2 6 11	16.5			**COHESIVE SOIL** Clayey SAND (SC), mostly fine sand, some clay, medium dense, olive brown, wet.		21			5	56	39					
25			10 11 10	15			As above except mostly fine to medium sand, brown.												
							29.0 ft.												
30			11 9	8			**NON-COHESIVE SOIL** Clayey SAND with Gravel (SC), mostly fine sand, little clay, little fine gravel, very stiff, olive brown, wet. Poorly-Graded SAND (SP), mostly coarse sand, few fine gravel, medium dense, brown, wet.		13			21	56	23					

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	28JAN25	1 hr	16.0'
▼	28JAN25	2 hr	15.6'
▼			

BORING: NTE-18-MW

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 28JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal., Split-Spoon
Sampler Diameter(s): 2.5-, 2.0-inches

GEI Consultants

Boring Location: 40.631926, -105.001741
Boring Elevation:
Notes: Location from handheld GPS unit. Well abandoned on 10/10/2025

Sampling Data							Visual Material Description Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions		Laboratory Testing Results										
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic		Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
35			5 11 7	14			As above. Poorly-Graded SAND with Silt (SP-SM), mostly fine sand, few silt, medium dense, brown, wet.												
							37.5 ft. **PIERRE SHALE, UPPER SHALE MEMBER**												
40			22 50/4"	12			SHALE, very soft, slightly weathered, grey to brown, very fine- to fine-grained, thin laminations, wet.		17	114				99	48	28	14,093		
							40.0 ft. **END OF EXPLORATION**												
45																			
50																			
55																			
60																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
28JAN25	1 hr	16.0'
28JAN25	2 hr	15.6'

BORING: NTE-19

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 27JAN25

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.631868, -105.006463
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧗	8 10	11			LEAN CLAY with Sand (CL), little fine sand, very stiff, pale olive, moist, little sulfates.												
		⧗	10 0	8			As above except stiff.												
5																			
		⧗	5 7	12			As above except few sand, very stiff, olive, moist.		21					90					
		⧗	3 4	12			As above except little sand, medium stiff.		22					78					
10																			
		⧗	2 3	12			As above except yellowish brown to olive.												
15																			
								(16.0 ft.) ▼											
							19.0 ft.												
		⧗	9 14	12			**NON-COHESIVE SOIL** Poorly-Graded SAND (SP), coarse sand, medium dense, brown, wet.												
20							20.0 ft.												
							END OF EXPLORATION												
25																			
30																			

General Notes:

1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	27JAN25	0.5 hr	16.0'
▼			
▼			

BORING: NTE-20

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 27JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.633614, -105.010041
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States		INDEX DATA						Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**COHESIVE SOIL**												
		⧓	5 7	10			LEAN CLAY (CL), few fine sand, stiff, olive brown, moist.												
5		⧓	7 10	10			As above except very stiff, olive yellow, some sulfates and calcite.												
		⧓	9 15	8			As above.				1.85								
10		⧓	12 14	12			As above except little sand.		13					80					
15		⧓	3 4	12			As above except olive brown, more moist.	(16.0 ft.) ▼ (17.2 ft.) ▽											
							19.0 ft.												
20		⧓	9 14	12			**NON-COHESIVE SOIL** Poorly-Graded SAND (SP), coarse sand, medium dense, brown, wet. 20.0 ft.												
							END OF EXPLORATION												
25																			
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	27JAN25	0.5 hr	16.0'
▽	27JAN25	1 hr	17.2'
▽			

BORING: NTE-21

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 27JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Solid-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.0-inch SSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

Boring Location: 40.636354, -105.010041
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States		INDEX DATA						Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0						▨	**COHESIVE SOIL**												
		⧗	4 5	10		▨	LEAN CLAY (CL), few fine sand, stiff, olive, moist, calcite and sulfates.												
		⧗	4 4	12		▨	As above except medium stiff.												
5						▨													
		⧗	4 4	12		░	Clayey SAND (SC), mostly sand, some clay, loose, olive, moist.		11					44					
		⧗	5 6	12		░	As above except medium dense.												
10						░													
						░	14.0 ft.												
		⧗	12 16	12		☰	**PIERRE SHALE, UPPER SHALE MEMBER** SHALE, very soft, moderately weathered, yellowish brown to olive grey, very fine-grained, thin laminations, moist.												
15						☰													
		⧗	19 25	12		☰	As above except slightly weathered.												
20							20.0 ft.												
							END OF EXPLORATION												
25																			
30																			

General Notes:

1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	27JAN25	0.5 hr	NE
▽			
▽			

BORING: NTE-22-MW

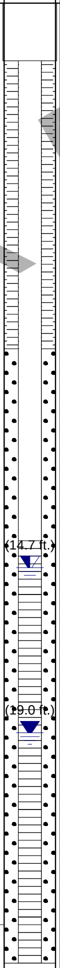
Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 28JAN2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal.
Sampler Diameter(s): 2.5-inches

GEI Consultants

Boring Location: 40.638893, -105.010022
Boring Elevation:
Notes: Location from handheld GPS unit. Well abandoned on 10/10/2025



Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0						▨	**COHESIVE SOIL**												
		⧗	4 5	12		▨	LEAN CLAY with sand (CL), few fine sand, stiff, olive brown, moist.												
5		⧗	3 4	12		▨	As above except medium stiff, brown.												
		⧗	3 7	12		▨	As above except stiff, little sulfates.				1.05								
10		⧗	3 6	12		▨	As above.												
15		⧗	4 6	12		▨	As above except no sulfates.	(14.7 ft.)	23					91					
20		⧗	5 7	12		▨	As above except wet.	(19.0 ft.)											
							24.0 ft.												
25		⧗	5 6	12		░	**NON-COHESIVE** SILT with Sand (ML), little fine sand, stiff, olive brown, wet, little iron oxidation.												
							25.0 ft.												
							END OF EXPLORATION												
30																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	28JAN25	1 hr	19.0'
▼	28JAN25	2 hr	14.7'
▼			

BORING: NTE-23

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 06FEB2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal., Split-Spoon
Sampler Diameter(s): 2.5-, 2.0-inches

GEI Consultants

Boring Location: 40.632157, -105.000915
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
							Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions		In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic		Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0							**FILL**												
5			4 6 9	15			LEAN CLAY (CL), few fine sand, stiff, olive brown, moist.												
							9.0 ft.												
10			4 5	9			**COHESIVE SOIL** LEAN CLAY with Sand (CL), little fine sand, stiff, olive brown, moist.												
			3 8 15	15			As above except very stiff.												
15							15.0 ft.		3			30	62	8					
							NON-COHESIVE SOIL Well-Graded SAND with Clay and Gravel (SW-SC), mostly fine to coarse sand, some fine gravel, few clay, medium dense, olive brown, moist.	(16.2 ft.)											
			14 25 24	14.5			As above except max particle size 0.75-inch, dense, brown.		3			30	62	8					
								(18.9 ft.)											
20			7 8 9	15			As above except medium dense, wet.		11			18	77	5					
			11 19 23	18			As above except dense.		11			18	77	5					
25			7 9 4	11			As above except medium dense.		13			15	75	10					
							25.3 ft.												
							COHESIVE SOIL LEAN CLAY (CL), stiff, olive, wet, encountered in shoe of sampler.												
							29.0 ft.												
30			7 17 14	15			**NON-COHESIVE SOIL** Well-Graded SAND with Clay and Gravel (SW-SC), mostly fine to coarse sand, little fine gravel, few clay, dense, brown, wet.		13			15	75	10					
							30.5 ft.												
							COHESIVE SOIL												

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
06FEB25	1 hr	18.9'
60FEB25	2 hr	16.2'

BORING: NTE-23

Project Name: Thornton Segment F.2
Project Number: 2505320
Client's Name: HDR Engineers, Inc.
Owner's Name: City of Thornton
Drilling Subcontractor: Terracon
GEI Representative: Colby C.
Date(s) of Drilling: 06FEB2025

Drilling and Sampling Methods

Drill Make and Model: CME-75
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: 4.25-inch HSA
Hammer Weight (lbs)/Fall (in): 140lbs./30-inches
Sampler Type(s): Mod. Cal., Split-Spoon
Sampler Diameter(s): 2.5-, 2.0-inches

GEI Consultants

Boring Location: 40.632157, -105.000915
Boring Elevation:
Notes: Location from handheld GPS unit.

Sampling Data							Visual Material Description		Laboratory Testing Results										
									In-Situ States			INDEX DATA					Strength & Compressibility		
Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
							LEAN CLAY with Sand (CL), little fine sand, brown, wet. Note: Material change in tip of spoon.												
35			3 5 8	15			As above except stiff, pale olive, little iron oxidation.		26					78	37	22			
							39.0 ft.												
40			5 10	12			**NON-COHESIVE SOIL** Poorly-Graded SAND with Gravel (SP), mostly fine sand, little fine gravel, medium dense, brown, wet.												
							44.0 ft.												
45			20 37	12			**PIERRE SHALE, UPPER SHALE MEMBER** SHALE, very soft, moderately weathered, olive, very fine-grained, thin laminations, olive, wet.		18	113				98	48	27	13,486		
							45.0 ft.												
							END OF EXPLORATION												
50																			
55																			
60																			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
06FEB25	1 hr	18.9'
60FEB25	2 hr	16.2'

Appendix B Geotechnical Laboratory Testing Results

B.1. Geotechnical Laboratory Testing Summary Table

B.2. Geotechnical Laboratory Graphical Testing Results

B.1. Geotechnical Laboratory Testing Summary Table

Sample Identification		In-Place States			Particle Size Distribution			Atterberg Limits[2]		Strength	Soil/Rock Classification[1,3]	
Boring	Sample Depth (ft)	Moisture Content (%)	Dry Density (pcf)	Water Soluble Sulfates (%)	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit (%)	Plasticity Index (%)	Unconfined Compressive Strength (psf)	USCS Symbol	Description
NTBH-1	10	16		0.0015			44				SC	Clayey SAND
NTBH-2	5	19					72				CL	Sandy LEAN CLAY
NTBH-2	7.5	26					81	30	11		CL	LEAN CLAY with Sand
NTBH-2	10	24					84				CL	LEAN CLAY with Sand
NTBH-3-MW	5	11		0.0550			77	36	19		CL	LEAN CLAY with Sand
NTBH-3-MW	10	17					89				CL	LEAN CLAY
NTBH-4	5	17					51	34	15		CL	Sandy LEAN CLAY
NTE-6-MW	5	23					73	40	25		CL	LEAN CLAY with Sand
NTE-6-MW	7.5	25	99		0	11	89			2,469	CL	LEAN CLAY
NTE-6-MW	10	25	102					44	29	2,672	CL	LEAN CLAY
NTE-6-MW	12.5	20					46	29	16		SC	Clayey SAND
NTE-6-MW	15	19.0					55				CL	Sandy LEAN CLAY
NTE-6-MW	20	18	116				51	26	10	1,658	CL	Sandy LEAN CLAY
NTE-7	5	17	112				67	26	13	2,590	CL	Sandy LEAN CLAY
NTE-7	7.5	26					66	27	14		CL	Sandy LEAN CLAY
NTE-7	10	21.0					57				CL	Sandy LEAN CLAY
NTE-8	5	15					53	28	13		CL	Sandy LEAN CLAY
NTE-8	7.5	24.0			0	24	76				CL	LEAN CLAY with Sand
NTE-8	10	26	102				54	31	16		CL	Sandy LEAN CLAY
NTE-8	15	16					36				SC	Clayey SAND
NTE-9	5	9					53	29	14		CL	Sandy LEAN CLAY
NTE-9	7.5	19					73				CL	LEAN CLAY with Sand
NTE-9	10	21					67	32	17		CL	Sandy LEAN CLAY
NTE-9	12.5	19			1	57	42				SC	Clayey SAND
NTE-9	15	6					8	NP	NP		BR	SANDSTONE with Silt
NTE-9	17.5	17					35				BR	Silty SANDSTONE
NTE-9	20	16					38				BR	Silty SANDSTONE
NTE-9	25	17	112				37	28	5	3,145	BR	Silty SANDSTONE
NTE-10-MW	5			0.0402							CL	Sandy LEAN CLAY
NTE-10-MW	7.5						51	28	13		CL	Sandy LEAN CLAY
NTE-10-MW	10	20	109				67	28	13		CL	Sandy LEAN CLAY
NTE-10-MW	12.5	25	106				56	28	13		CL	Sandy LEAN CLAY
NTE-10-MW	15	16					68				BR	Sandy CLAYSTONE

Sample Identification		In-Place States			Particle Size Distribution			Atterberg Limits[2]		Strength	Soil/Rock Classification[1,3]	
Boring	Sample Depth (ft)	Moisture Content (%)	Dry Density (pcf)	Water Soluble Sulfates (%)	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit (%)	Plasticity Index (%)	Unconfined Compressive Strength (psf)	USCS Symbol	Description
NTE-10-MW	20	18	111				54			1,531	BR	Sandy CLAYSTONE
NTE-10-MW	25	11	125				53			10,081	BR	Sandy CLAYSTONE
NTE-11	5	16					62				CL	Sandy LEAN CLAY
NTE-11	7.5	18	109				26	29	7	931	BR	Clayey SANDSTONE
NTE-11	10	11					40				BR	Clayey SANDSTONE
NTE-11	15	15					38				BR	Clayey SANDSTONE
NTE-12	5	12		0.087							SC	Clayey SAND
NTE-12	7.5	19					61	27	9		CL	Sandy LEAN CLAY
NTE-12	10	18					39				SC	Clayey SAND
NTE-13	5	16					72	25	12		CL	LEAN CLAY with Sand
NTE-13	7.5						55	23	9		CL	Sandy LEAN CLAY
NTE-13	10	18					54				CL	Sandy LEAN CLAY
NTE-14-MW	5	8	102								SM	Silty SAND
NTE-14-MW	7.5	13					45	NP	NP		SM	Silty SAND
NTE-14-MW	10	16					59				ML	Sandy SILT
NTE-14-MW	15	20			1	30	69				CL	Sandy LEAN CLAY
NTE-15	2.5	20					85	40	23		CL	LEAN CLAY with Sand
NTE-15	7.5	31			0	22	78				CL	LEAN CLAY with Sand
NTE-15	10	28					90				CL	LEAN CLAY
NTE-15	15	10			33	57	10				SW-SC	Well-Graded SAND with Clay and Gravel
NTE-16	5	22					62	36	19		CL	Sandy LEAN CLAY
NTE-16	10	17					48	32	15		SC	Clayey SAND
NTE-16	15	17	115				100	43	26	18,421	BR	SHALE
NTE-17-MW	7.5			0.210							CL	LEAN CLAY
NTE-17-MW	10, 12.5	2			30	64	6				SW-SC	Well-Graded SAND with Clay and Gravel
NTE-17-MW	17.5, 20	10			21	71	8				SW-SC	Well-Graded SAND with Clay and Gravel
NTE-17-MW	30	12			16	73	11				SW-SC	Well-Graded SAND with Clay and Gravel
NTE-17-MW	40	17	116				100	50	31	14,610	BR	SHALE
NTE-18-MW	5	14	114								CL	LEAN CLAY with Sand
NTE-18-MW	10	21	106				77	32	16		CL	LEAN CLAY with Sand
NTE-18-MW	12.5, 15	4			26	69	5				SP-SC	Poorly Graded SAND with Clay and Gravel
NTE-18-MW	17.5, 20	9			24	71	5				SP-SC	Poorly Graded SAND with Clay and Gravel
NTE-18-MW	22.5	21			5	56	39				SC	Clayey SAND

Sample Identification		In-Place States			Particle Size Distribution			Atterberg Limits[2]		Strength	Soil/Rock Classification[1,3]	
Boring	Sample Depth (ft)	Moisture Content (%)	Dry Density (pcf)	Water Soluble Sulfates (%)	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit (%)	Plasticity Index (%)	Unconfined Compressive Strength (psf)	USCS Symbol	Description
NTE-18-MW	30	13			21	56	23				SC	Clayey SAND with Gravel
NTE-18-MW	40	17	114				99	48	28	14,093	BR	SHALE
NTE-19	7.5	21					90				CL	LEAN CLAY with Sand
NTE-19	10	22					78				CL	LEAN CLAY with Sand
NTE-20	7.5			1.8476							CL	LEAN CLAY
NTE-20	10	13					80				CL	Sandy LEAN CLAY
NTE-21	7.5	11					44				SC	Clayey SAND
NTE-22-MW	7.5			1.0460							CL	LEAN CLAY
NTE-22-MW	15	23					91				CL	LEAN CLAY with Sand
NTE-23-MW	15, 17.5	3			30	62	8				SW-SC	Well-Graded SAND with Clay and Gravel
NTE-23-MW	20, 22.5	11			18	77	5				SW-SC	Well-Graded SAND with Clay and Gravel
NTE-23-MW	25, 30	13			15	75	10				SW-SC	Well-Graded SAND with Clay and Gravel
NTE-23-MW	35	26					78	37	22		CL	LEAN CLAY with Sand
NTE-23-MW	45	18	113				98	48	27	13,486	BR	SHALE

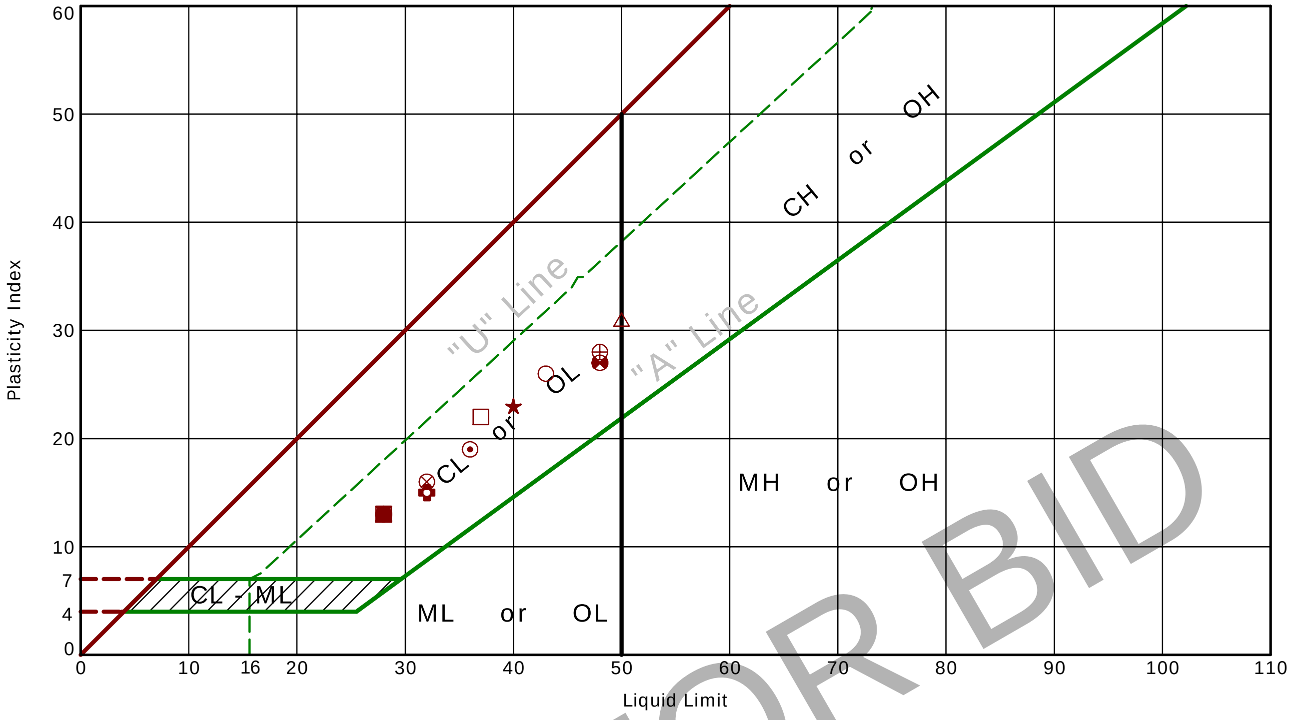
Notes:

1. USCS Symbol column is provided for soil. "BR" indicates bedrock.
2. NV and NP indicate "Non-Viscous" and "Non-Plastic" Atterberg Limits
3. Where Atterberg Limits were not performed, classifications were determined by field observations

B.2. Geotechnical Laboratory Graphical Testing Results

Atterberg Limit Results

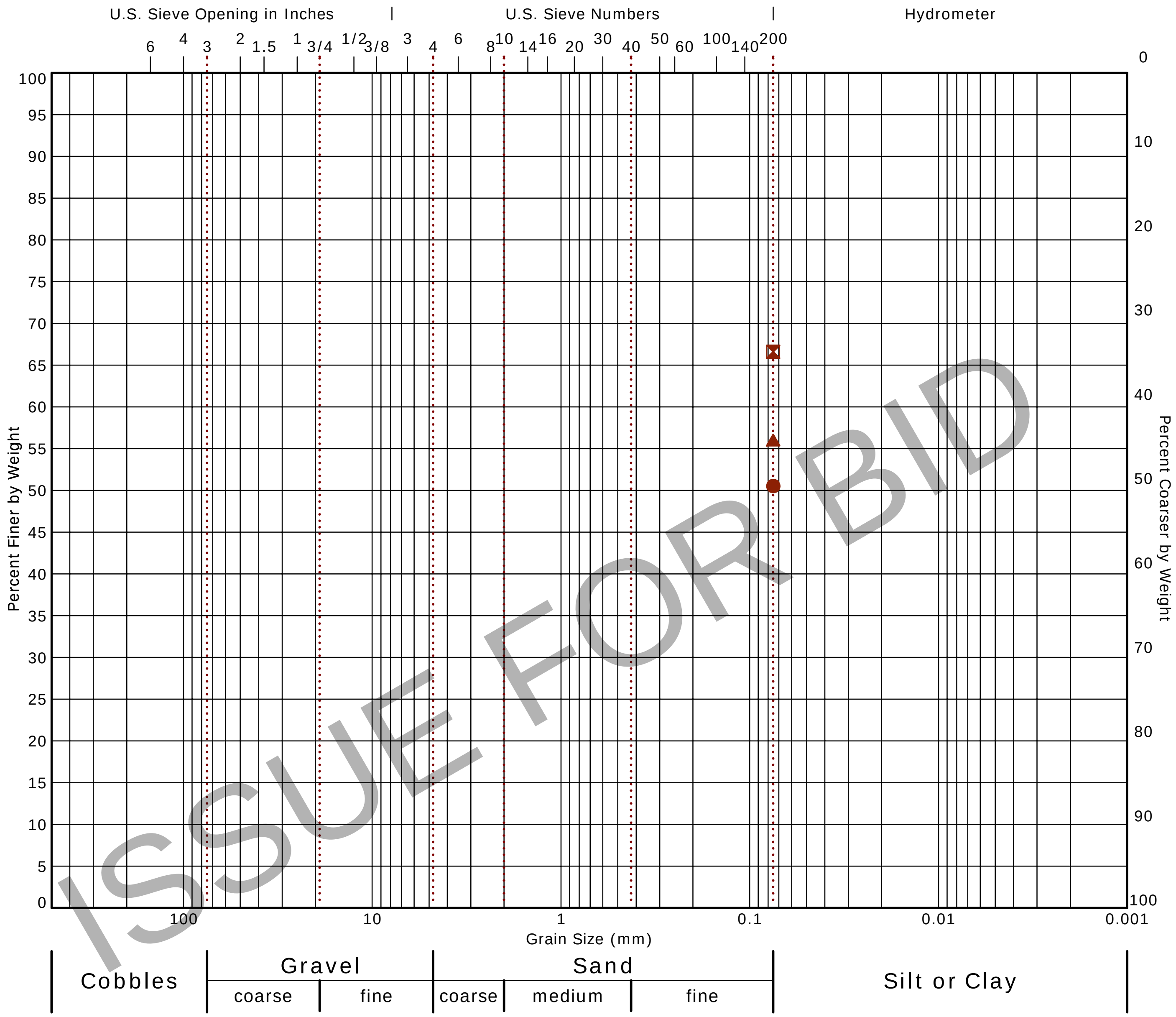
ASTM D4318



	Boring ID	Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	NTE-10-MW	7.5	28	15	13	50.5	CL	SANDY LEAN CLAY
⊠	NTE-10-MW	10	28	15	13	66.6	CL	SANDY LEAN CLAY
▲	NTE-10-MW	12.5	28	15	13	56.0	CL	SANDY LEAN CLAY
★	NTE-15	2.5	40	17	23	85.3	CL	LEAN CLAY
⊙	NTE-16	5	36	17	19	62.0	CL	SANDY LEAN CLAY
✚	NTE-16	10	32	17	15	47.8	SC	CLAYEY SAND
○	NTE-16	15	43	17	26	99.5	CL	LEAN CLAY
△	NTE-17-MW	40	50	19	31	99.7	CH	FAT CLAY
⊗	NTE-18-MW	10	32	16	16	77.4	CL	LEAN CLAY with SAND
⊕	NTE-18-MW	40	48	20	28	99.1	CL	LEAN CLAY
□	NTE-23-MW	35	37	15	22	78.2	CL	LEAN CLAY with SAND
⨂	NTE-23-MW	45	48	21	27	97.7	CL	LEAN CLAY

Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27



Boring ID		Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-10-MW	7.5				50.5			CL
☒	NTE-10-MW	10				66.6			CL
▲	NTE-10-MW	12.5				56.0			CL

Description	
●	SANDY LEAN CLAY
☒	SANDY LEAN CLAY
▲	SANDY LEAN CLAY

Remarks	
●	
☒	
▲	

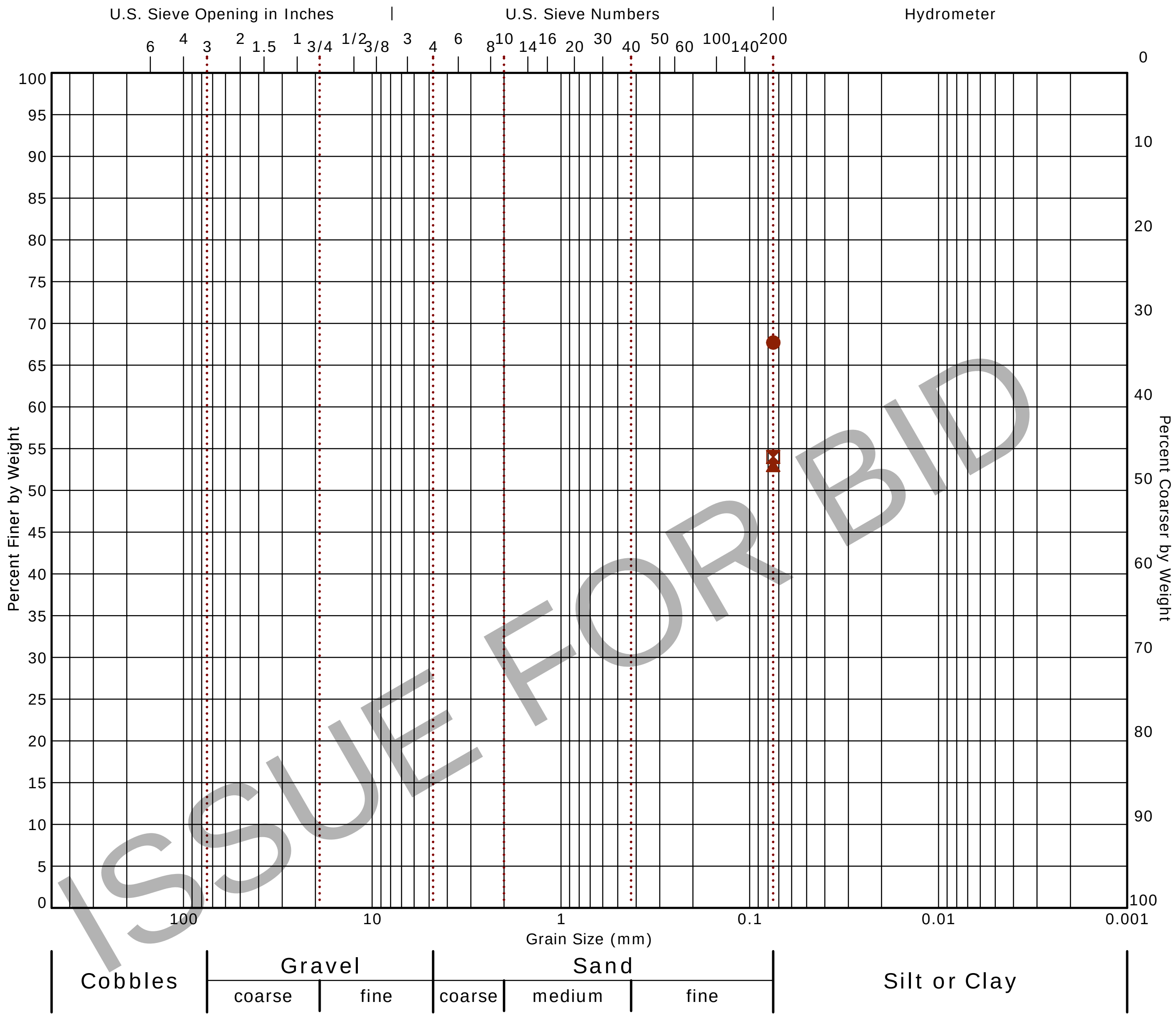
●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
#200	50.52	#200	66.62	#200	56.03

Grain Size			
	●	☒	▲
D_{60}			
D_{10}			

Coefficients			
	●	☒	▲
C_C			
C_U			

Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27



	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-10-MW	15				67.7			
☒	NTE-10-MW	20				54.0			
▲	NTE-10-MW	25				52.9			

	Description
●	
☒	
▲	

	Remarks
●	
☒	
▲	

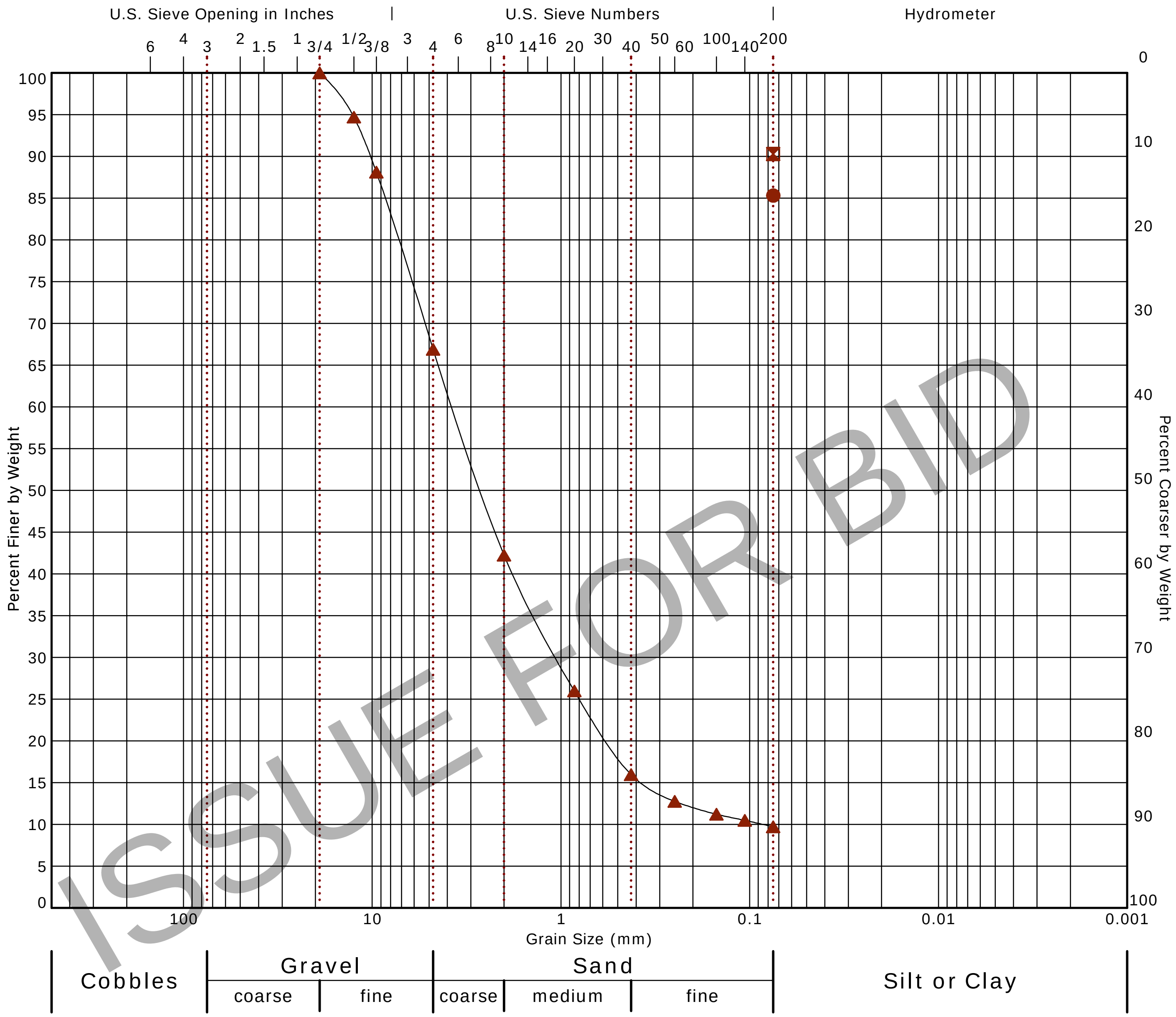
●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
#200	67.7	#200	54.02	#200	52.93

Grain Size			
	●	☒	▲
D_{60}			
D_{10}			

Coefficients			
	●	☒	▲
C_C			
C_U			

Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27



	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-15	2.5				85.3			CL
☒	NTE-15	10				90.3			
▲	NTE-15	15	0.0	33.1	57.2	9.7			

	Description
●	LEAN CLAY
☒	
▲	

	Remarks
●	
☒	
▲	

●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
#200	85.31	#200	90.27	3/4"	100.0
				1/2"	94.69
				3/8"	88.1
				#4	66.89
				#10	42.23
				#20	25.98
				#40	15.96
				#60	12.76
				#100	11.21
				#140	10.47
				#200	9.72

Grain Size

	●	☒	▲
D_{60}			3.73
D_{10}			0.085

Coefficients

	●	☒	▲
C_C			3.47
C_U			43.75

Grain Size Distribution

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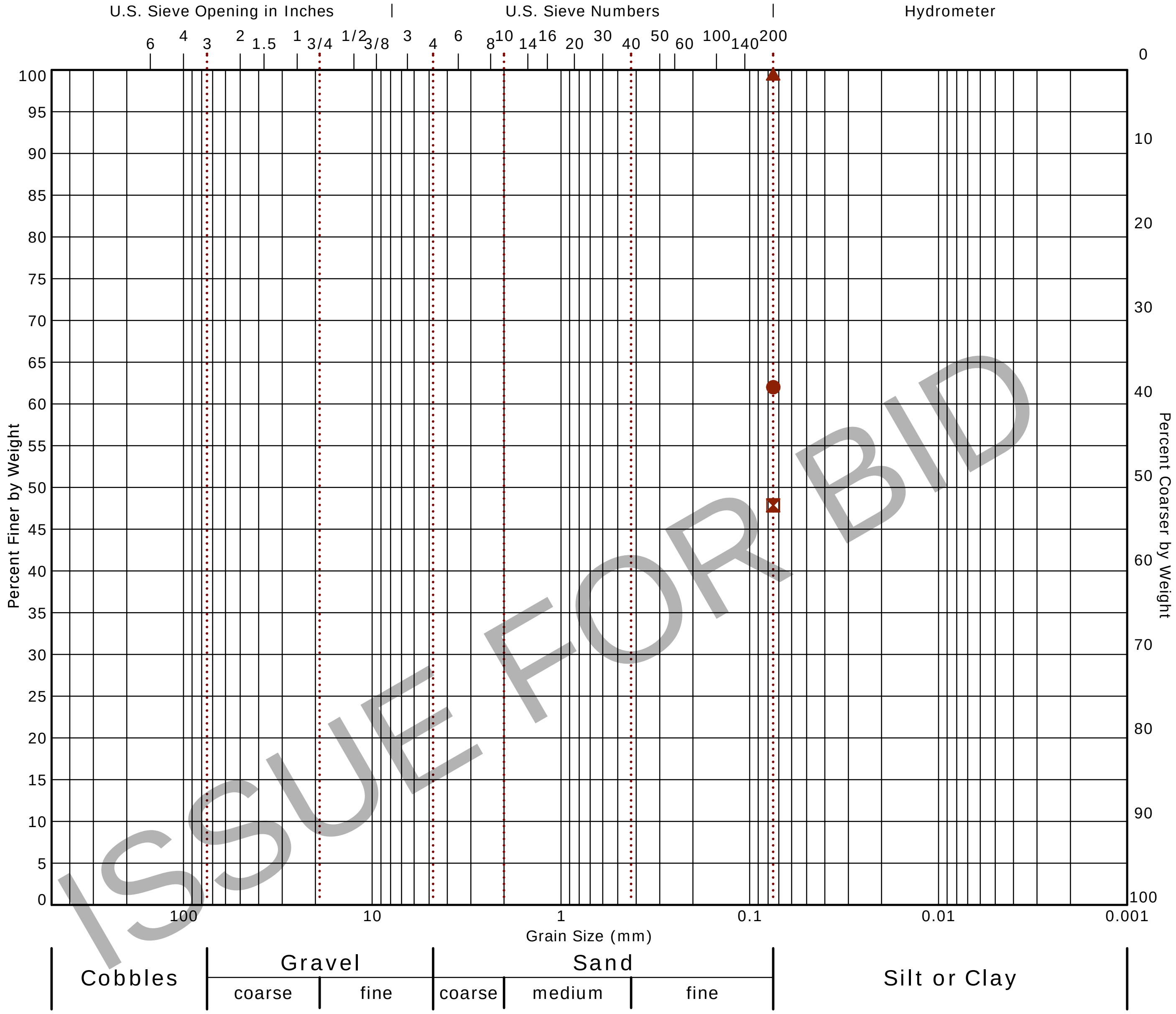

	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-16	5				62.0			CL
☒	NTE-16	10				47.8			SC
▲	NTE-16	15				99.5			CL

	Description
●	SANDY LEAN CLAY
☒	CLAYEY SAND
▲	LEAN CLAY

	Remarks
●	
☒	
▲	

●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
#200	62.0	#200	47.84	#200	99.49

Grain Size			
	●	☒	▲
D_{60}			
D_{10}			

Coefficients			
	●	☒	▲
C_C			
C_U			

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Grain Size Distribution

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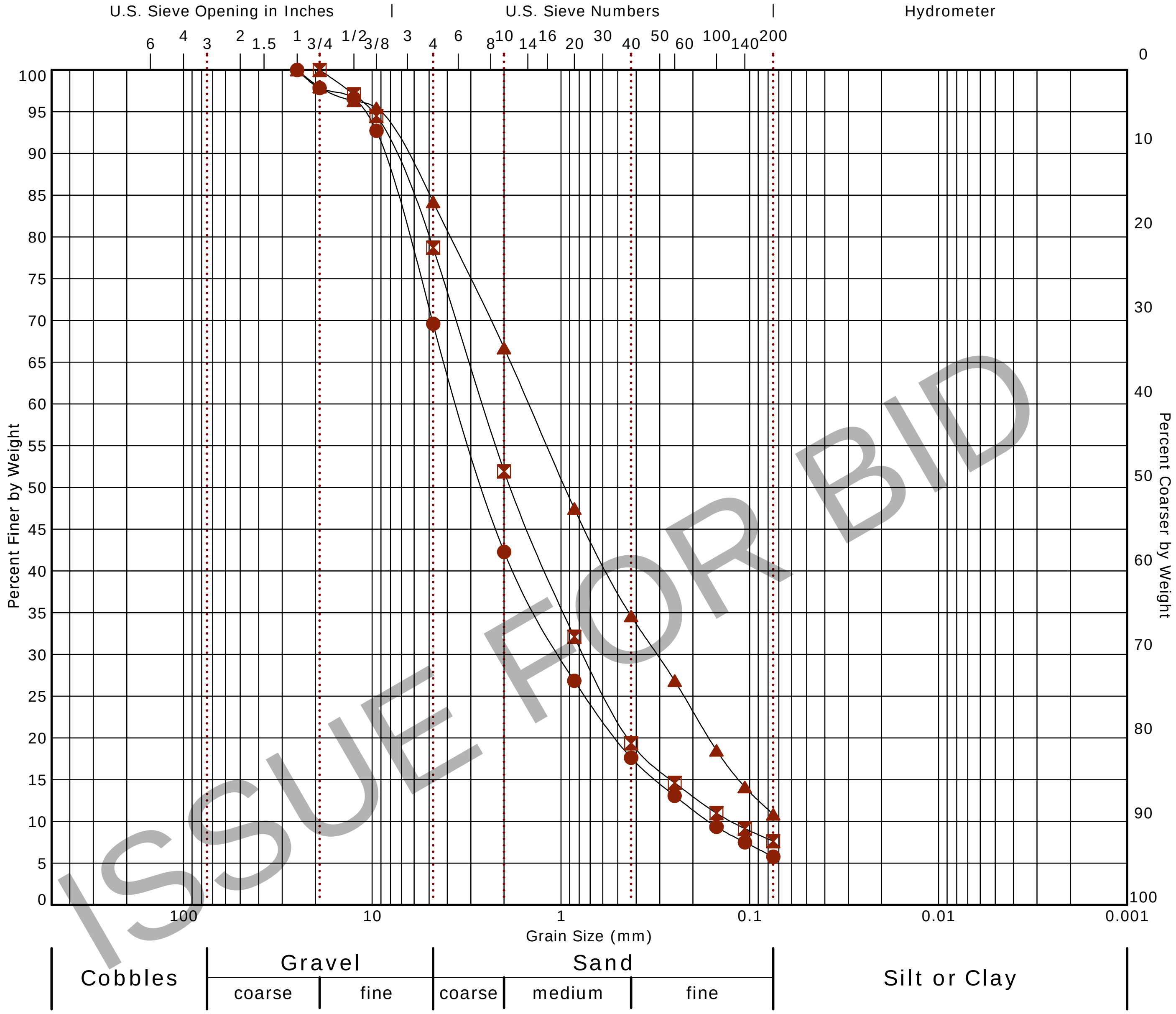

	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-17-MW	10, 12.5	0.0	30.4	63.8	5.8			
☒	NTE-17-MW	17.5, 20	0.0	21.3	71.1	7.6			
▲	NTE-17-MW	30	0.0	15.8	73.4	10.8			

	Description
●	
☒	
▲	

	Remarks
●	
☒	
▲	

●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
1"	100.0	3/4"	100.0	1"	100.0
3/4"	97.83	1/2"	97.09	3/4"	97.93
1/2"	96.58	3/8"	94.48	1/2"	96.31
3/8"	92.71	#4	78.71	3/8"	95.46
#4	69.6	#10	51.93	#4	84.21
#10	42.27	#20	32.11	#10	66.69
#20	26.84	#40	19.36	#20	47.47
#40	17.62	#60	14.61	#40	34.59
#60	13.07	#100	10.98	#60	26.86
#100	9.34	#140	9.14	#100	18.51
#140	7.49	#200	7.62	#140	14.11
#200	5.77			#200	10.85

Grain Size			
	●	☒	▲
D_{60}	3.506	2.595	1.485
D_{10}	0.164	0.125	

Coefficients			
	●	☒	▲
C_C	1.78	1.78	0.94
C_U	21.36	20.82	21.66

Grain Size Distribution

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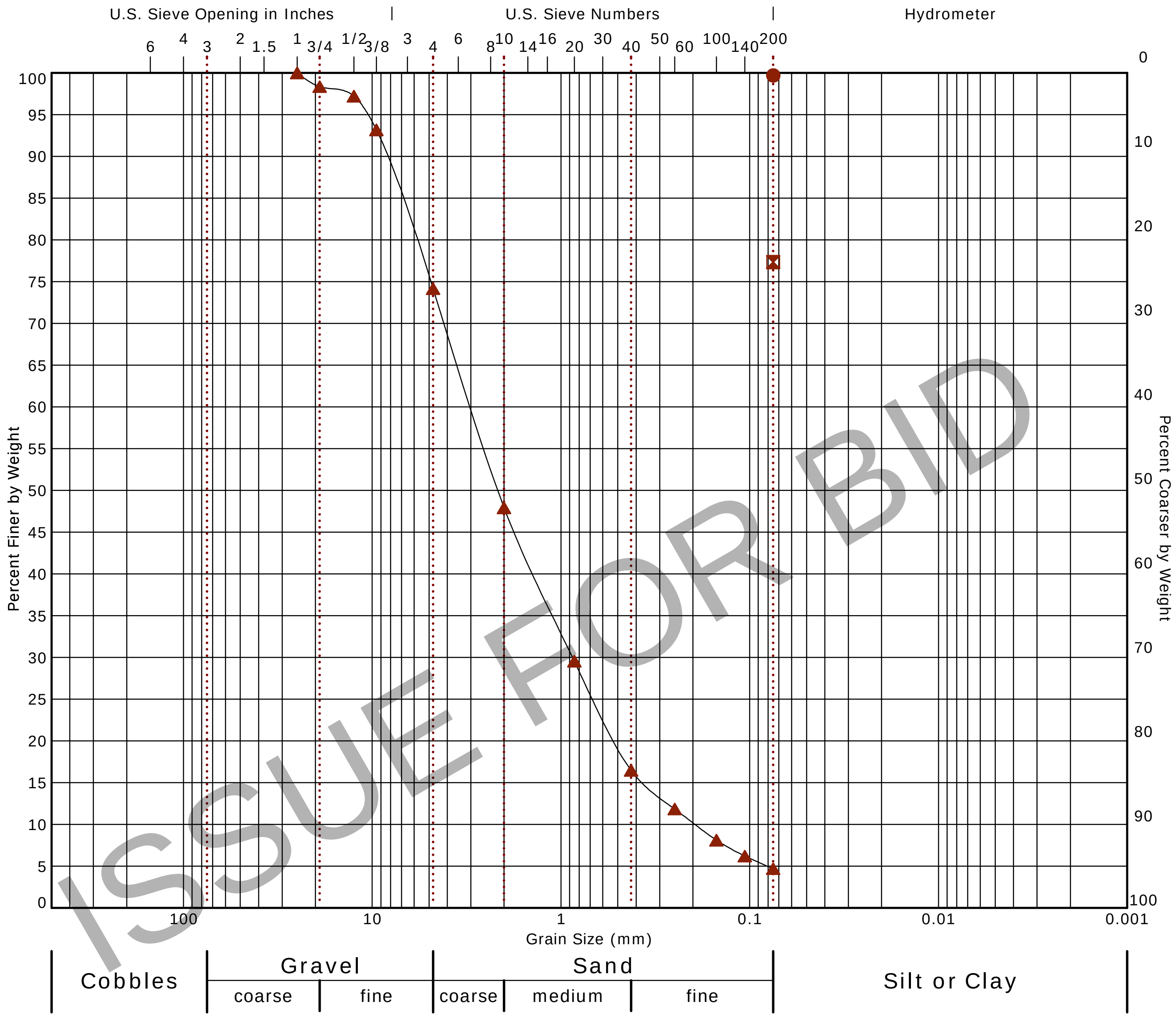

	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-17-MW	40				99.7			CH
☒	NTE-18-MW	10				77.4			CL
▲	NTE-18-MW	12.5, 15	0.0	25.8	69.5	4.7			SW

	Description
●	FAT CLAY
☒	LEAN CLAY with SAND
▲	WELL-GRADED SAND with GRAVEL

	Remarks
●	
☒	
▲	

●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
#200	99.69	#200	77.35	1"	100.0
				3/4"	98.35
				1/2"	97.21
				3/8"	93.18
				#4	74.16
				#10	47.91
				#20	29.55
				#40	16.47
				#60	11.84
				#100	8.12
				#140	6.21
				#200	4.69

Grain Size			
	●	☒	▲
D_{60}			2.979
D_{10}			0.194

Coefficients			
	●	☒	▲
C_C			1.30
C_U			15.34

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Grain Size Distribution

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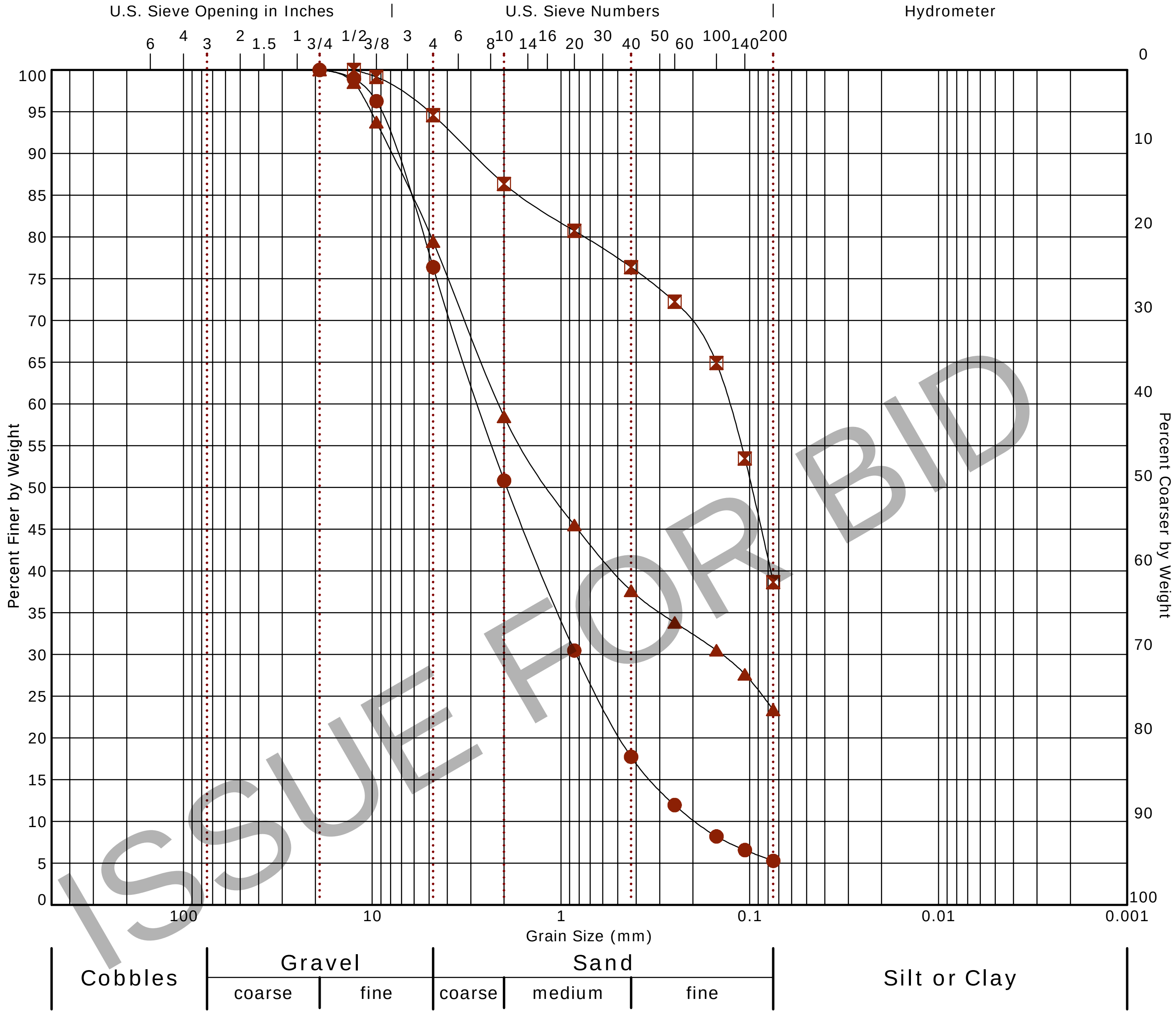

	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-18-MW	17.5, 20	0.0	23.6	71.1	5.3			
☒	NTE-18-MW	22.5	0.0	5.4	55.9	38.6			
▲	NTE-18-MW	30	0.0	20.5	56.1	23.4			

	Description
●	
☒	
▲	

	Remarks
●	
☒	
▲	

●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
3/4"	100.0	1/2"	100.0	3/4"	100.0
1/2"	98.94	3/8"	99.15	1/2"	98.49
3/8"	96.26	#4	94.59	3/8"	93.75
#4	76.37	#10	86.35	#4	79.45
#10	50.82	#20	80.74	#10	58.46
#20	30.46	#40	76.38	#20	45.49
#40	17.73	#60	72.25	#40	37.63
#60	11.95	#100	64.9	#60	33.83
#100	8.2	#140	53.47	#100	30.49
#140	6.57	#200	38.64	#140	27.61
#200	5.27			#200	23.36

Grain Size			
	●	☒	▲
D_{60}	2.729	0.129	2.131
D_{10}	0.192		

Coefficients			
	●	☒	▲
C_C	1.31		
C_U	14.24		

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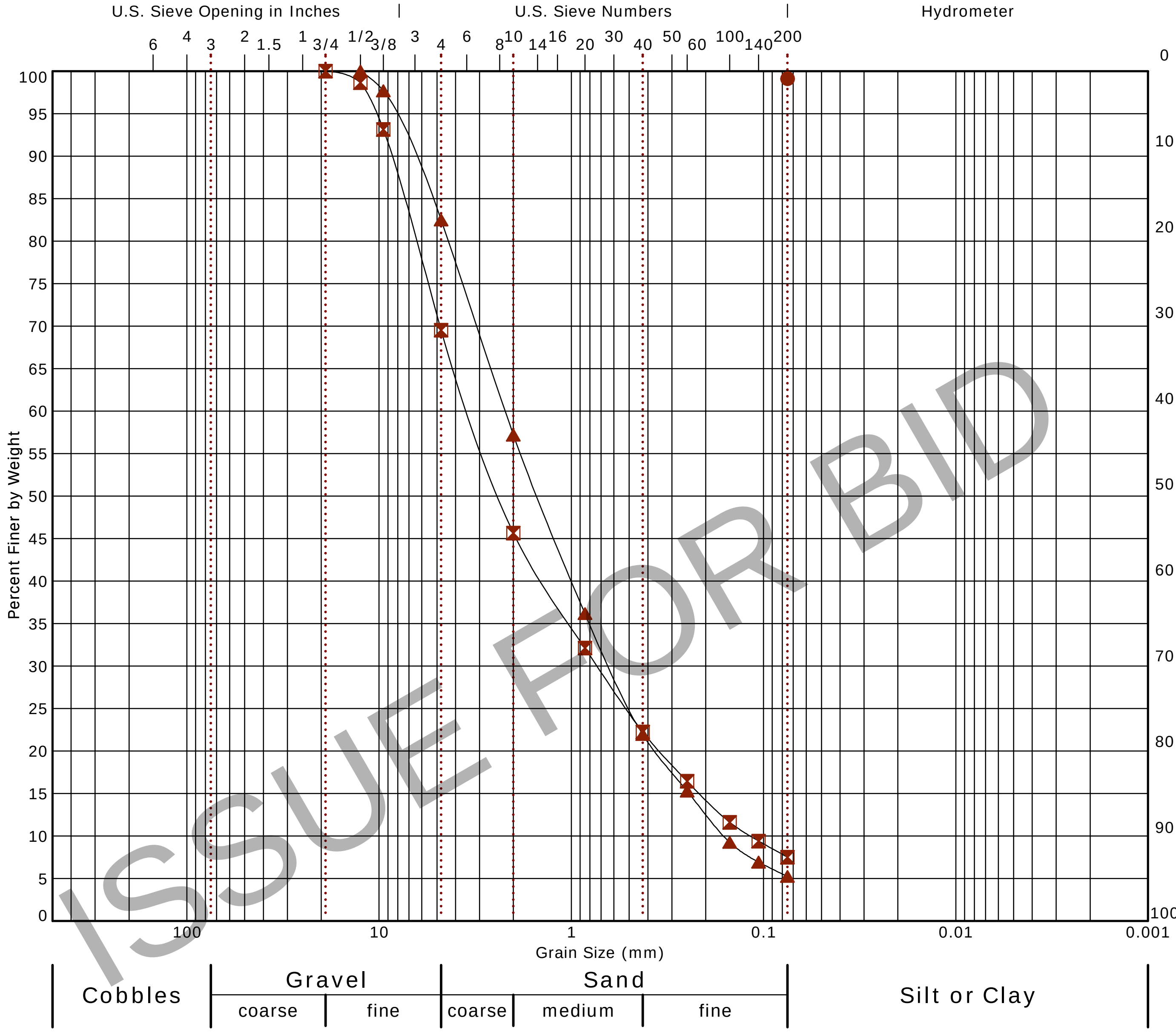
Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27



	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-18-MW	40				99.1			CL
☒	NTE-23-MW	15, 17.5	0.0	30.5	62.0	7.5			
▲	NTE-23-MW	20, 22.5	0.0	17.5	77.3	5.2			

	Description
●	LEAN CLAY
☒	
▲	

	Remarks
●	
☒	
▲	

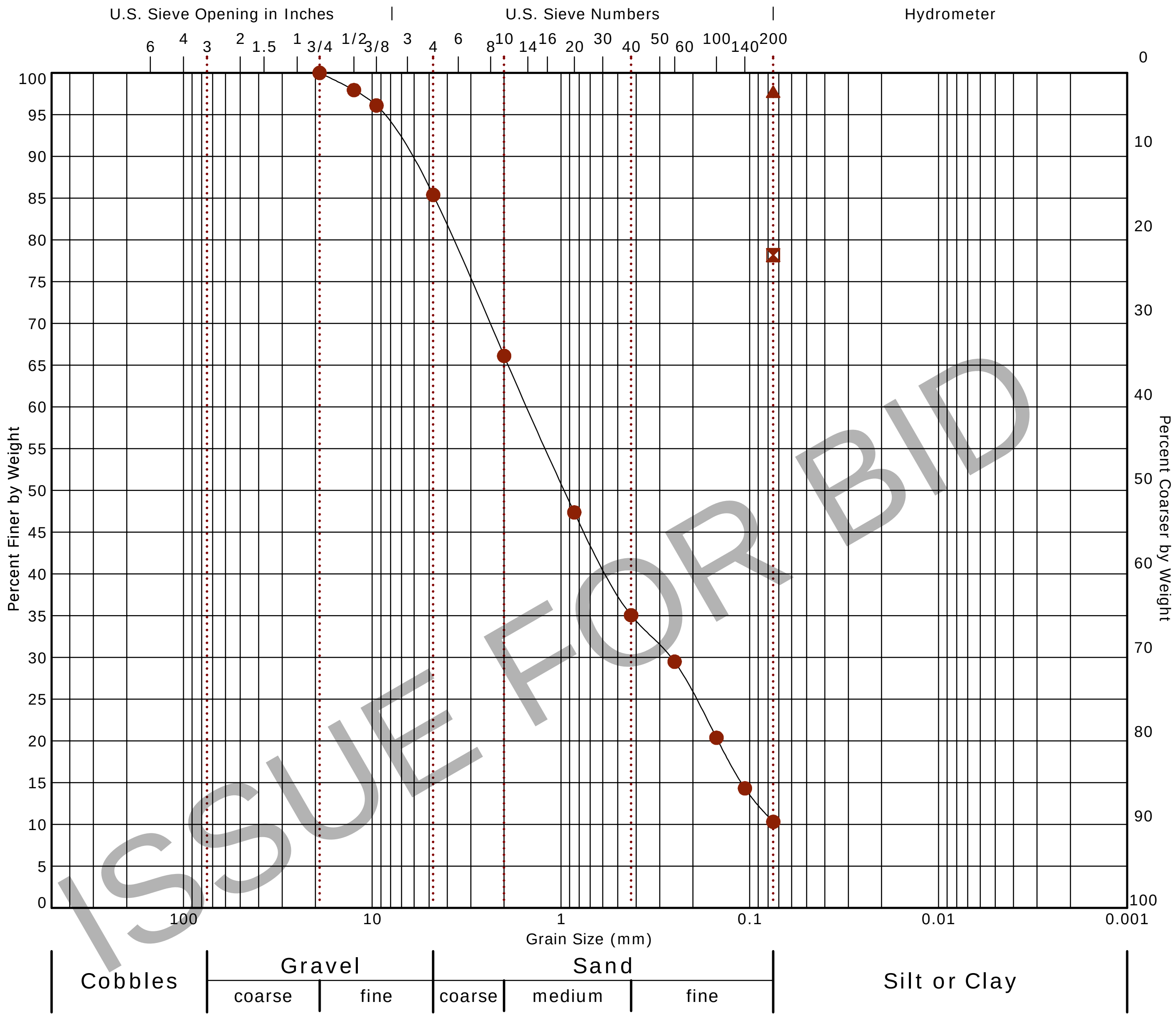
●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
#200	99.11	3/4"	100.0	1/2"	100.0
		1/2"	98.64	3/8"	97.69
		3/8"	93.14	#4	82.49
		#4	69.51	#10	57.19
		#10	45.63	#20	36.18
		#20	32.1	#40	21.94
		#40	22.24	#60	15.3
		#60	16.44	#100	9.25
		#100	11.62	#140	6.92
		#140	9.4	#200	5.24
		#200	7.51		

Grain Size			
	●	☒	▲
D_{60}		3.366	2.202
D_{10}		0.116	0.16

Coefficients			
	●	☒	▲
C_C		1.37	1.13
C_U		28.91	13.77

Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27



	Boring ID	Depth	% Cobbles	% Gravel	% Sand	% Fines	% Silt	% Clay	USCS
●	NTE-23-MW	25, 30	0.0	14.6	75.1	10.3			
☒	NTE-23-MW	35				78.2			CL
▲	NTE-23-MW	45				97.7			CL

	Description
●	
☒	LEAN CLAY with SAND
▲	LEAN CLAY

	Remarks
●	
☒	
▲	

●		☒		▲	
Sieve	% Finer	Sieve	% Finer	Sieve	% Finer
3/4"	100.0	#200	78.17	#200	97.74
1/2"	97.94				
3/8"	96.09				
#4	85.39				
#10	66.11				
#20	47.36				
#40	35.04				
#60	29.49				
#100	20.38				
#140	14.32				
#200	10.31				

Grain Size

	●	☒	▲
D_{60}	1.513		
D_{10}			

Coefficients

	●	☒	▲
C_C	0.62		
C_U	20.73		

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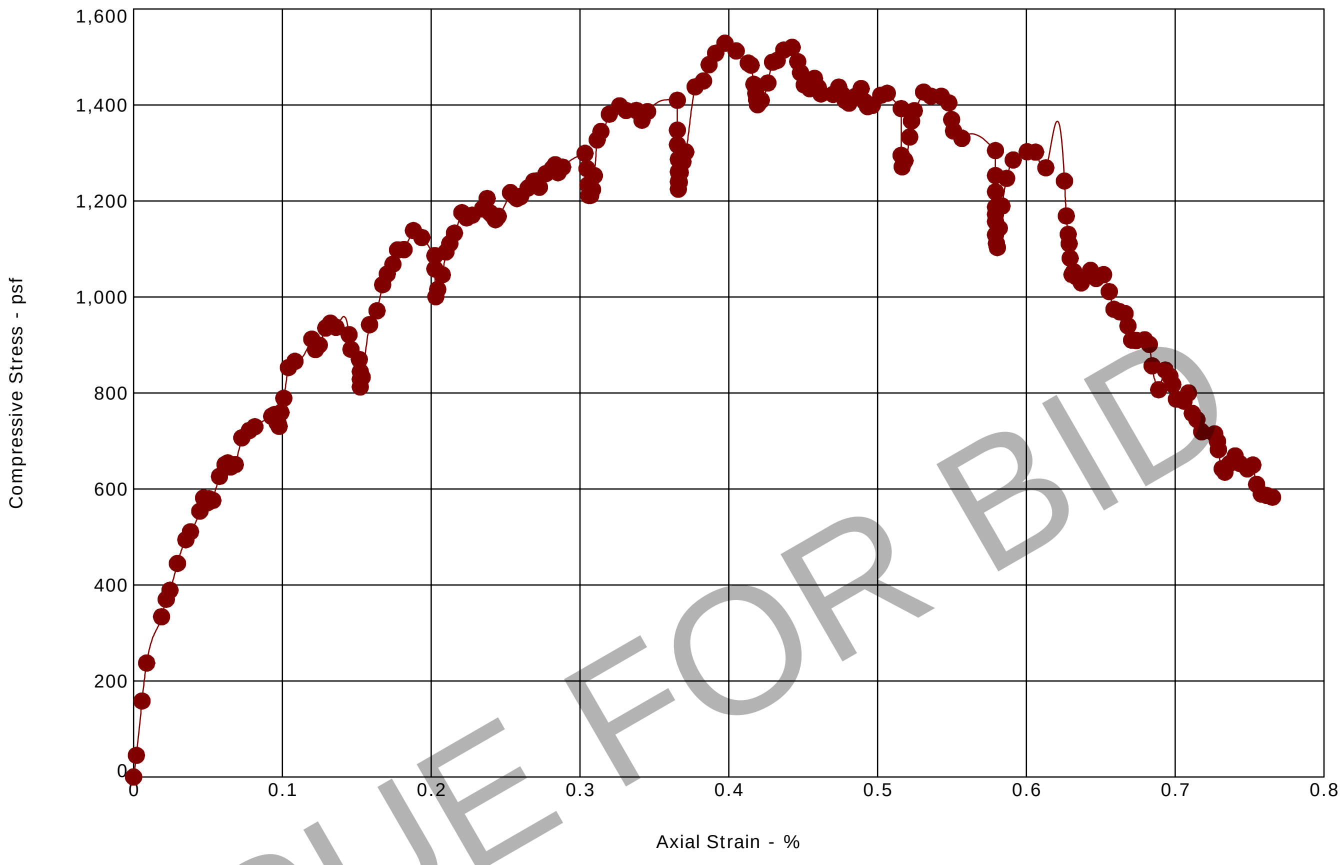
Fort Collins, CO

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-10-MW	20	CARS				54.0	

Specimen Failure Mode

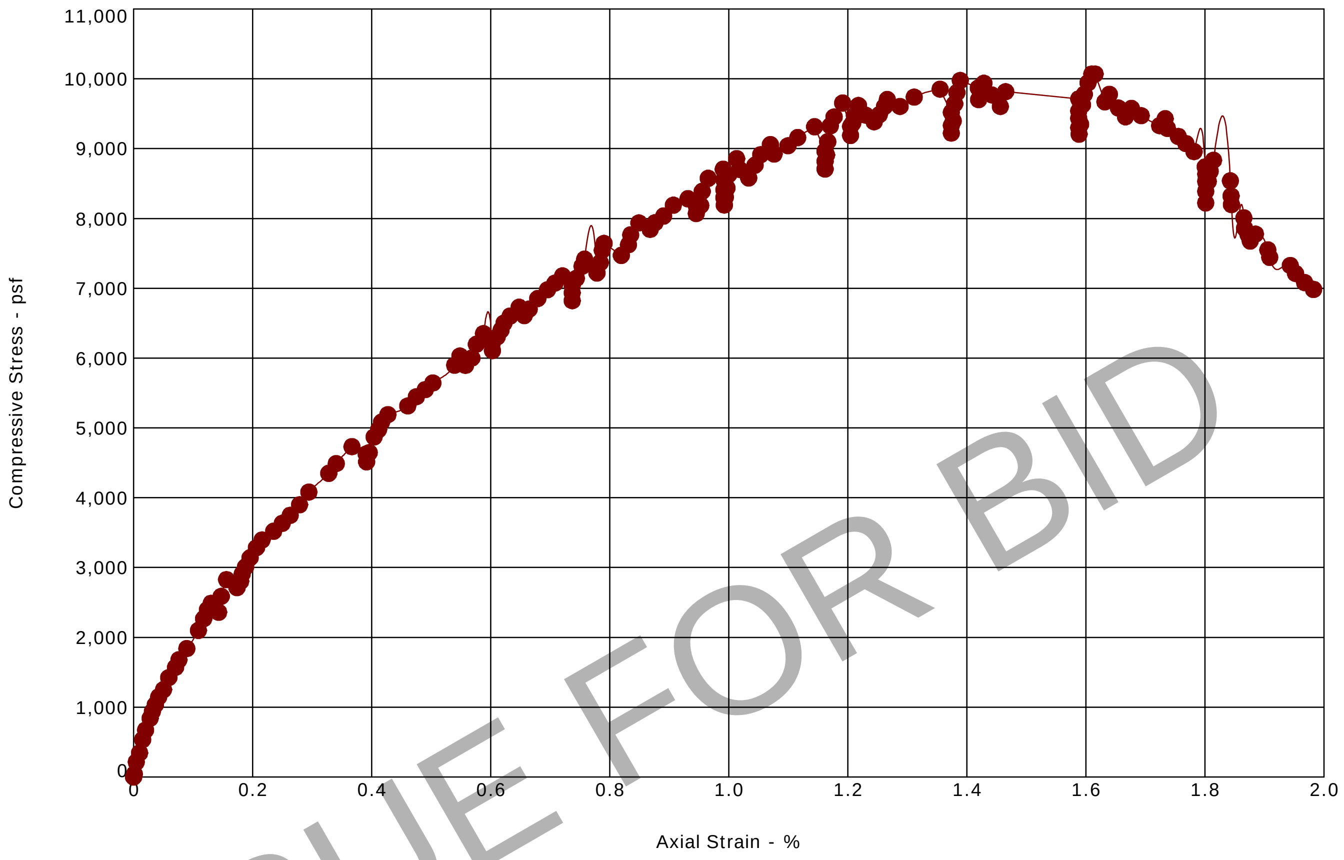
Specimen Test Data

Moisture Content (%):	17.9
Dry Density (pcf):	111
Diameter (in.):	1.94
Height (in.):	3.99
Height / Diameter Ratio:	2.06
Calculated Saturation (%):	93.04
Calculated Void Ratio:	0.52
Assumed Specific Gravity:	2.7
Failure Strain (%):	0.40
Unconfined Compressive Strength (psf):	1529
Undrained Shear Strength (psf):	764
Strain Rate (in/min):	0.0800

Remarks:

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-10-MW	25	CARS				52.9	

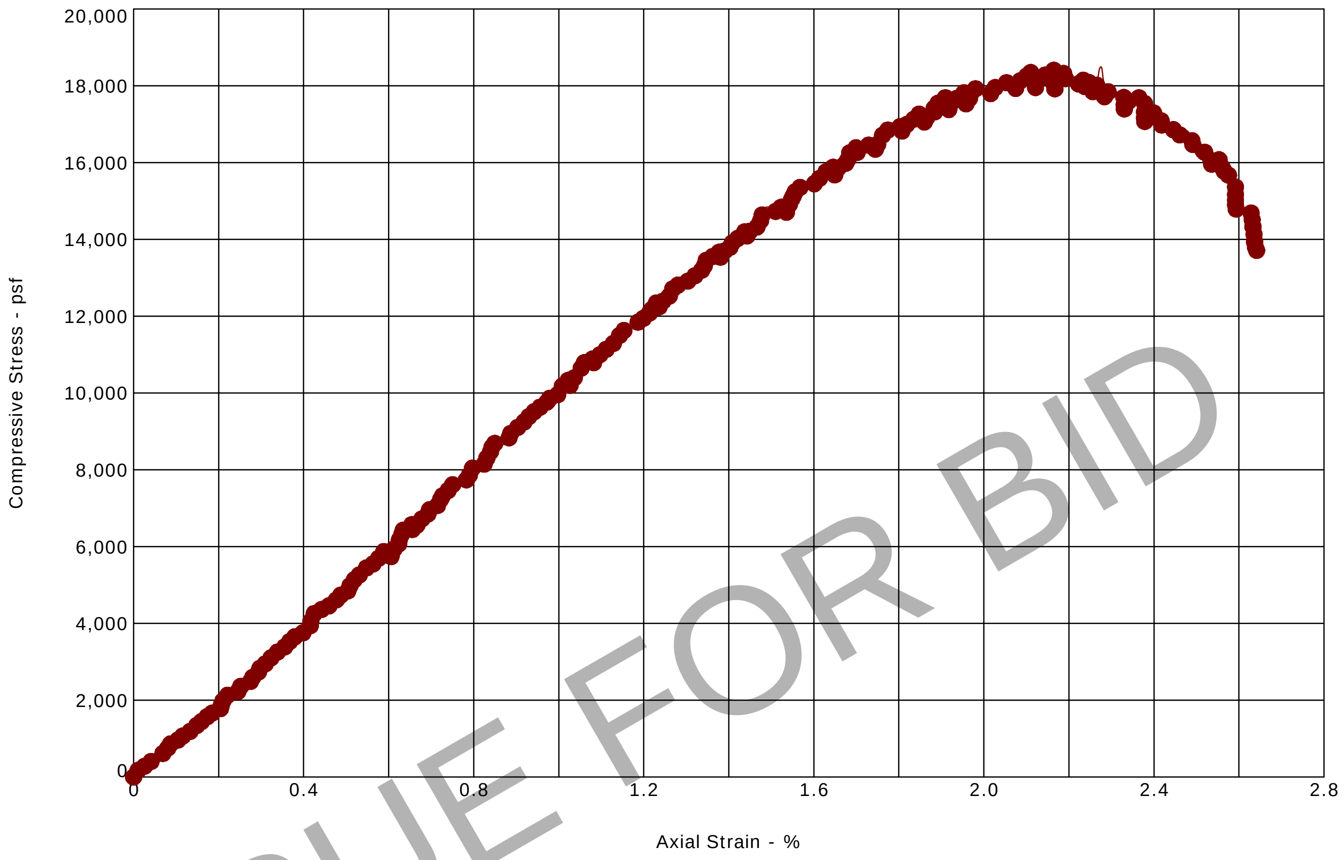
Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	11.1
Dry Density (pcf):	123
Diameter (in.):	1.94
Height (in.):	3.97
Height / Diameter Ratio:	2.05
Calculated Saturation (%):	81.70
Calculated Void Ratio:	0.37
Assumed Specific Gravity:	2.7
Failure Strain (%):	1.62
Unconfined Compressive Strength (psf):	10069
Undrained Shear Strength (psf):	5034
Strain Rate (in/min):	0.0800
Remarks:	

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-16	15	CARS	43	17	26	99.5	LEAN CLAY(CL)

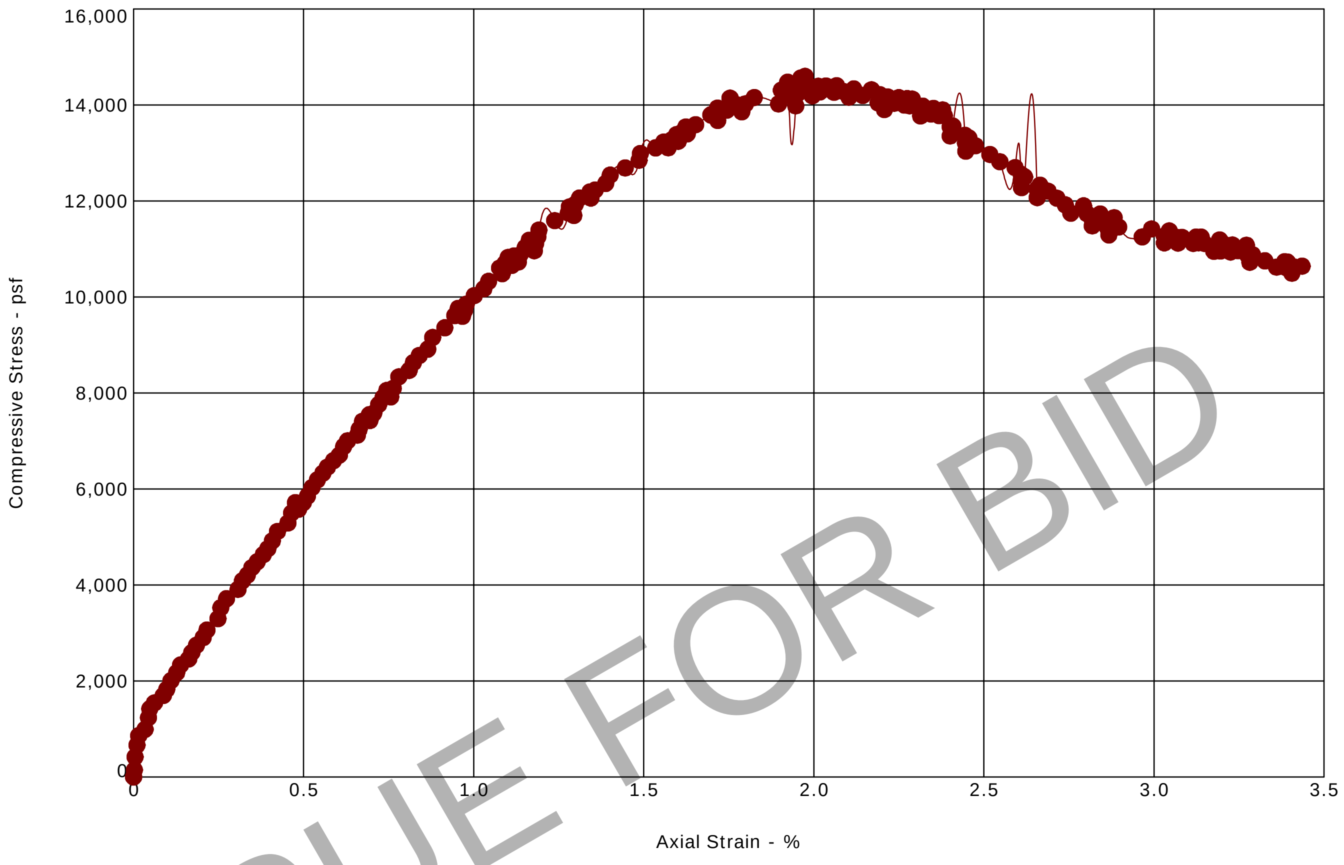
Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	16.6
Dry Density (pcf):	115
Diameter (in.):	1.94
Height (in.):	4.01
Height / Diameter Ratio:	2.06
Calculated Saturation (%):	94.89
Calculated Void Ratio:	0.47
Assumed Specific Gravity:	2.7
Failure Strain (%):	2.16
Unconfined Compressive Strength (psf):	18406
Undrained Shear Strength (psf):	9203
Strain Rate (in/min):	0.0800
Remarks:	

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-17-MW	40	CARS	50	19	31	99.7	FAT CLAY(CH)

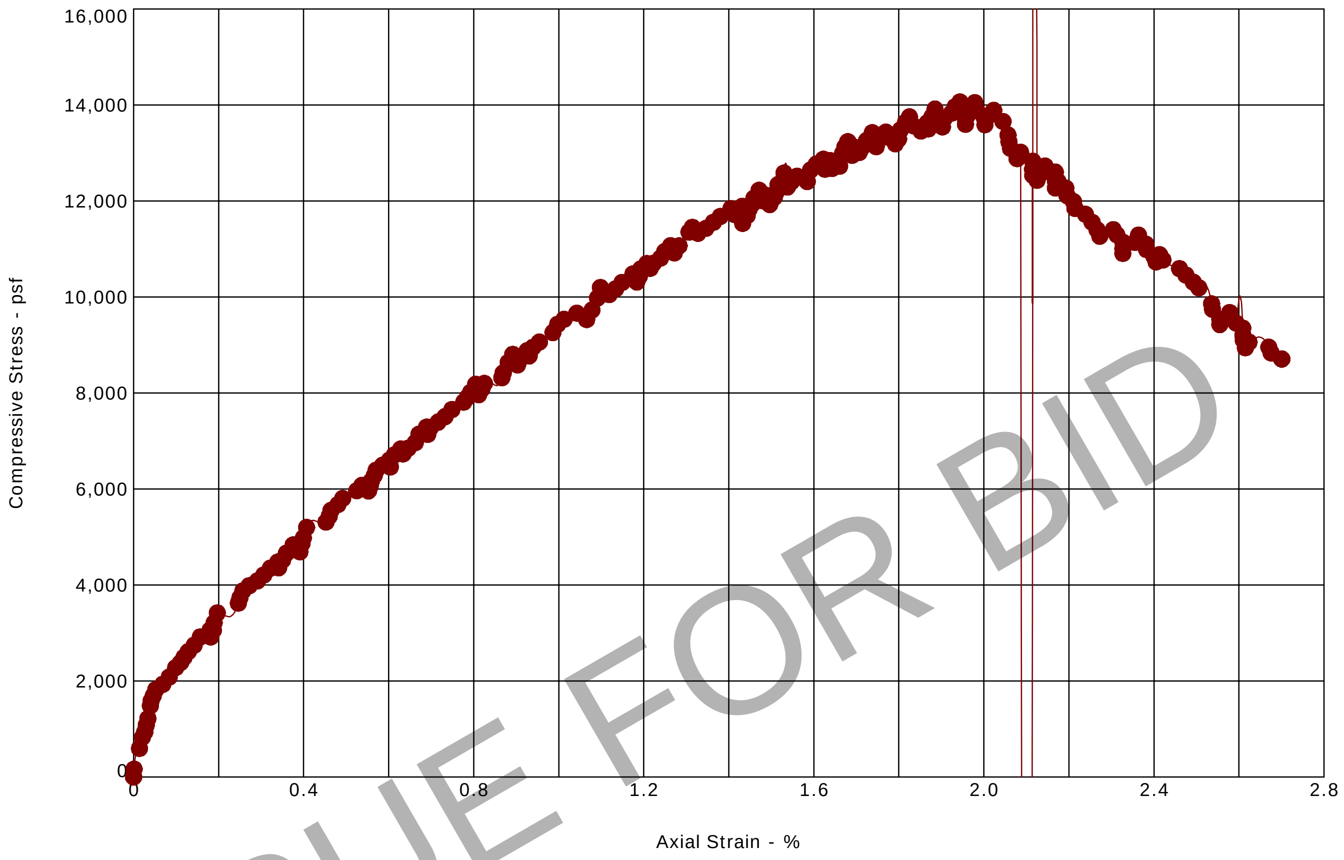
Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	16.6
Dry Density (pcf):	116
Diameter (in.):	1.94
Height (in.):	4.00
Height / Diameter Ratio:	2.06
Calculated Saturation (%):	98.58
Calculated Void Ratio:	0.45
Assumed Specific Gravity:	2.7
Failure Strain (%):	1.97
Unconfined Compressive Strength (psf):	14598
Undrained Shear Strength (psf):	7299
Strain Rate (in/min):	0.0800
Remarks:	

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-18-MW	40	CARS	48	20	28	99.1	LEAN CLAY(CL)

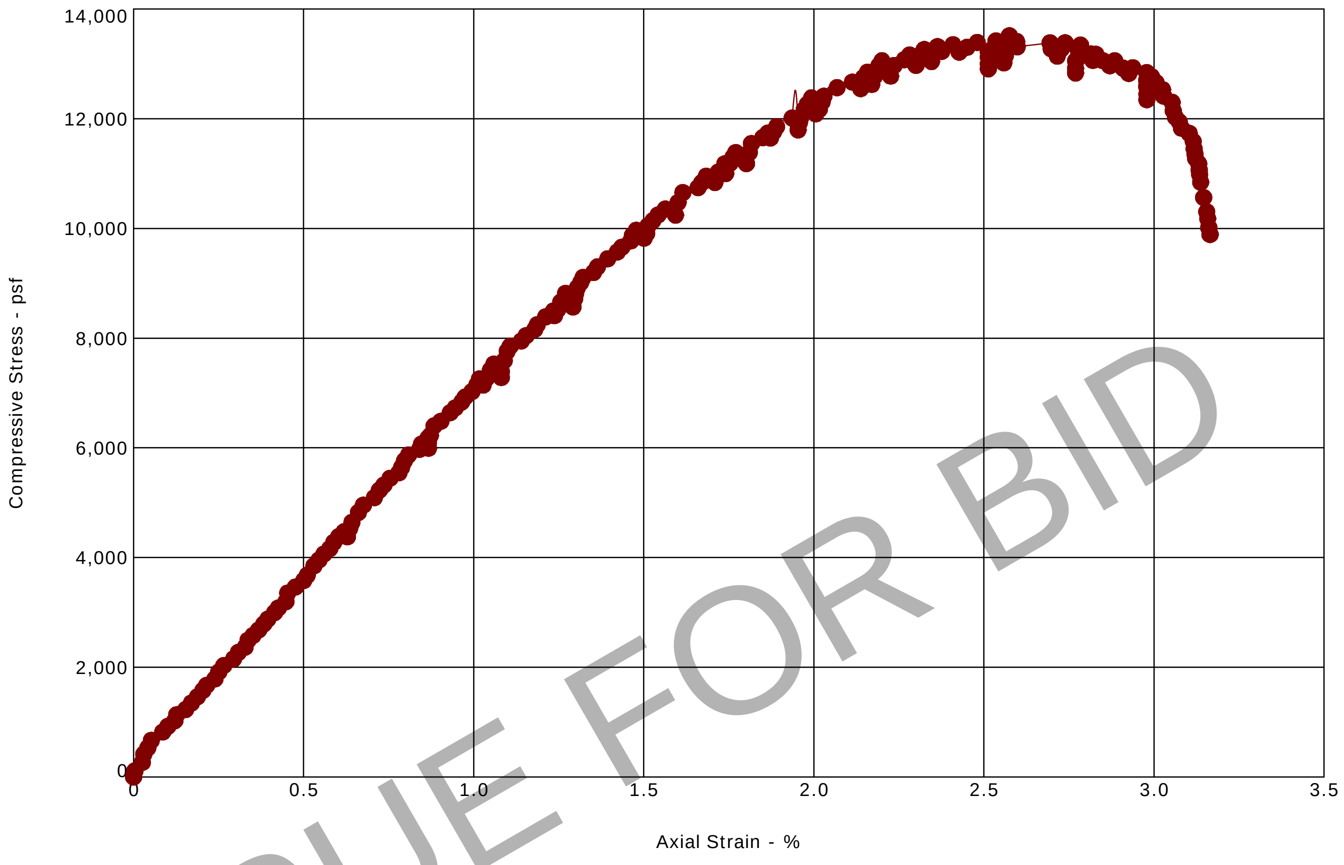
Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	17.1
Dry Density (pcf):	114
Diameter (in.):	1.94
Height (in.):	4.00
Height / Diameter Ratio:	2.06
Calculated Saturation (%):	97.10
Calculated Void Ratio:	0.48
Assumed Specific Gravity:	2.7
Failure Strain (%):	1.94
Unconfined Compressive Strength (psf):	14064
Undrained Shear Strength (psf):	7032
Strain Rate (in/min):	0.0800
Remarks:	

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-23-MW	45	CARS	48	21	27	97.7	LEAN CLAY(CL)

Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	17.6
Dry Density (pcf):	113
Diameter (in.):	1.94
Height (in.):	4.00
Height / Diameter Ratio:	2.06
Calculated Saturation (%):	96.02
Calculated Void Ratio:	0.49
Assumed Specific Gravity:	2.7
Failure Strain (%):	2.58
Unconfined Compressive Strength (psf):	13513
Undrained Shear Strength (psf):	6756
Strain Rate (in/min):	0.0800

Remarks:

Client

Lithos Engineering
Fort Collins, CO

Project

GEI-Lithos Lab Testing - NISP Northern Tier East
20255003-2

Date Received: 2/20/2025

Results from Corrosion Testing

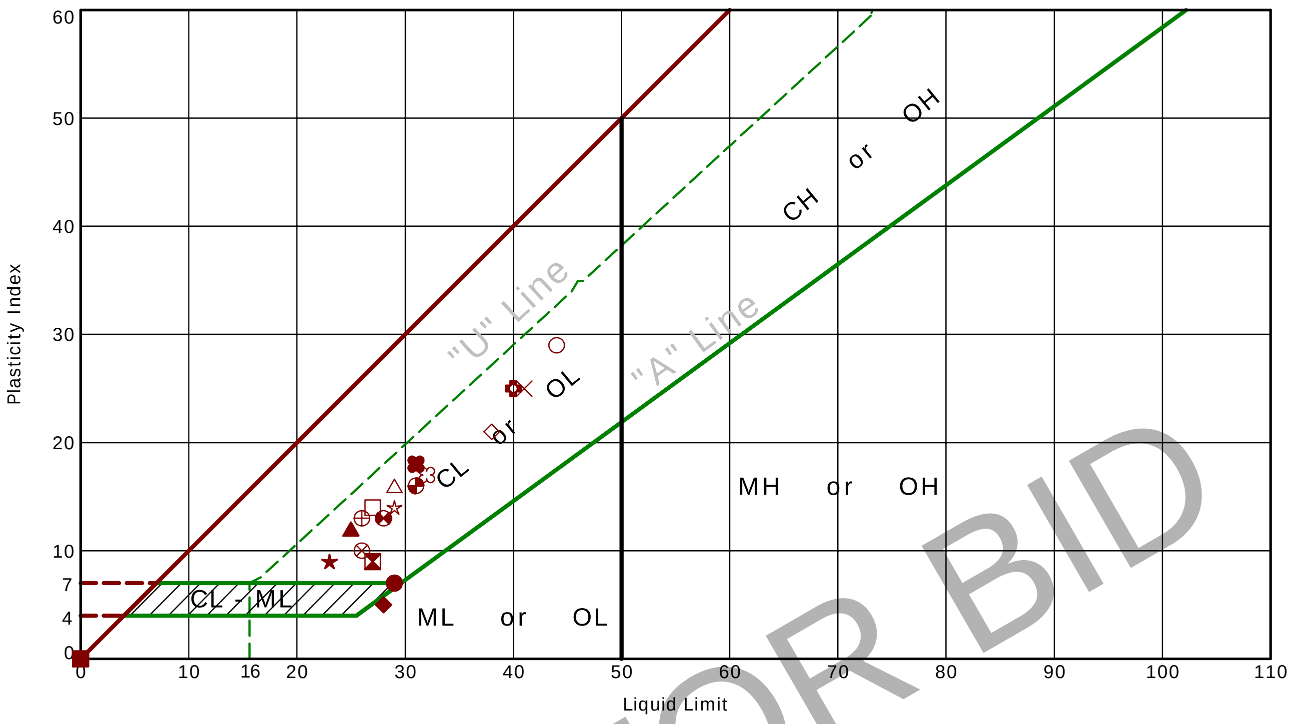
Sample Location	NTE-10-MW	NTE-17-MW	NTE-20	NTE-22-MW
Sample Depth (ft.)	2.5', 5' & 10'	7.5'	7.5'	7.5'
pH Analysis, AASHTO T289	8.26	7.68	NA	NA
Water Soluble Sulfate, ASTM C1580, (mg/kg)	402	2100	18476	10460
Sulfides, AWWA 4500-S D, (mg/kg)	Nil	Nil	NA	NA
Chloride, ASTM D512, (mg/kg)	1	9	NA	NA
Red-Ox, ASTM G200, (mV)	+214	+246	NA	NA
Total Salts, AWWA 2520 B, (mg/kg)	458	2265	NA	NA
Resistivity (Saturated), ASTM G57, (ohm-cm)	1600	1200	NA	NA

Analyzed By: Kyle Lemcke
Laboratory Manager

Terracon
1901 Sharp Point Dr Ste C
Fort Collins, CO

Atterberg Limit Results

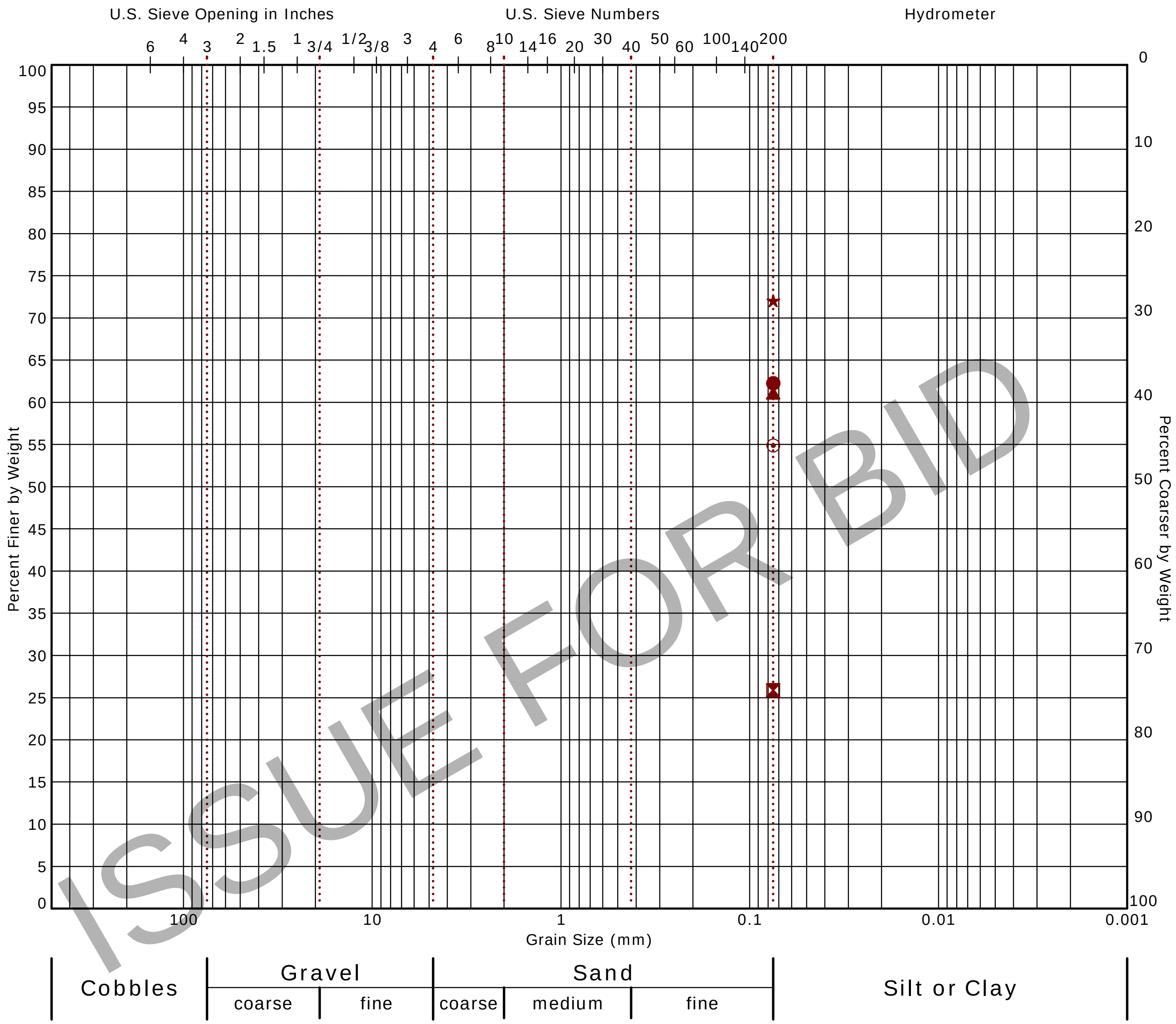
ASTM D4318



	Boring ID	Depth (Ft)	LL	PL	PI	Fines	USCS	Description
●	NTE-11	7.5	29	22	7	25.9	SC-SM	SILTY, CLAYEY SAND
⊠	NTE-12	7.5	27	18	9	61.1	CL	SANDY LEAN CLAY
▲	NTE-13	5	25	13	12	72.1	CL	LEAN CLAY with SAND
★	NTE-13	7.5	23	14	9	54.9	CL	SANDY LEAN CLAY
⊙	NTE-14-MW	7.5	NP	NP	NP	44.8	SM	SILTY SAND
✚	NTE-6-MW	5	40	15	25	73.0	CL	LEAN CLAY with SAND
○	NTE-6-MW	10	44	15	29			
△	NTE-6-MW	12.5	29	13	16	45.7	SC	CLAYEY SAND
⊗	NTE-6-MW	20	26	16	10	50.8	CL	SANDY LEAN CLAY
⊕	NTE-7	5	26	13	13	66.6	CL	SANDY LEAN CLAY
□	NTE-7	7.5	27	13	14	65.5	CL	SANDY LEAN CLAY
●	NTE-8	5	28	15	13	53.2	CL	SANDY LEAN CLAY
◕	NTE-8	10	31	15	16			
☆	NTE-9	5	29	15	14	53.4	CL	SANDY LEAN CLAY
⌘	NTE-9	10	32	15	17	67.0	CL	SANDY LEAN CLAY
■	NTE-9	15	NP	NP	NP	8.0		
◆	NTE-9	25	28	23	5	37.1	SM	SILTY SAND
◇	NTW-24	5	38	17	21	72.7	CL	LEAN CLAY with SAND
×	NTW-25	5	41	16	25	89.3	CL	LEAN CLAY
✤	NTW-26	12.5	31	13	18	64.5	CL	SANDY LEAN CLAY

Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27



Boring ID	Depth (Ft)	Description	USCS	LL	PL	PI	Cc	Cu
● NTE-11	5							
⊠ NTE-11	7.5	SILTY, CLAYEY SAND	SC-SM	29	22	7		
▲ NTE-12	7.5	SANDY LEAN CLAY	CL	27	18	9		
★ NTE-13	5	LEAN CLAY with SAND	CL	25	13	12		
⊙ NTE-13	7.5	SANDY LEAN CLAY	CL	23	14	9		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
● NTE-11	5	0.075							62.3		
⊠ NTE-11	7.5	0.075							25.9		
▲ NTE-12	7.5	0.075							61.1		
★ NTE-13	5	0.075							72.1		
⊙ NTE-13	7.5	0.075							54.9		

Grain Size Distribution

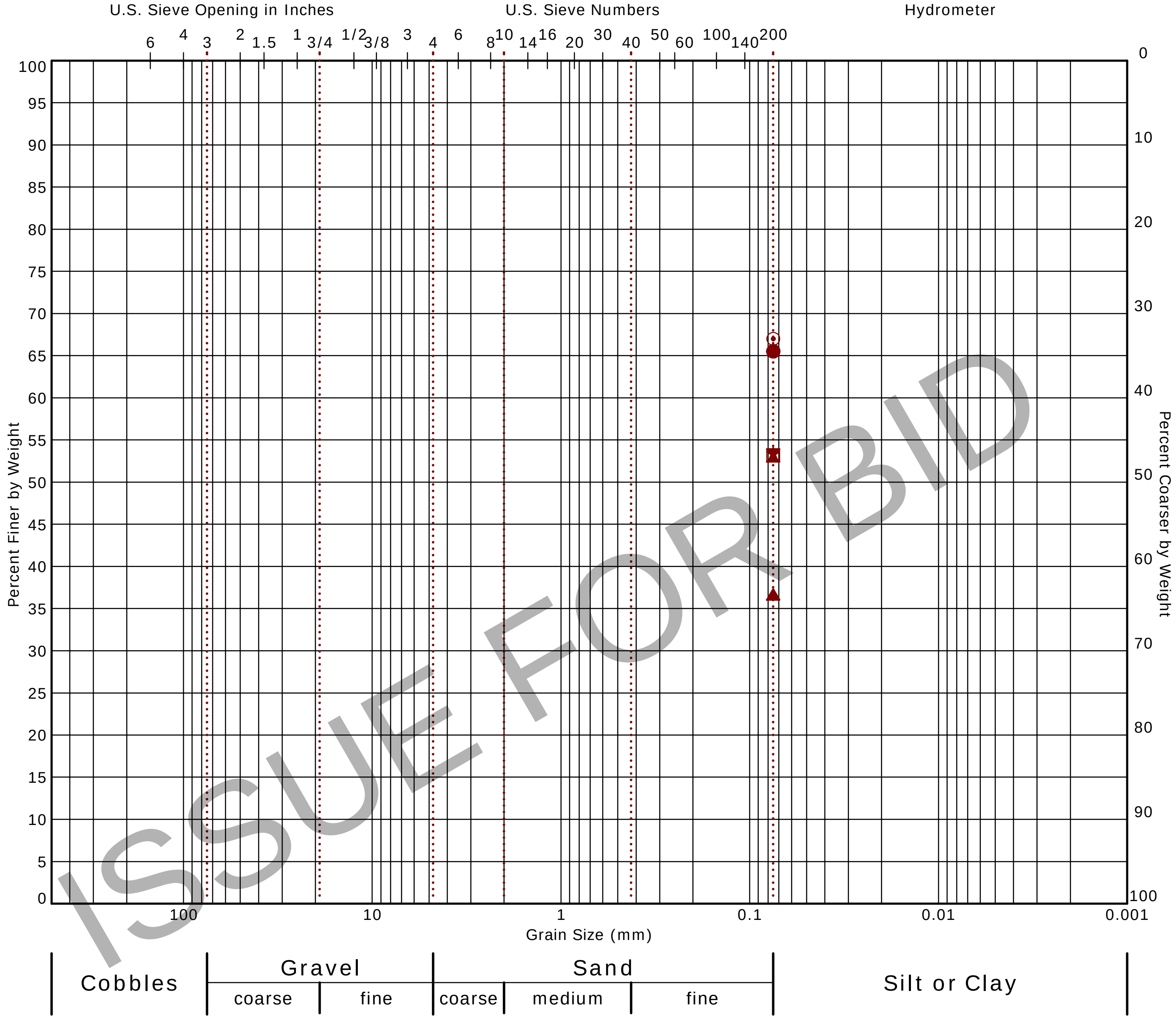
ASTM D422 / ASTM C136 / AASHTO T27

Boring ID	Depth (Ft)	Description	USCS	LL	PL	PI	Cc	Cu
● NTE-14-MW	7.5	SILTY SAND	SM	NP	NP	NP		
☒ NTE-6-MW	5	LEAN CLAY with SAND	CL	40	15	25		
▲ NTE-6-MW	12.5	CLAYEY SAND	SC	29	13	16		
★ NTE-6-MW	20	SANDY LEAN CLAY	CL	26	16	10		
⊙ NTE-7	5	SANDY LEAN CLAY	CL	26	13	13		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
● NTE-14-MW	7.5	0.075							44.8		
☒ NTE-6-MW	5	0.075							73.0		
▲ NTE-6-MW	12.5	0.075							45.7		
★ NTE-6-MW	20	0.075							50.8		
⊙ NTE-7	5	0.075							66.6		

Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27



Boring ID		Depth (Ft)	Description	USCS	LL	PL	PI	Cc	Cu
●	NTE-7	7.5	SANDY LEAN CLAY	CL	27	13	14		
⊠	NTE-8	5	SANDY LEAN CLAY	CL	28	15	13		
▲	NTE-8	15							
★	NTE-9	5	SANDY LEAN CLAY	CL	29	15	14		
⊙	NTE-9	10	SANDY LEAN CLAY	CL	32	15	17		

Boring ID		Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
●	NTE-7	7.5	0.075							65.5		
⊠	NTE-8	5	0.075							53.2		
▲	NTE-8	15	0.075							36.7		
★	NTE-9	5	0.075							53.4		
⊙	NTE-9	10	0.075							67.0		

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Grain Size Distribution

ASTM D422 / ASTM C136 / AASHTO T27

Boring ID	Depth (Ft)	Description	USCS	LL	PL	PI	Cc	Cu
● NTE-9	15			NP	NP	NP		
⊠ NTE-9	25	SILTY SAND	SM	28	23	5		
▲ NTW-24	5	LEAN CLAY with SAND	CL	38	17	21		
★ NTW-25	5	LEAN CLAY	CL	41	16	25		
⊙ NTW-26	12.5	SANDY LEAN CLAY	CL	31	13	18		

Boring ID	Depth (Ft)	D_{100}	D_{60}	D_{30}	D_{10}	%Cobbles	%Gravel	%Sand	%Fines	%Silt	%Clay
● NTE-9	15	0.075							8.0		
⊠ NTE-9	25	0.075							37.1		
▲ NTW-24	5	0.075							72.7		
★ NTW-25	5	0.075							89.3		
⊙ NTW-26	12.5	0.075							64.5		

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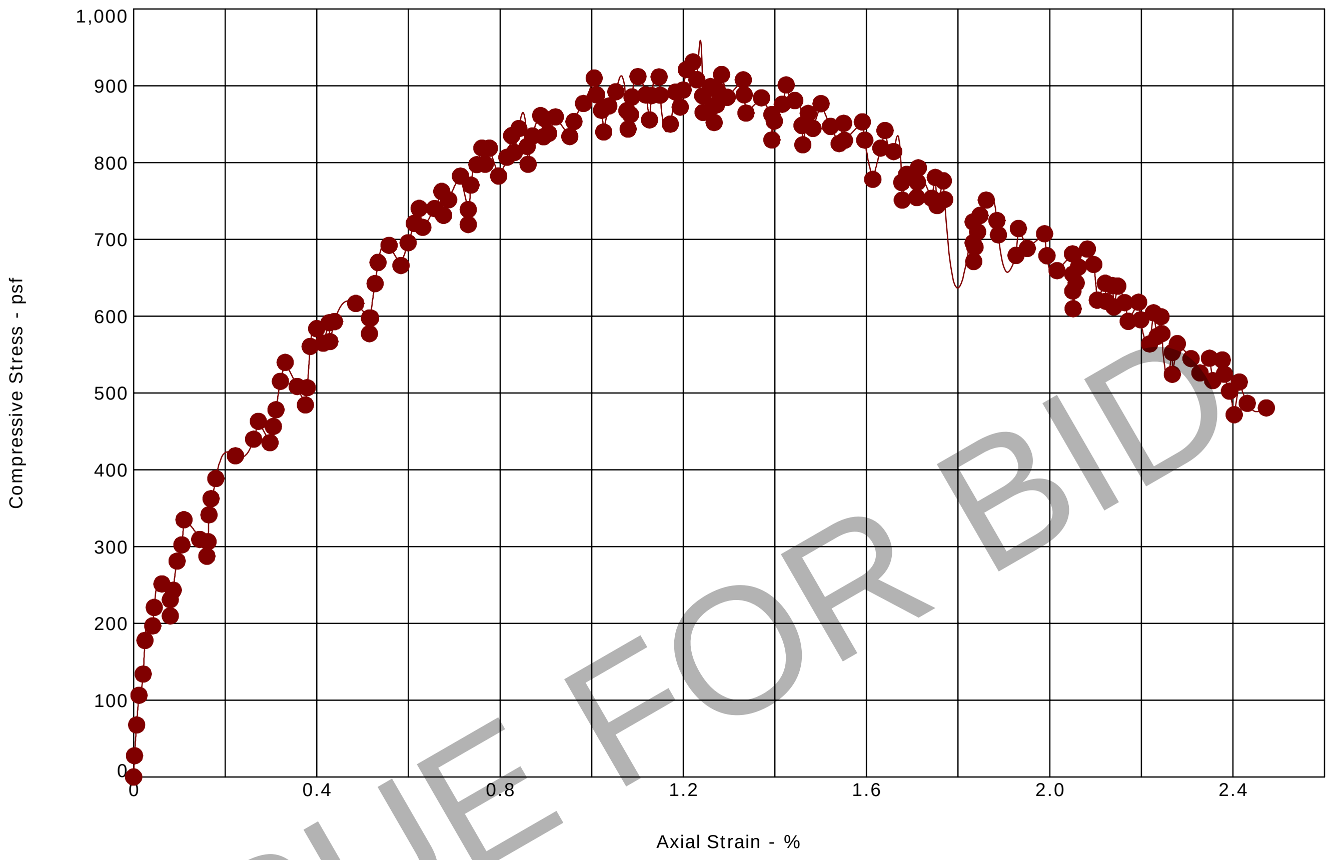
Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-11	7.5	CARS	29	22	7	25.9	SILTY, CLAYEY SAND(SC-SM)

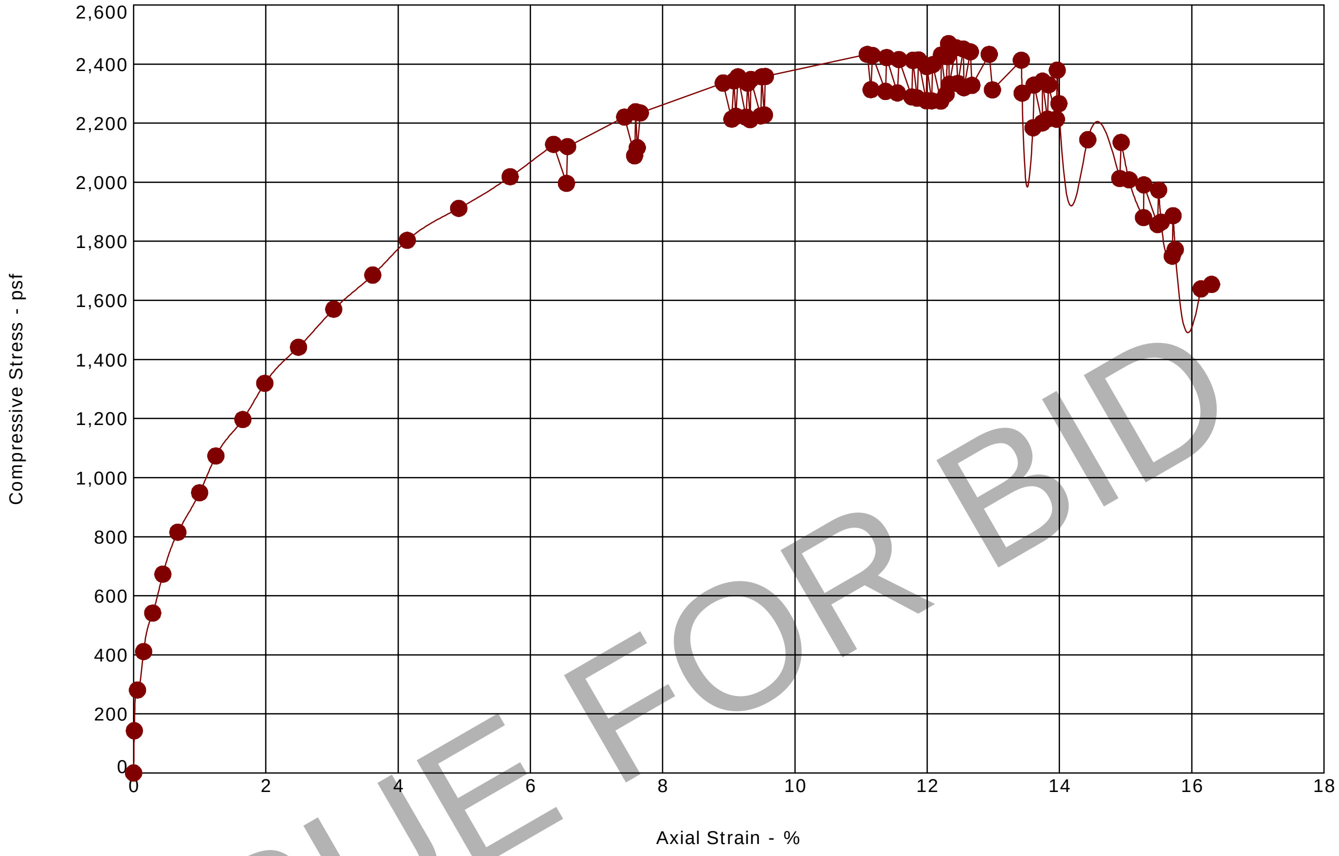
Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	18.4
Dry Density (pcf):	109
Diameter (in.):	1.93
Height (in.):	3.85
Height / Diameter Ratio:	1.99
Calculated Saturation (%):	90.27
Calculated Void Ratio:	0.55
Assumed Specific Gravity:	2.7
Failure Strain (%):	1.22
Unconfined Compressive Strength (psf):	931
Undrained Shear Strength (psf):	466
Strain Rate (in/min):	0.0800
Remarks:	

Unconfined Compression Test

ASTM D2166

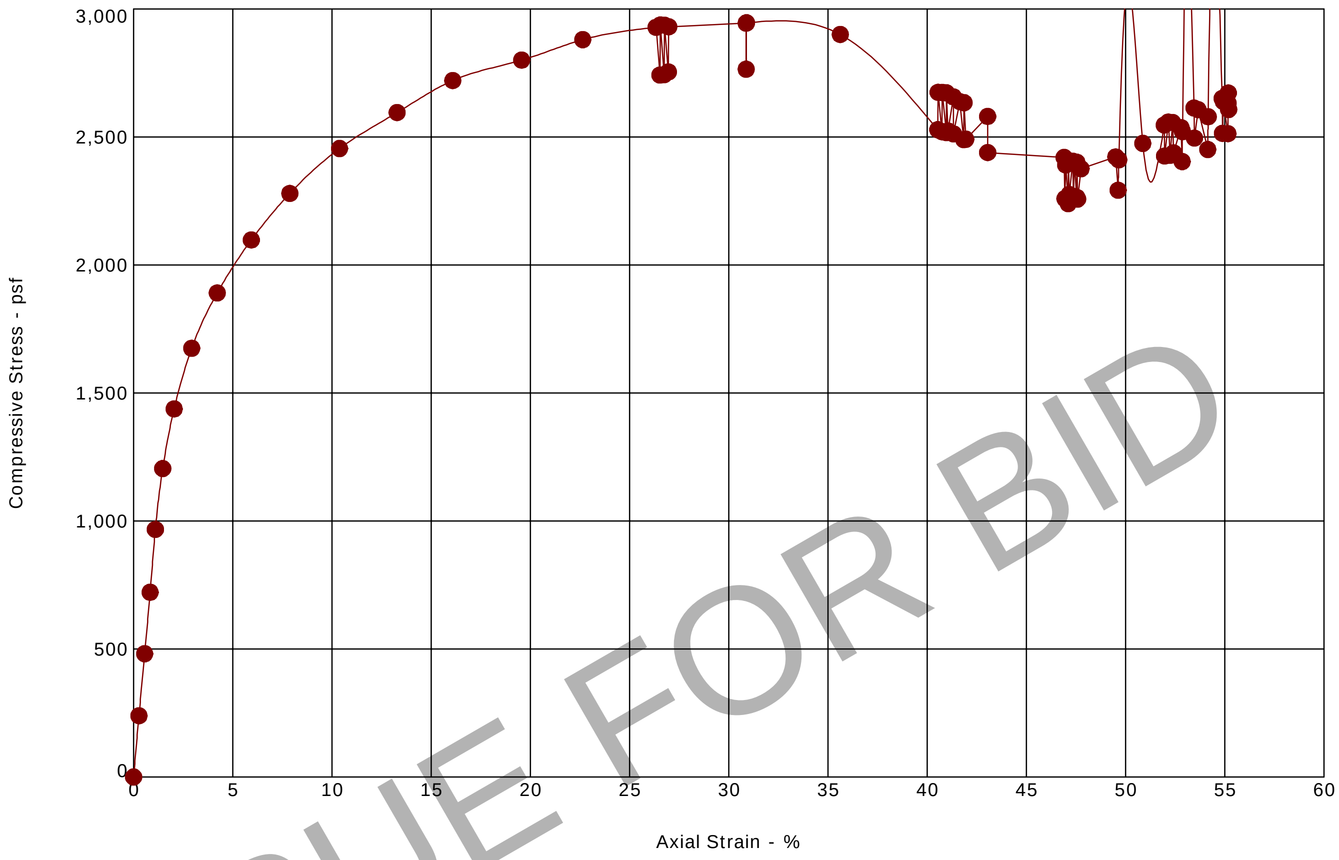


Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-6-MW	7.5	CARS					

Specimen Failure Mode	Specimen Test Data	
	Moisture Content (%):	25.4
	Dry Density (pcf):	99
	Diameter (in.):	1.94
	Height (in.):	3.85
	Height / Diameter Ratio:	1.99
	Calculated Saturation (%):	97.36
	Calculated Void Ratio:	0.70
	Assumed Specific Gravity:	2.7
	Failure Strain (%):	12.32
	Unconfined Compressive Strength (psf):	2469
	Undrained Shear Strength (psf):	1235
	Strain Rate (in/min):	0.0800
	Remarks:	

Unconfined Compression Test

ASTM D2166

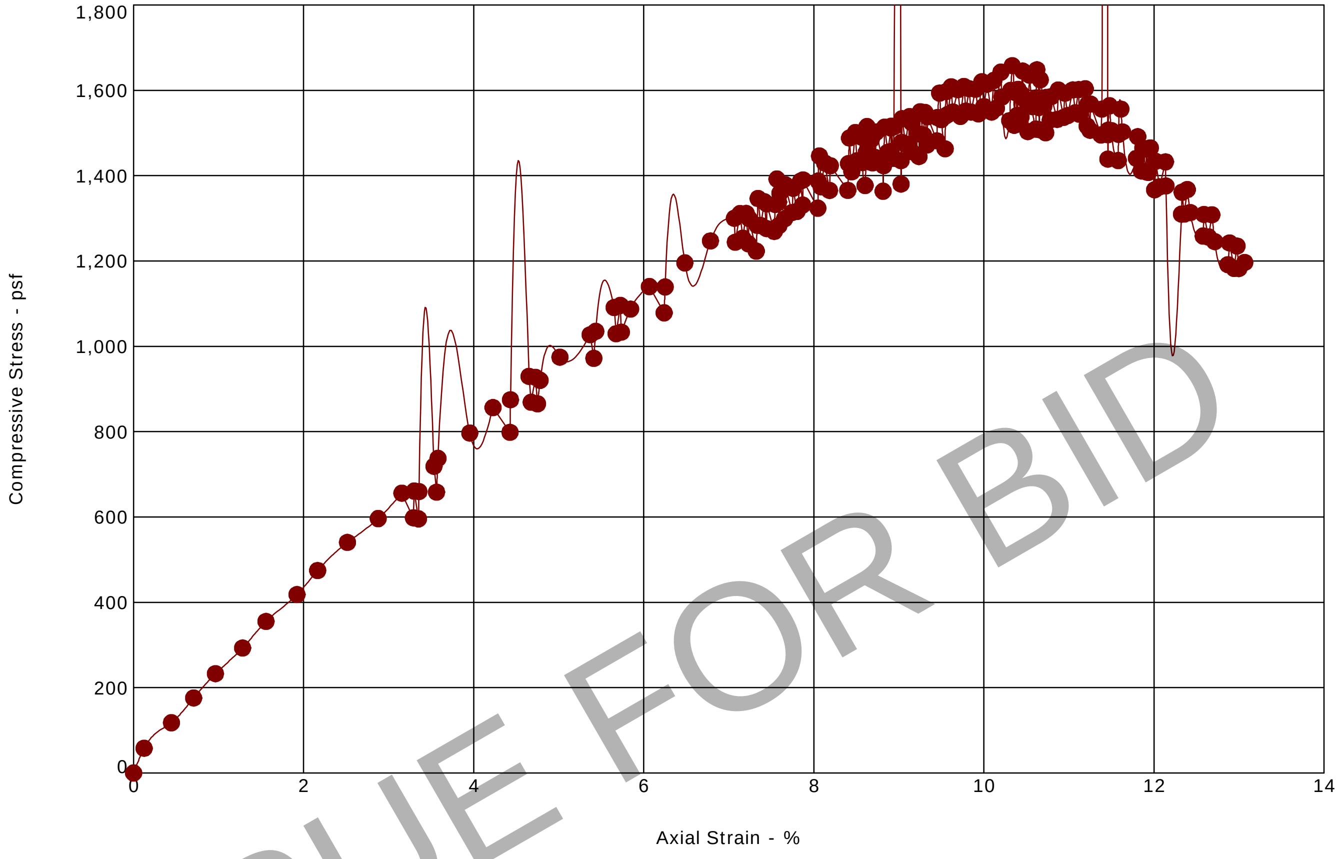


Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-6-MW	10	CARS	44	15	29		

Specimen Failure Mode	Specimen Test Data	
	Moisture Content (%):	24.8
	Dry Density (pcf):	102
	Diameter (in.):	1.92
	Height (in.):	3.93
	Height / Diameter Ratio:	2.05
	Calculated Saturation (%):	102.68
	Calculated Void Ratio:	0.65
	Assumed Specific Gravity:	2.7
	Failure Strain (%):	15.00
	Unconfined Compressive Strength (psf):	2672
	Undrained Shear Strength (psf):	1336
	Strain Rate (in/min):	0.0800
	Remarks:	

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-6-MW	20	CARS	26	16	10	50.8	SANDY LEAN CLAY(CL)

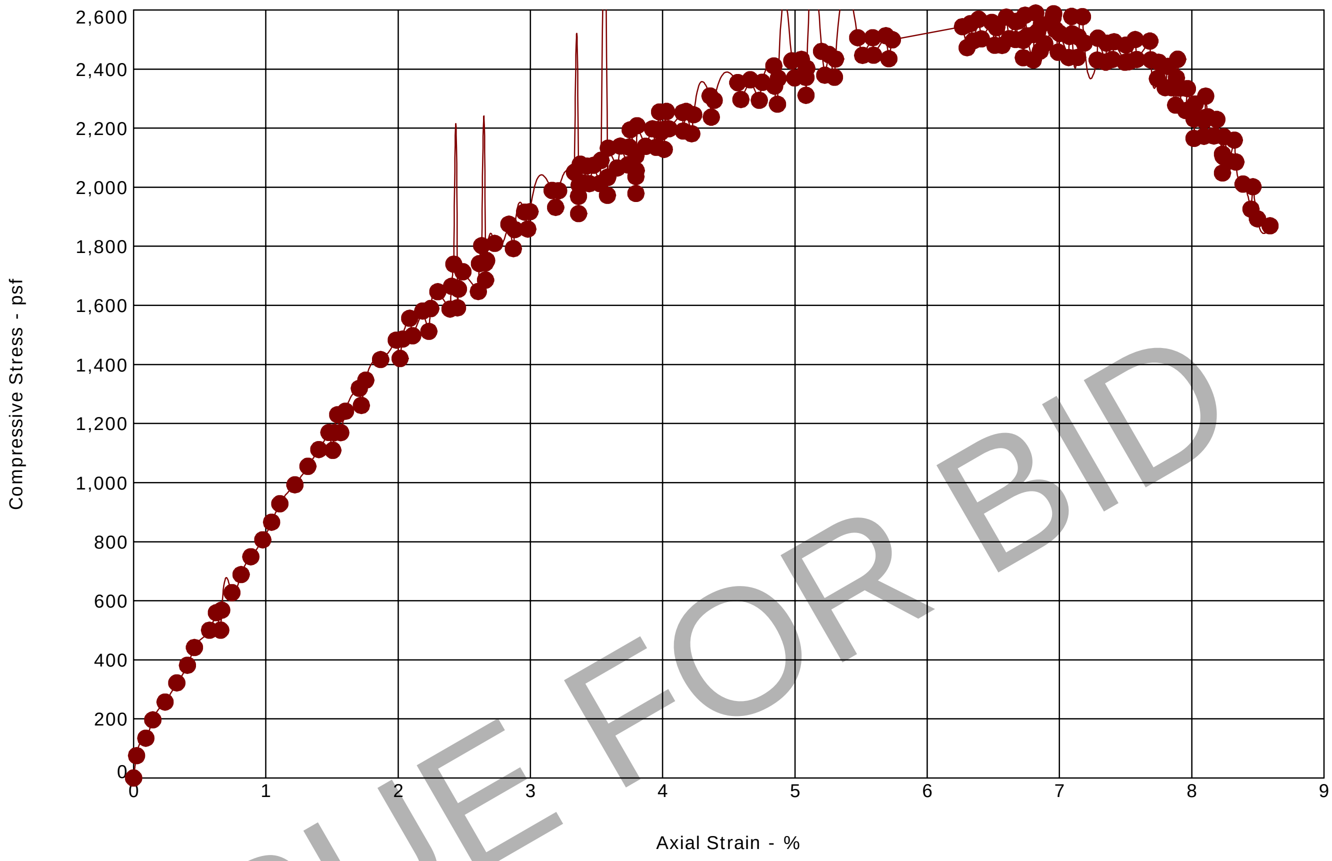
Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	18.3
Dry Density (pcf):	116
Diameter (in.):	1.90
Height (in.):	3.96
Height / Diameter Ratio:	2.08
Calculated Saturation (%):	109.26
Calculated Void Ratio:	0.45
Assumed Specific Gravity:	2.7
Failure Strain (%):	10.33
Unconfined Compressive Strength (psf):	1658
Undrained Shear Strength (psf):	829
Strain Rate (in/min):	0.0800
Remarks:	

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-7	5	CARS	26	13	13	66.6	SANDY LEAN CLAY(CL)

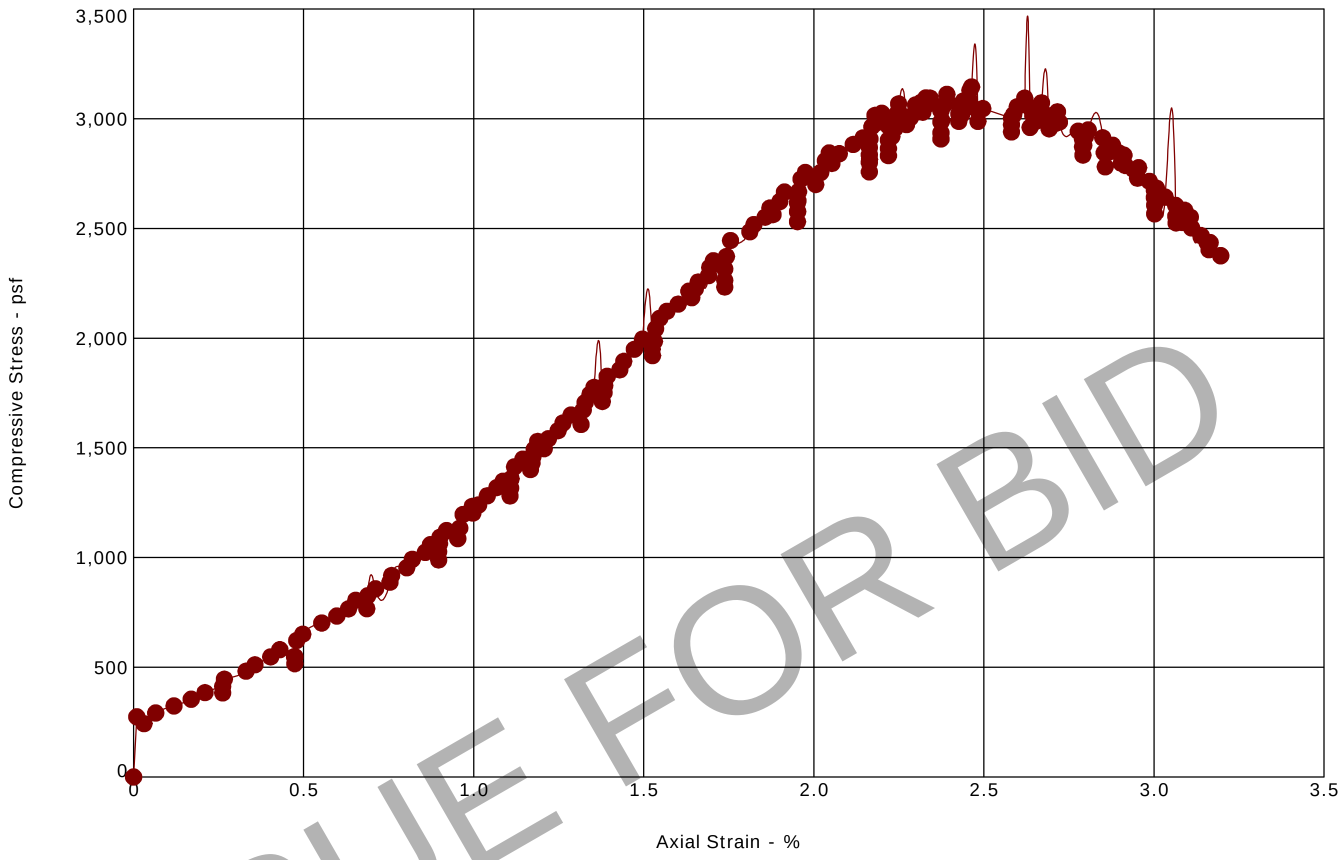
Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	16.6
Dry Density (pcf):	112
Diameter (in.):	1.92
Height (in.):	3.93
Height / Diameter Ratio:	2.05
Calculated Saturation (%):	89.44
Calculated Void Ratio:	0.50
Assumed Specific Gravity:	2.7
Failure Strain (%):	6.82
Unconfined Compressive Strength (psf):	2590
Undrained Shear Strength (psf):	1295
Strain Rate (in/min):	0.0800
Remarks:	

Unconfined Compression Test

ASTM D2166



Boring ID	Depth (Ft)	Sample type	LL	PL	PI	Fines (%)	Description
NTE-9	25	CARS	28	23	5	37.1	SILTY SAND(SM)

Specimen Failure Mode

Specimen Test Data

Moisture Content (%):	17.3
Dry Density (pcf):	112
Diameter (in.):	1.93
Height (in.):	4.00
Height / Diameter Ratio:	2.08
Calculated Saturation (%):	92.33
Calculated Void Ratio:	0.51
Assumed Specific Gravity:	2.7
Failure Strain (%):	2.46
Unconfined Compressive Strength (psf):	3145
Undrained Shear Strength (psf):	1572
Strain Rate (in/min):	0.0800
Remarks:	

Client

GEI Consultants, Inc.
724 Whalers Way, Suite H100
Fort Collins, CO

Project

NISP NTE-NTW
20255003-7

Date Received: 4/9/2024

Results from Corrosion Testing

Sample Location	NTE-12	NTW-24	NTW-26	NTW-29
Sample Depth (ft.)	5	7.5	7.5	15
Water Soluble Sulfate (SO4), AASHTO T290, (mg/kg)	870	804	810	879

Analyzed By: Chloe Lewis
Laboratory Supervisor

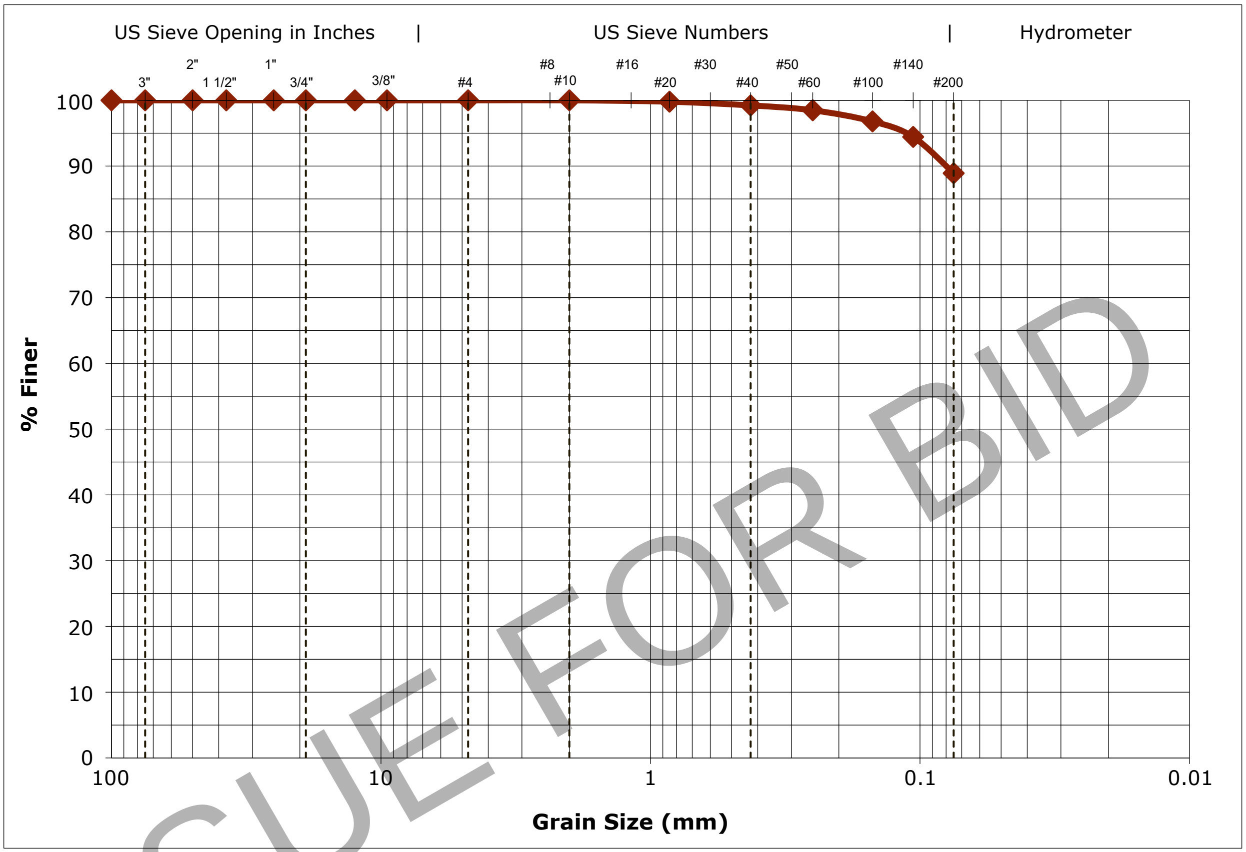
The tests were performed in general accordance with applicable ASTM and AASHTO test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

GEI **Misc Lab Testing**
GEI Job No. 2505320 | Thornton Seg F
Terracon Project No. 20265012

Fort Collins, CO 80525

Particle-Size Distribution of Soils Using Sieve Analysis

ASTM D6913 - Single Set Method



Boring ID	Depth (Ft.)	Description	USCS	% Cobbles	% Gravel	% Sand	% Fines
NTE-6-MW	7.5			0.0	0.0	11.1	88.9

Sieve	% Finer	Sieve	% Finer	Coefficients	
5"	100.0	#20	99.8	C_C	
4"	100.0	#40	99.2		
3"	100.0	#60	98.5	C_U	
2"	100.0	#100	96.8		
1 1/2"	100.0	#140	94.4		
1"	100.0	#200	88.9		
3/4"	100.0	**Grain Size**		**Remarks**	
1/2"	100.0	D_{100}	2.000		
3/8"	100.0	D_{60}			
#4	100.0	D_{30}			
#10	100.0	D_{10}			

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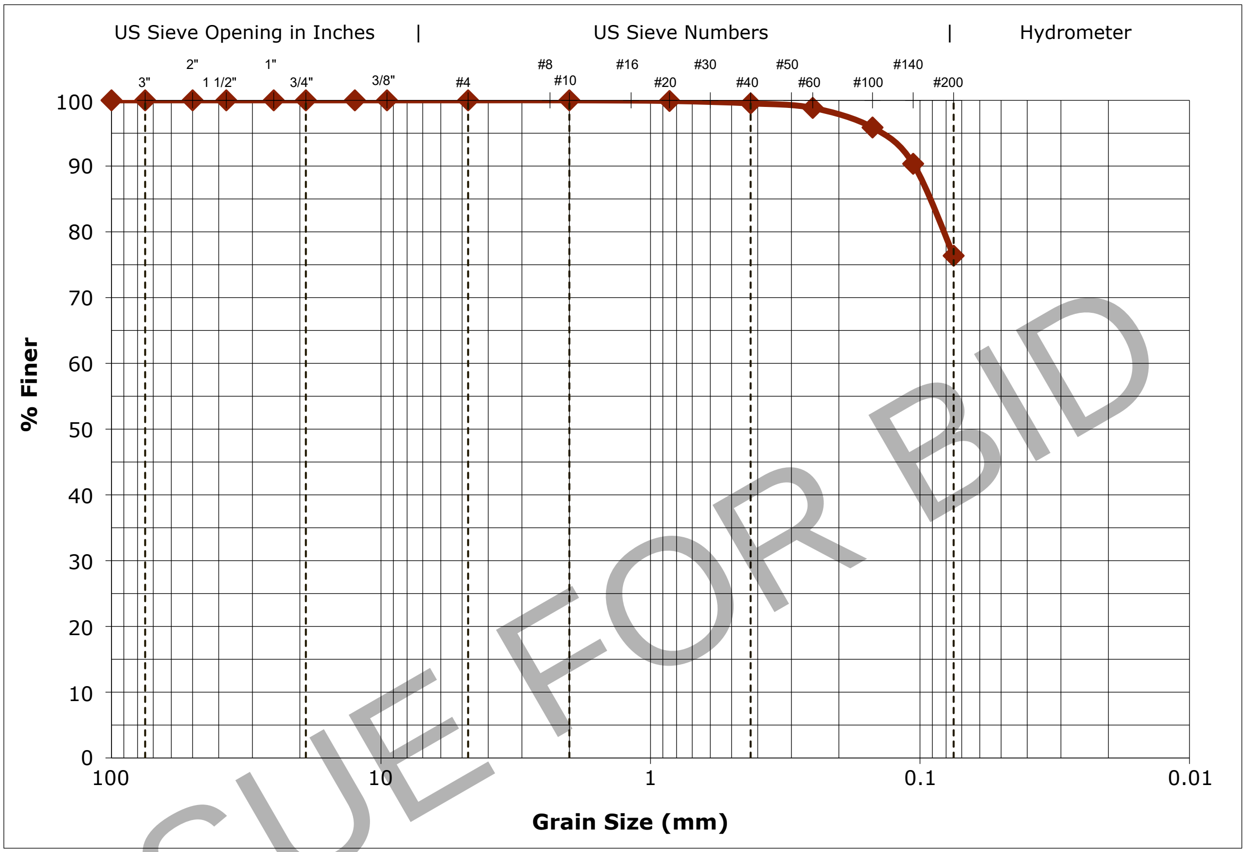
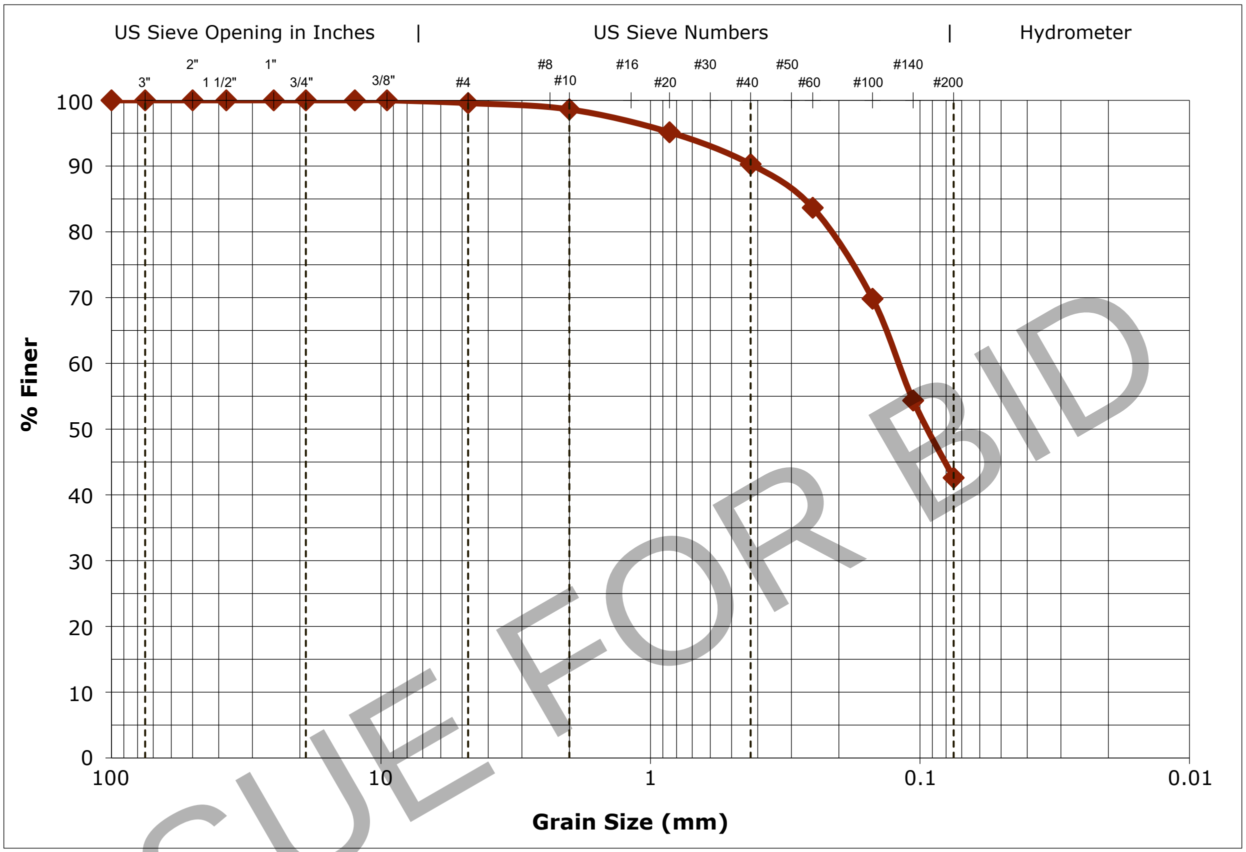


Boring ID	Depth (Ft.)	Description	USCS	% Cobbles	% Gravel	% Sand	% Fines
NTE-8	7.5			0.0	0.0	23.6	76.4

Sieve	% Finer	Sieve	% Finer	Coefficients	
5"	100.0	#20	99.9	C_C	
4"	100.0	#40	99.5		
3"	100.0	#60	98.8	C_U	
2"	100.0	#100	95.9		
1 1/2"	100.0	#140	90.3		
1"	100.0	#200	76.4		
3/4"	100.0	**Grain Size**		**Remarks**	
1/2"	100.0	D_{100}	2.000		
3/8"	100.0	D_{60}			
#4	100.0	D_{30}			
#10	100.0	D_{10}			

Particle-Size Distribution of Soils Using Sieve Analysis

ASTM D6913 - Single Set Method

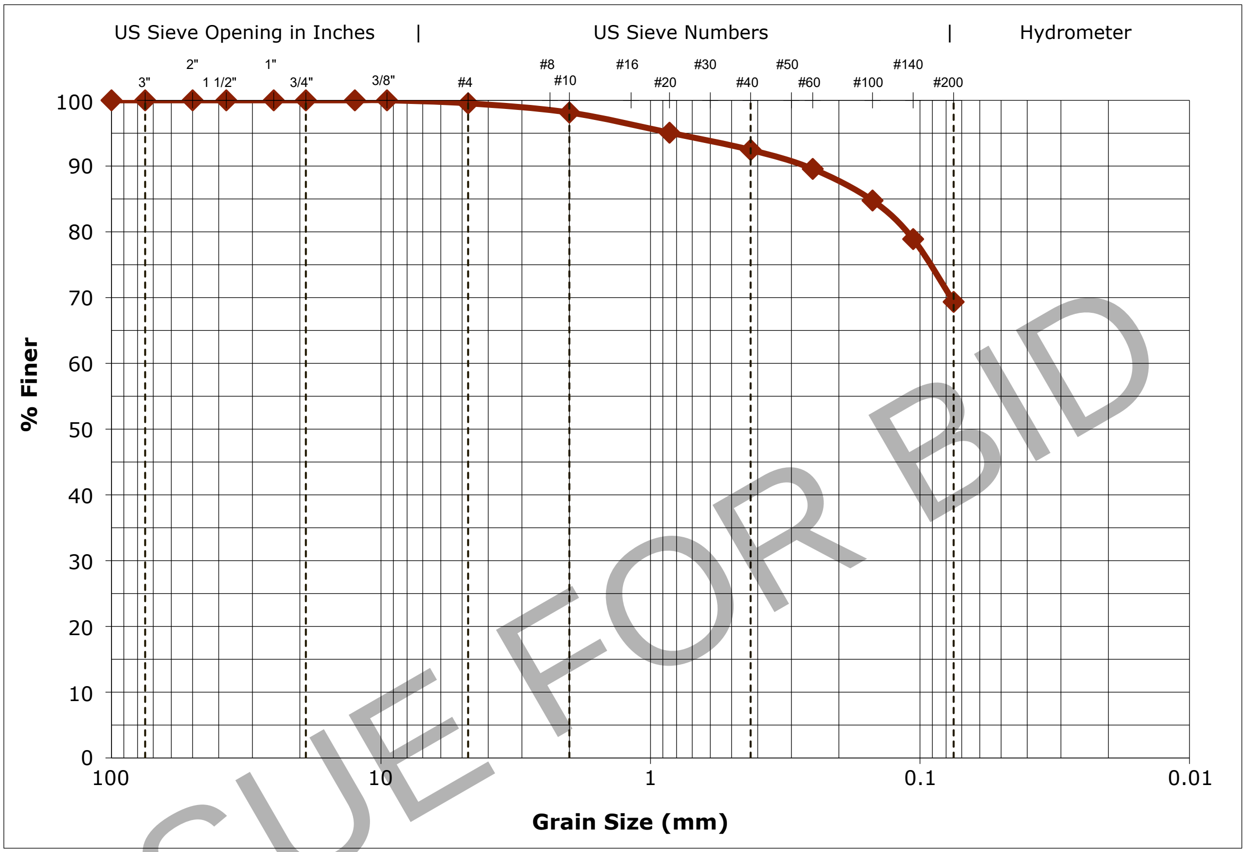


Boring ID	Depth (Ft.)	Description	USCS	% Cobbles	% Gravel	% Sand	% Fines
NTE-9	12.5			0.0	0.4	57.0	42.6

Sieve	% Finer	Sieve	% Finer	Coefficients	
5"	100.0	#20	95.1	C_C	
4"	100.0	#40	90.3		
3"	100.0	#60	83.7	C_U	
2"	100.0	#100	69.8		
1 1/2"	100.0	#140	54.4		
1"	100.0	#200	42.6		
3/4"	100.0	Grain Size		Remarks	
1/2"	100.0	D_{100}	9.500		
3/8"	100.0	D_{60}	0.120		
#4	99.6	D_{30}			
#10	98.6	D_{10}			

Particle-Size Distribution of Soils Using Sieve Analysis

ASTM D6913 - Single Set Method

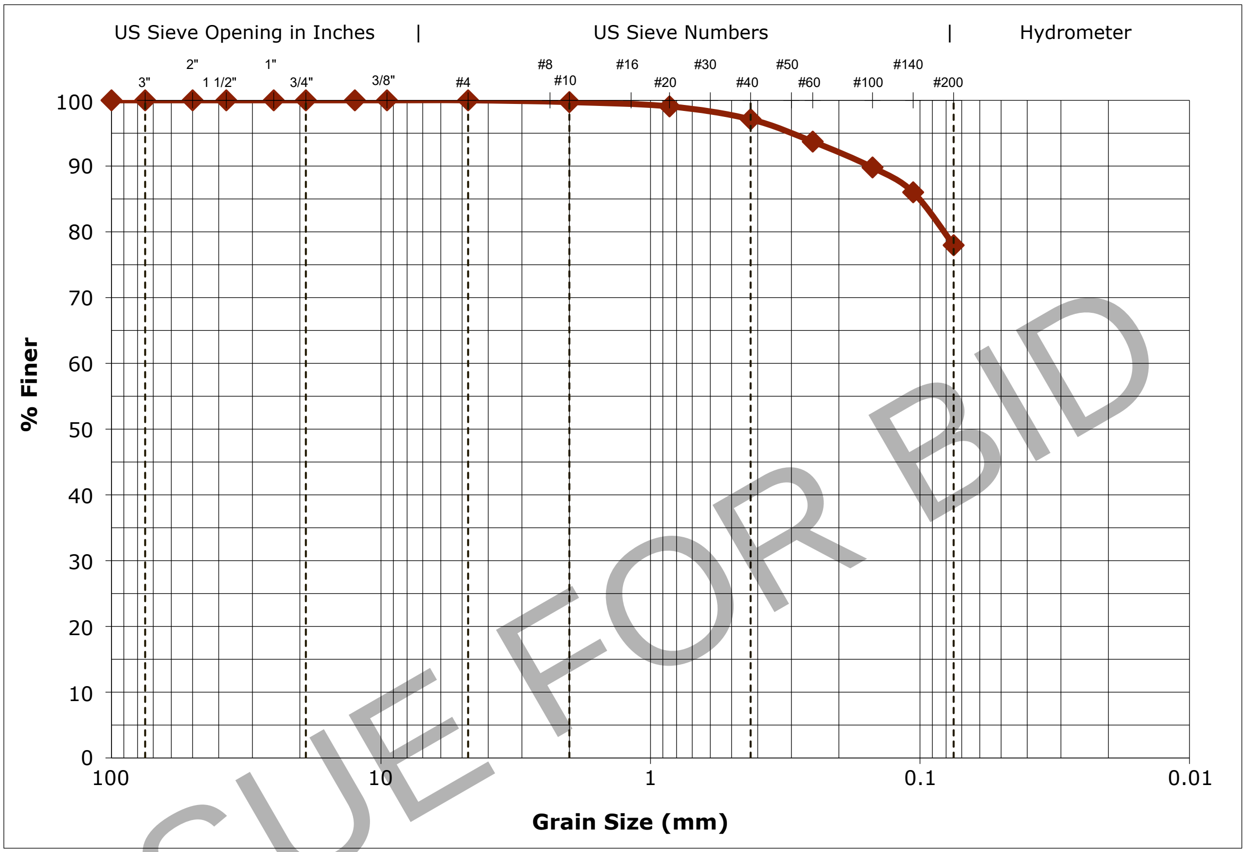


Boring ID	Depth (Ft.)	Description	USCS	% Cobbles	% Gravel	% Sand	% Fines
NTE-14-MW	15			0.0	0.5	30.2	69.4

Sieve	% Finer	Sieve	% Finer	Coefficients	
5"	100.0	#20	95.1	C_C	
4"	100.0	#40	92.5		
3"	100.0	#60	89.6	C_U	
2"	100.0	#100	84.8		
1 1/2"	100.0	#140	78.9		
1"	100.0	#200	69.3		
3/4"	100.0	**Grain Size**		**Remarks**	
1/2"	100.0	D_{100}	9.500		
3/8"	100.0	D_{60}			
#4	99.5	D_{30}			
#10	98.1	D_{10}			

Particle-Size Distribution of Soils Using Sieve Analysis

ASTM D6913 - Single Set Method



Boring ID	Depth (Ft.)	Description	USCS	% Cobbles	% Gravel	% Sand	% Fines
NTE-15	7.5			0.0	0.0	22.0	78.0

Sieve	% Finer	Sieve	% Finer	Coefficients	
5"	100.0	#20	99.1	C_C	
4"	100.0	#40	97.1		
3"	100.0	#60	93.7	C_U	
2"	100.0	#100	89.8		
1 1/2"	100.0	#140	86.0		
1"	100.0	#200	78.0		
3/4"	100.0	**Grain Size**		**Remarks**	
1/2"	100.0	D_{100}	4.750		
3/8"	100.0	D_{60}			
#4	100.0	D_{30}			
#10	99.7	D_{10}			

Appendix C Laboratory Corrosion Testing Results

C.1. Laboratory Corrosion Testing Summary Table

C.2. Field Resistivity Testing Summary Table

C.1. Laboratory Corrosion Testing Summary Table

Sample Identification		Corrosion Testing[1,2]						
Boring	Sample Depth (ft)	Sulfates (ppm)	Chlorides (ppm)	Resistivity (ohm-cm)	pH	Redox (mV)	Sulfide (ppm)	Total Salts (ppm)
NTE-10-MW	2.5, 5, 10	402	1	1,600	8.3	214	ND	458
NTE-17-MW	7.5	2,100	9	1,200	7.7	246	ND	2265
NTE-20	7.5	18,476	NA	NA	NA	NA	NA	NA
NTE-22-MW	7.5	10,460	NA	NA	NA	NA	NA	NA

Notes:

1. "ND" indicates not detected.
2. "NA" indicates not tested.

C.2. Field Resistivity Testing Summary Table

C.2. Field Resistivity Testing Summary Table

Sample Identification		Sample Properties			Corrosion Classifications		
Test ID	**Test Depth (ft.)**	**Geologic Classification**	**Field Resistivity (ohm-cm)**	**Lab Resistivity (Saturated) (ohm-cm)**	**Soil Group for Soil Resistivity**	**Drainage Ability[1]**	**Corrosion Potential**
FR-1	5	Lean Clay (CL)	3667		III	Poor	Severely Corrosive
	10	Lean Clay (CL)	1953		IV	Poor	Unusually Corrosive
	15	Lean Clay (CL)	2183		III	Poor	Severely Corrosive
	20	Lean Clay (CL)	2834		III	Poor	Severely Corrosive
FR-2	5	Lean Clay (CL)	1034		IV	Poor	Unusually Corrosive
	10	Lean Clay (CL)	1168	1200	IV	Poor	Unusually Corrosive
	15	Poorly Graded Sand with Clay and Gravel (SP-SC)	1293		IV	Fair	Unusually Corrosive
	20	Poorly Graded Sand with Clay and Gravel (SP-SC)	1341		IV	Good	Unusually Corrosive
FR-3	5	Poorly Graded Sand with Clay (SP-SC)	1963		IV	Fair	Unusually Corrosive
	10	Lean Clay (CL)	1513		IV	Poor	Unusually Corrosive
	15	Well-Graded Sand with Clay and Gravel (SW-SC)	1379		IV	Fair	Unusually Corrosive
	20	Shale	1302		IV	Poor	Unusually Corrosive
FR-4	5	Clayey Sand (SC)	1034		IV	Poor	Unusually Corrosive
	10	Lean Clay (CL)	1053	1600	IV	Poor	Unusually Corrosive
	15	Sandstone	1120		IV	Good	Unusually Corrosive
	20	Sandstone	1111		IV	Good	Unusually Corrosive
FR-5	5	Silty Clay (CL-ML)	1187		IV	Poor	Unusually Corrosive
	10	Lean Clay (CL)	651		IV	Poor	Unusually Corrosive
	15	Clayey Sand (SC)	575		IV	Poor	Unusually Corrosive
	20	-	575		IV	-	Unusually Corrosive

Notes:

1. Drainage ability based on subsurface conditions near Test ID identified in the boring logs

Technical Memorandum

724 Whalers Way ● Fort Collins, CO 80525 ● 970.373.3195

Via Email: Peter.brask@hdrinc.com
To: Peter Brask, PE, HDR Engineering, Inc.
From: Dylan Fawaz, PE
Date: August, 2026
Re: Geotechnical Design Memorandum
Thornton Water Segment F.2 – Issue For Bid
Fort Collins, Colorado
Project No.: 2505320

Mr. Brask,

This memorandum presents our geotechnical recommendations for the Thornton Water Pipeline Project – Segment F.2. This study was conducted in general accordance with our Master Subconsultant Agreement with HDR Engineering Inc., and project specific task order dated September 10th, 2025.

If you have any questions regarding the contents of this memorandum, please contact the undersigned.

Sincerely,

GEI Consultants

Luke Hitchens, EI
Staff Engineer

Dylan Fawaz, PE
Project Manager

Nate Soule, PE, PG
Vice President

Table of Contents

1. Introduction

The Thornton Raw Waterline – Segment F.2 (Project), part of the Thornton Raw Water Project, owned by City of Thornton (Owner) includes the installation of a water pipeline collocated with the Northern Tier East (NTE) pipeline alignment which is a part of the greater Northern Integrated Supply Project (NISP). The purpose of the project is to construct infrastructure for the City of Thornton (City) to divert water from the Cache La Poudre River to provide to their customers and meet increasing demand (Thornton, 2025). The Thornton Water Project is broken into six sections labeled A, B, C, D, E, and F. Sections A, B, and C are under active construction while section D is complete. Section E is currently under construction, and section F is currently undergoing design (Thornton, 2025).

The purpose of this memorandum is to provide geotechnical recommendations for design and construction of the pipelines and associated project components based on the geotechnical information gathered and presented in the project Geotechnical Data Report (GDR). A Geotechnical Baseline Report (GBR) has been generated as part of this Project and will be provided under a separate cover to further discuss geotechnical baselines and tunneling means and methods for the trenchless crossings based on geotechnical data.

2. Geotechnical Design Recommendations

The following sections are included primarily for the engineer performing design. If additional geotechnical design recommendations are necessary, GEI should be contacted to provide the required information.

2.1. Lateral Earth Pressures

Lateral earth pressures presented in Table 2-1 below should be considered during the structural design process for the pipeline and other elements extending below grade. Lateral earth pressure values are a function of the properties and the geometry of the retained fill, soil, and/or bedrock and anticipated magnitude of lateral deflection. In addition, the presence of groundwater and saturated materials will increase the total horizontal stress, resulting in higher lateral earth pressures in comparison to retained materials above a groundwater table.

Table 2-1. Static Lateral Earth Pressures

Backfill Material Type	Unit Weight (pcf)	Friction Angle (degrees)	Static Earth Pressure Coefficients			Static Equivalent Fluid Pressure (pcf)					
						Active		At-Rest		Passive	
			Active	At-Rest	Passive	Above GWT[1]	Below GWT[1]	Above GWT[1]	Below GWT[1]	Above GWT[1]	Below GWT[1]
Structure Backfill	130	34	0.28	0.44	3.54	37	82	57	92	460	302
General Backfill	125	30	0.33	0.5	3.00	42	83	63	94	375	250

Notes:
1. GWT stands for Groundwater Table.

For the lateral earth pressures presented above to remain applicable, backfill material placement adjacent to below-grade walls should be in accordance with procedures outlined in Section 3.2.3. I Consideration has not been given to vertical loads applied to the backfill surfaces during or after construction as a result of traffic and/or other surcharge loads. The design high groundwater elevation should be taken as the 100-year flood elevation of the nearby Cache la Poudre River.

2.2. Geotechnical Parameters for Counteracting Buoyancy

Pipe segments which extend below the highwater elevation should be evaluated for buoyancy. When evaluating pipe segments for buoyancy, we recommend designing the pipe under the assumption that the pipe is empty during a critical high-water event, such as the 100-year flood, given the proximity of nearby water sources. Where the loading on the pipe segments is not sufficient to counteract buoyancy, additional resistance to uplift can be achieved by widening the pipe trench and placing concrete or controlled low-strength material (CLSM) around the pipe and within the wider pipe trench section to engage the weight of an additional soil wedge.

For design purposes, the wedge of soil providing resistance can be defined by including the soil within a 12-degree slope (measured from vertical) up and away from the top exterior edge of the extended footing or pipe trench to the ground surface. A saturated unit weight of 125 pcf may be used for the soil wedge if the buoyant force on the pipe segment includes the weight of water displaced by the soil wedge. If the buoyant force on the structure or pipe segment does not include the weight of water displaced by the soil wedge (i.e., only the volume of water that is displaced by the structure itself) then a soil unit weight of 63 pcf should be used.

2.3. Seismic Site Classification

Based on the International Building Code, the American Society of Civil Engineers Minimum Design Loads for Buildings and other Structures, our subsurface investigation, and our experience and knowledge of seismic conditions in the area, a Site Classification of C is recommended for seismic design.

2.4. Surface and Subsurface Drainage

The migration of groundwater can alter local hydrogeologic regimes; therefore, we recommend that trench plugs be placed along the pipeline alignment at a spacing not to exceed 1,500 feet and one at each tunnel crossing as well as on either side of any structures. Trench plugs should be constructed from impervious material as detailed in Section 3.2.2.3, be a minimum of 2 feet thick when measured parallel to the pipe and should be keyed into the in-situ soils or bedrock along the trench bottom and sidewalls, extending at least 6 inches to 12 inches above the top of the bedding elevation.

2.5. Water Soluble Sulfates

Water soluble sulfate testing was conducted on 6 representative samples. The test results ranged from 0.002 to 1.8476% which would characterize the concrete risk as “Not Applicable” to “Severe” as shown in Table 2-2 below. These results should be considered when specifying the allowable cement types and concrete mixes. We recommend HDR take proper precautions to prevent degradation of concrete structures in contact with the ground from sulfate attack.

Table 2-2. American Concrete Institute Code 318-19 Water Soluble Sulfates

Cement Type	Water-Soluble Sulfate in Soil SO_4, Percent by Weight	Risk
--	SO_4 <0.10	Not Applicable
II, IP (MS), IS(MS), I(PM)(MS), I(SM)(MS)	0.10< SO_4 <0.20	Moderate
V	0.20< SO_4 <2.00	Severe
V plus pozzolan	SO_4 >2.00	Very Severe

2.6. Corrosion

As discussed in the GDR, corrosion potential testing was conducted along the alignment, as shown in Figures 1.1 through 1.4. Results of the laboratory corrosion potential tests are presented in the GDR, Appendix C. Based on laboratory and field resistivity testing results along the proposed alignment, portions of the waterline will be within a subsurface environment corrosive to steel piping. Corrosion protection is recommended on all metallic piping and fittings per AWWA M27.

Corrosion potential varies along the length of the alignment; however, common practice would typically include installing a standard corrosion protection program for any future metallic piping. Corrosion protection systems common in the industry and suitable for this project include but are not limited to polyethylene encasement, coal tar tape and enamel, cement mortar lining, or cathodic protection. Depending on the severity and rate of corrosion these corrosion protection systems maybe be coupled with each other to further limit corrosion. Corrosion potential testing data provided in the GDR.

2.7. Pipeline Recommendations

2.7.1. Differential Movement

Pipelines excavated through various soils and bedrock will be susceptible to differential movements up to 1 inch. Pipe penetrations into structures should be designed to tolerate a total of 1 inch of upward or downward relative movement. Typically, structures along pipelines are expected to function as relatively rigid structures; therefore, flexible joints and/or connections between lines and structures are recommended. Allowance for differential movement should be expected and planned for where pipelines penetrate structures. We recommend CLSM backfill be used in pipe trenches within 10 feet of structures, in lieu of traditional pipe bedding and pipe trench backfill to mitigate the migration of groundwater which could lead to soil movement. GEI recommends pipe couplings at structure penetrations are capable of tolerating in-service dynamic movements.

2.7.2. Thrust Restraint

Buried, pressurized pipes experience thrust forces at various pipe configurations including tees, reducers, dead ends, valves, bends, and wyes. In order to balance internal transient pressures, thrust blocks or restrained joints are recommended for pipe restraint. For thrust block design, an allowable lateral bearing pressure of 1,500 psf is recommended. A minimum of 2 feet of cover over thrust blocks is recommended and thrust blocks should be oriented such that the passive pressure influence zones do not overlap for adjacent blocks and do not impact other subsurface utilities. If restrained joints are selected, various coefficients of friction for potential pipe materials against anticipated trench backfill material are presented in Table 2-3 below.

Table 2-3. Coefficient of Friction for Buried Pipe

Pipe Material	Coefficient of Friction
Steel	0.30

Notes:
1. Per AWWA M11 (American Water Works Association, 2019).

2.7.3. Modulus of Soil Reaction (E')

The modulus of soil reaction (E') is an empirically derived coefficient which is related to the stiffness of the soil type in the envelop surrounding the pipe and degree of compaction of the pipe bedding as further described in 3.2.2.2. The fifth edition of the American Water Works Association M11 Design Manual was utilized to provide recommended values for E'. For full embedment of pipe in compacted granular pipe bedding corresponding to a Soil Stiffness Category of SC1 as presented in Table 5-3 (American Water Works Association, 2019) compacted to 65% relative density and where the trench width measured at the pipe elevation (Bd) is at least two times the pipe diameter (D) (ASCE, 2009), modulus of soil reaction values as shown in Table 2-4 below should be used.

Table 2-4. Modulus of Soil Reaction (E')

Pipe Type	E' (psi)	
	0- to 5-foot Depth of Cover	5- to 10-foot Depth of Cover
Steel[1]	1,000	1,500

Notes:
1. Per AWWA M11 (American Water Works Association, 2019).

In several areas along the alignment, subsurface conditions near the anticipated pipe elevation had blow counts of 4 or less resulting in poor soil conditions. Generally, these areas were observed at the borings from stations 87+00 to 213+00. At these locations, we recommend that subgrade improvement procedures as outlined in Section 3.5 are implemented. Following the subgrade improvement procedures, the E' values identified in Table 2-4 above may be utilized.

3. Construction Recommendations

The following sections are intended for the Engineer producing specifications and the contractor constructing the proposed Project. Construction considerations include temporary excavations, preparation of excavated surfaces for foundations, backfill materials, fill placement and compaction, bedrock or oversize material excavation, and construction dewatering.

3.1. Temporary Excavations

General site safety including temporary excavations are the sole responsibility of the contractor performing construction. GEI is providing temporary excavation information strictly as an informational benefit to the project team, specifically the general contractor. An Occupational Safety and Health Administration (OSHA) defined competent person should be identified by the contractor to be in charge of temporary excavations. In general, the contractor's competent person should have experience or training in determining soil types, benching and shoring, and have the ability to detect potential temporary slope stability and protective system issues.

OHSA defines an excavation as a man-made cut, trench, or depression formed by the removal of earth. A trench is a specific type of narrow excavation with a geometry including a greater depth than width and a width of 15 feet or less. Trenches 5 feet deep or greater should be sloped, retained with shoring, or shielded appropriately. Shielding most commonly includes trench boxes. In general, shoring can include inclined, horizontal, or vertical systems depending on the excavation geometry and availability of retention alternatives. Sloping and benching should be in accordance with OSHA guidelines (Ocupational Safety and Hazard Administration, 2024). Benching should include a maximum 4-foot vertical face for each bench and overall excavation geometry less than or equal to the OSHA defined slope.

At locations where deep excavations are anticipated, a registered professional engineer should approve the contractor's approach for trenches greater than or equal to 20 feet in depth. In addition, shoring for trench excavations should be designed by a professional engineer or be based on tabulated data prepared or approved by a registered professional engineer in accordance with OSHA 1926.652(b) and (c) (Ocupational Safety and Hazard Administration, 2024).

GEI has evaluated observed soil conditions likely to be penetrated by the proposed construction. Based on the OSHA determined soil Types, Table 3-1 below presents maximum recommended temporary excavation slopes to be utilized during construction.

Table 3-1. OSHA Temporary Excavation Slopes

Material Type	OSHA Classification	Maximum Recommended Slope[1] (H:V[2])
Non-Cohesive Soil	Type C	1½:1
Cohesive Soil	Type B	1:1 or 1½:1[3]
Bedrock	Type A	¾:1

Notes:
1. Valid for trench excavations less than 20 feet in depth.
2. H:V stands for Horizontal:Vertical.
3. Applies in layered strata where Type B soil overlies Type C soil.

During construction, heavy equipment or excavated material stockpiles should be kept away from excavation edges to the extent possible. It is recommended that heavy equipment or excavated material stockpiles be kept at least 10 feet from the edges of excavations. Underground utilities should be fully understood and documented prior to initiating excavations. Finally, the contractor's competent person should inspect trenches and excavations routinely for signs of instability including sliding, toppling, subsidence and bulging, heaving or squeezing, boiling, and/or other visual concerns.

3.1.1. Shored Temporary Excavations

The contractor may elect to use a temporary shoring system to limit excavation extents, particularly if other site infrastructure may be impacted. Typically trench boxes are used to support lateral loads during excavation and construction in soils that have sufficient standup time to excavate the trench, install the trench box, complete installation, and remove the trench box without full contact of the soils. Tight shoring typically involves full contact of the soils with the shoring system. Typical tight shoring systems that could be utilized during the installation of the Project include slide rail systems or sheet pile walls.

3.2. Site Grading and Earthwork

Appropriate site preparation, material placement and compaction, and backfill selection can reduce the risk of post-construction settlement and potential issues related to lateral earth pressures. General site grading and earthwork considerations are presented in the following sections.

3.2.1. Site Preparation

Areas supporting backfill and pipe bedding should be properly prepared. Once the rough grade has been established in excavated areas, and prior to placement of backfill, the exposed subgrade should be carefully inspected via either proofrolling or probing and testing, as determined necessary by the geotechnical engineer and as outlined in Section 3.2.3. Should the subgrade be considered unstable by the geotechnical engineer or should the contractor desire to improve workability conditions in the trench or excavation, the procedures outlined in Section 3.5 should be followed. Frozen, wet, soft, or loose soil, as well as any other undesirable material should be removed. Once suitable soil conditions are achieved, the subgrade should be scarified and compacted prior to fill placement. The suitable exposed soil materials should be scarified and moistened or dried, as necessary, to a minimum depth of 8 inches below the proposed construction. Scarified material should be compacted to the minimum specifications defined in the following sections.

3.2.2. Backfill Material

Backfill will be required for pipeline trenches and around proposed construction. Material recommendations and the intended use of each backfill material type is further detailed in the following sections.

3.2.2.1. General Backfill

General Backfill material can be composed of processed onsite material and may be used above pipe bedding sections within pipeline trenches in order to meet design grade requirements providing the appropriate lateral earth pressures are used in design as outlined in Section 2.1. For General Backfill, bedrock, particles greater than 6-inches, frozen soil, trash, and organic material should be removed.

3.2.2.2. Pipe Bedding

Pipe bedding is anticipated to be within cohesive or non-cohesive soil for the alignment. Material meeting the requirements of a CDOT fine aggregate presented in CDOT Standard Specifications Table 703-1 or CLSM is recommended as backfill for the pipe bedding zone. The pipe bedding zone considered extends a minimum of 6 inches above the crown and 6 inches below the invert of the backfilled pipe.

3.2.2.3. Trench Plug Material

Trench plugs may be constructed from compacted clay soils with a USCS classification of CL or with at least 60 percent fines and a PI of 15 or greater. It is anticipated that onsite soils will not be able to meet the above criteria. Trench plugs may be constructed from imported clay material, reinforced concrete, lean concrete, or CLSM.

3.2.3. Fill Placement and Compaction

We recommend fill placement occurs in maximum 8-inch loose lifts for fill under and backfill adjacent to structures. Lift thickness for pipe bedding should not exceed 8 inches. Minimum recommended compaction specifications are outlined in the Table 3-2 below.

Table 3-2. Soil Compaction Recommendations

Backfill Material Type	Moisture and Compaction Specifications		
	Moisture Content^1	Dry Density^2	Relative Density^3
Pipe Bedding			≥ 65%
General Backfill (fines < 35%)	-2% to +2%	≥ 95%	
General Backfill (fines > 35%)	0% to 3%	≥ 95%	
Trench Plug	-2% to +2%	≥ 90%	

Notes:
1. Moisture content relative to the optimum moisture content as determined by ASTM D698.
2. Dry density relative to the maximum dry density as determined by ASTM D698.
3. Relative density as determined by ASTM D4253 and D 4254.

Mechanical compaction is required for all materials placed as backfill during construction. Compaction of cohesive soil is best accomplished with equipment such as a jumping jack or padfoot roller. Non-cohesive soil is best compacted with a vibratory plate or vibratory smooth-drum roller. Compaction utilizing any flooding type technique should not be allowed. Care should be taken when compacting backfill adjacent to structures. Generally, we recommend operating only light-weight compaction equipment such as jumping jacks and vibratory plates immediately adjacent to structures.

Quality assurance of backfill material and backfill placement will be necessary to reduce potential for long term differential settlements. Inspection of subgrade materials prior to placing or forming and casting structural elements is also critical to project success. GEI recommends a qualified testing agency is retained to provide quality assurance services during the backfill process.

3.3. Bedrock or Oversized Material Excavation

Based on the subsurface investigation and our preliminary understanding of the depth of the alignment, bedrock consisting of claystone is anticipated to be encountered during excavation at limited portions of the alignment. Specifically, near boring NTE-11 it is anticipated that bedrock excavation will be required.

The use of heavy-duty excavation equipment is anticipated to be sufficient to excavate the bedrock present at the project site. Heavy-duty excavation equipment may consist of excavators using a bucket equipped with appropriate teeth. Table 3-3 below summarizes borings and associated project components where bedrock excavation is anticipated to be required.

Table 3-3. Anticipated Bedrock Excavation Locations

Boring No.	Project Component	Station	Anticipated Bedrock Depth (feet)
NTBH-4	Immediately West of County Road 1	232+00	14.0
NTE-10	North Side of E County Road 52 Crossing	144+00	14.0
NTE-11	North Side of E County Road 52 Crossing	142+00	6.5
NTE-12	North Side of E County Road 52 Crossing – along canal	135+00	14.0
NTE-13	North Side of E County Road 52 Crossing – along canal	123+00	13.0
NTE-16	¼ mile East of I-25 crossing	70+00	14.0
NTE-21	¼ mile South of Segment Completion	18+00	14.0

3.4. *Construction Dewatering*

Groundwater was encountered during the subsurface investigation. Temporary construction dewatering should be anticipated for the proposed construction at locations where excavations extend below groundwater. Generally, sump pumps to control minor groundwater seepage should be anticipated for the majority of the excavations. Trench drains, deep wells and well points may also be needed when the depth of groundwater above the base of excavation exceeds 5-feet. Construction dewatering must adhere to the Colorado Department of Public Health and Environment (CDPHE) regulations and discharge permit requirements. GEI is available to assist with dewatering design if required. Dewatering should be carefully evaluated and accounted for in the construction estimate to avoid construction cost and time increases. Table 3-4 below identifies hydraulic conductivity ranges based on conducted particle size distribution and -200 content testing. The hydraulic conductivity of the geologic units varies with fines content, void ratio and particle size. The Contractor should be aware that horizontal hydraulic conductivity in these deposits is significantly greater (from 5x to 10x) than vertical hydraulic conductivity.

Table 3-4. Ranges Hydraulic Conductivity of Materials

Geologic Unit	Horizontal Hydraulic Conductivity (cm/s)
	Range
Cohesive Soil	$1x10^{-6}$ to $1x10^{-3}$
Non-cohesive Soil	$1x10^{-3}$ to $1x10^{-1}$
Bedrock	$1x10^{-6}$ to $1x10^{-3}$

Table 3-5 below summarizes borings and associated project components where construction dewatering is anticipated to be required based on an assumed alignment depth of 5-feet of cover above the pipe crown. As further discussed in the Geotechnical Baseline Report, dewatering is likely to be required at and around the tunnel shaft locations for the I-25 crossing. Although not further described in the below table, due to the anticipated subsurface conditions and the depth of groundwater head at the base of the excavation, it is anticipated that deep wells will be required at this location for transitioning out of the tunnel shafts and into the open cut alignment portions.

Table 3-5. Anticipated Construction Dewatering Locations

Boring No.	Station	Shallowest Groundwater Depth Encountered (feet)	Assumed Excavation Depth (feet)	Anticipated Groundwater Depth Above Base of Excavation
NTBH-2	205+00	7	9.5	2.5
NTE-6	178+00	3.6	9.5	5.9
NTE-8	156+00	7.5	9.5	2.0
NTE-15	87+00	4.5	9.5	5.0

3.5. Subgrade Improvement

In several areas along the alignment, subsurface conditions near the anticipated pipe elevation had blow counts of 4 or less resulting in poor soil conditions. Generally, these areas were observed at the borings from stations 87+00 to 213+00. In this reach and if other areas of poor soil are encountered, the proposed excavations may be re-established by backfilling after the soft/loose material has been sufficiently removed as defined below. At locations where the subgrade material is too soft to facilitate adequate workmanship for the proposed pipeline or results in undesirable deflections, we recommend an over-excavation of 12-inches beneath the bottom of the pipe bedding zone and replacing with crowding aggregate. Crowding aggregate material up to 3- to 4-inches in diameter, such as recycled concrete, is recommended to stabilize the soft subgrade beneath the pipe bedding zone. We recommend placing a separating geofabric such as Mirafi 150N between the stabilization aggregate and pipe bedding to prevent material migration. Should an over-excavation be undesirable, a stabilization fabric such as a Tensar Biaxial Geogrid BX1200 or Mirafi Woven Geotextile HP270 may be utilized in substitute of over-excavation and crowding aggregate.

4. Construction Observation and Quality Assurance

Site observations during construction specifically to address the geotechnical components of the Project by GEI are recommended, including during subgrade preparation and stabilization, trench excavations, placement of pipe bedding, and backfill placement and compaction. Quality assurance of compaction and backfill materials are necessary to increase long-term performance of the proposed waterline. GEI recommends that a qualified testing agency is retained during construction to monitor backfill materials and compaction. GEI should be notified if unanticipated subsurface conditions are encountered during construction to re-evaluate and potentially change the design and/or construction recommendations presented in this memorandum.

Limitations

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principles; no warranty, express or implied is made. The subsurface conditions described in this memorandum were based on data obtained from widely spaced exploratory borings, geotechnical laboratory testing, information provided by HDR, engineering judgement, and our experience with similar subsurface conditions and projects. The boring logs utilized in this memorandum only depict the subsurface conditions at the actual boring locations. Subsurface conditions are typically variable, both laterally and vertically and the nature and extent of the subsurface variations across the site(s) may not become evident until construction. The boundaries between different soil types and bedrock presented in the GDR are approximate and, in some cases, may be more abrupt or gradational than described herein. Groundwater levels may vary with time, precipitation, and changes to the hydrogeological conditions at and/or surrounding the project site.

This memorandum has been prepared exclusively for HDR for design purposes for the subject project. GEI Consultants is not responsible for technical interpretations by others of the data presented in this memorandum or use of this memorandum by others for the subject project or other projects. If differing site conditions are encountered during further evaluation of the subsurface conditions by others or during construction, GEI Consultants should be notified immediately to determine if any changes to our recommendations presented in this memorandum are warranted.

The recommendations presented in this memorandum are only intended for the proposed design and construction as understood by GEI Consultants at the time of issuing this memorandum. If the proposed design and construction changes, GEI Consultants should be notified immediately and given the opportunity to review the proposed changes and if necessary, modify our recommendations presented herein.

An environmental assessment was not included in the GEI Consultants scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for informational purposes. If HDR is concerned about the environmental conditions at the site, GEI Consultants recommends HDR and/or owner retain a qualified environmental firm to conduct an environmental site assessment.

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GEI Consultants

Geotechnical Baseline Report

Thornton Segment F.2 – Issue For Bid

Larimer County, Colorado

Submitted to:
HDR Engineering, Inc.
1670 Broadway, Suite 3400
Denver, CO 80202

Submitted by:
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724 Whalers Way, H100
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August, 2026
Project No. 2505320

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Project Manager

Nate Soule, P.E., P.G.
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Appendices

Report Organization

The Geotechnical Baseline Report (GBR) is organized as follows:

Section 1: Introduction

Describes the project background and discusses the purpose and intended usage of the GBR.

Section 2: Geology and Subsurface Conditions

Provides background on the site geology and describes the investigations undertaken to evaluate ground conditions along the alignment. Provides general baselines for the geologic units to be encountered including geologic and geotechnical characteristics and tunneling behavior. Baselines are provided for groundwater as well.

Section 3: Tunnels

Describes the subsurface conditions anticipated at each tunnel and provides specific baselines for the materials' geotechnical values and behavior in an excavation. Additional tunnel specific baselines are provided for groundwater and dewatering. Construction considerations specific to each tunnel are discussed in this section.

Section 4: General Construction Considerations

Discusses general shaft excavation and support, instrumentation and monitoring, and environmental considerations specific to tunneling, as well as general considerations for the tunnel methods appropriate for each tunnel. Additional considerations are given for general problems which may arise during shaft or tunnel construction, which the contractor should account for in their bid, designs, and performance.

Sections 5 and 6: Limitations and References

Describes limitations of the GBR and provides references for citations within the report.

1. Introduction

1.1. Project Description

The Thornton Water Project Pipeline is a multi-segment pipeline intended to provide water conveyance for the City of Thornton (City), of which Segment F.2 is to be collocated with the NTTO Segment of the North East Alignment of the NISP Pipeline. Segment F.2 of the project involves design and construction of approximately 4.39 miles of new water pipeline. New pipeline installation will be performed using open-cut and tunneling methods. Two tunnels are anticipated to be constructed using tunneling techniques with a 42-inch diameter steel pipe carrier pipe installed within a 54-inch diameter steel casing.

Tunnel construction has been chosen at specific locations due to the presence of roadways, utility corridors, and other features that will not allow conventional open cut construction.

1.2. Project Tunnels

Table 1-1 below provides approximate length and tunnel characteristics associated with each tunnel on the project. Actual lengths and depths of the tunnels are shown in the Contract Drawings. All casing pipe diameters provided in this report are for the nominal pipe diameter measurement.

Table 1-1. Project Tunnel Summary

Tunnel	Length (LF)	Cover Depth (FT)	Slope
I-25	295	13-18	0.44%
CR 52	81	19-24	0.51%

Overall tunnel excavation techniques considered viable for tunneling on the project include use of guided auger bore, tunnel boring machine (TBM), and microtunnel boring machine (MTBM). Initial support will consist of jacked steel casing. Specific tunnel techniques suited for each tunnel are described in their respective section within this report. Within the limits set by the Project Specifications and as discussed in this GBR, the Contractor is responsible for selecting the appropriate excavation and ground support methods for the work.

A minimum of two shafts will be required for each crossing. The optimal layout of the shafts will be at the Contractor's discretion; however, for the purposes of generating a baseline, it is assumed that the launch shaft (used to launch tunneling equipment) will be on the downhill side of each crossing and the receiving shaft (used to recover tunneling equipment) will be on the uphill side unless otherwise noted. The anticipated site layout including borings, tunnel alignment and assumed shafts are shown in Figures 1.1 and 1.2 for the I-25 and CR52 crossings, respectively.

1.3. Description and Purpose of the GBR

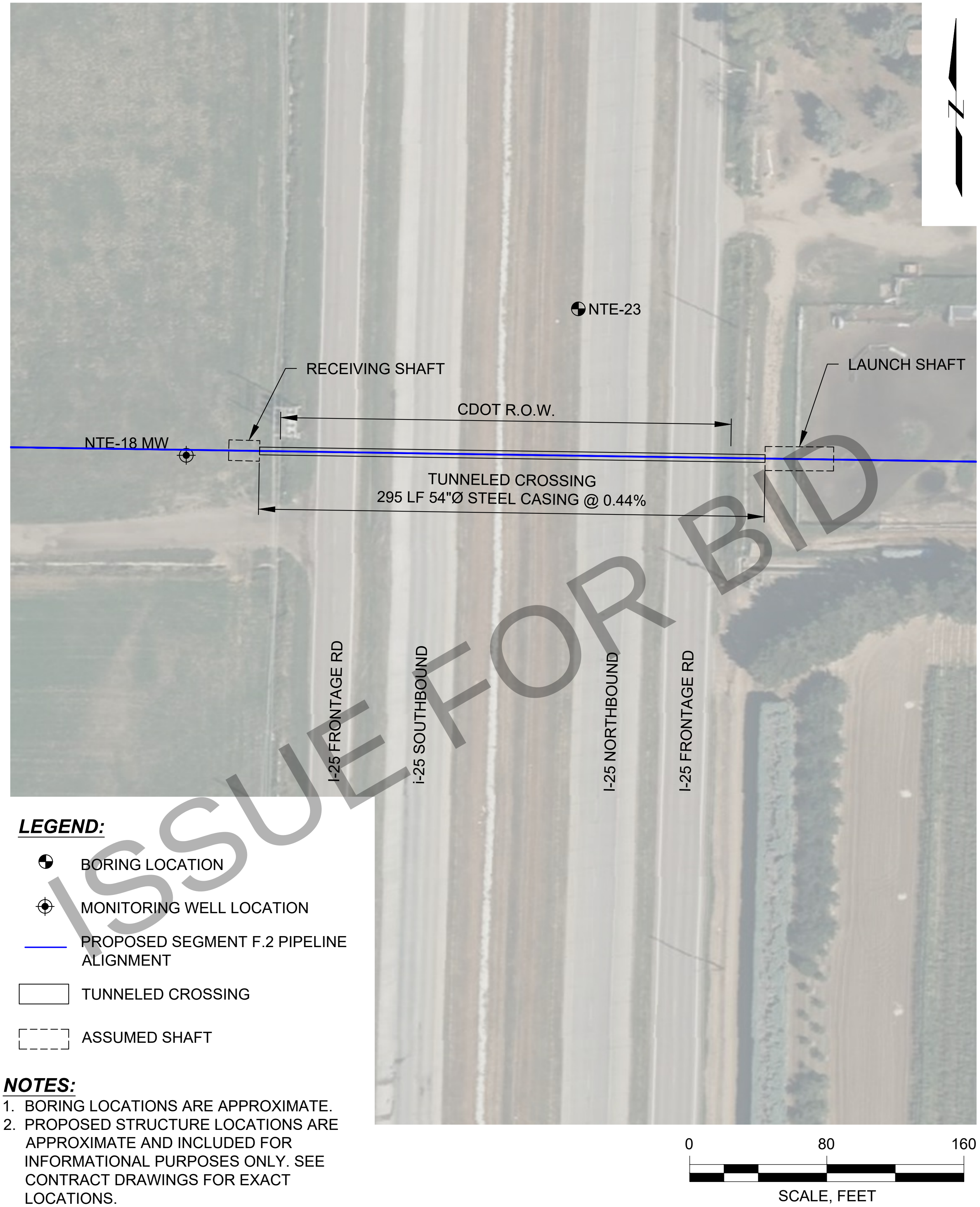
The main purpose of this GBR is to establish contractual baselines for anticipated ground conditions and behavior that will be encountered during shaft and tunnel construction (see Specifications for Contract

Document precedence and GBR use). Subsurface conditions observed through geotechnical field explorations and through laboratory analyses of collected samples are presented in the Geotechnical Data Report (GDR) (GEI, 2026). GBR preparation was performed in general accordance with an ASCE document entitled: “Geotechnical Baseline Reports, Suggested Guidelines,” dated 2022.

The baselines established in this GBR for the anticipated subsurface conditions are recommended to be used as the basis for developing bids and to help the Contractor evaluate means and methods. The baselines will be used for evaluating potential differing site conditions (DSC) during construction. This GBR also summarizes geotechnical and construction considerations that form the basis of the project design and Contract Documents. The GBR is prepared in tandem with the applicable Contract Documents, particularly Specification 31 71 00 Tunnel Excavation and Initial Support. In the event of a conflict, the Contract Drawings and Specifications take contractual precedence over the GBR, and the GBR takes precedence over the GDR.

The baselines for anticipated subsurface conditions presented in this GBR reflect the design team’s judgment of anticipated subsurface conditions and ground behavior based on assumed construction means and methods expected to be employed in the work. The baselines were established by considering available geologic and geotechnical data, together with previous construction experience in similar subsurface conditions. Development of the project design required interpretation, extrapolation, and interpolation between data obtained for the project including aerial imagery, geotechnical test boreholes (i.e. borings), groundwater monitoring, and laboratory tests. While the actual conditions encountered during construction of any given tunnel are expected to be within the range of conditions baselined herein, the locations where specific subsurface conditions are encountered may vary from those described in this GBR. The contractors should familiarize themselves with the DSC process to judge whether variances justify pursuit of a DSC claim.

Figure 1.1 Site Map (I-25 Crossing)



LEGEND:

◒	BORING LOCATION
⌖	MONITORING WELL LOCATION
—	PROPOSED SEGMENT F.2 PIPELINE ALIGNMENT
▭	TUNNELED CROSSING
⬚	ASSUMED SHAFT

NOTES:

1. BORING LOCATIONS ARE APPROXIMATE.
2. PROPOSED STRUCTURE LOCATIONS ARE APPROXIMATE AND INCLUDED FOR INFORMATIONAL PURPOSES ONLY. SEE CONTRACT DRAWINGS FOR EXACT LOCATIONS.

Thornton Raw Waterline Segment F.2

HDR Engineering, Inc. Denver, Colorado

GEI Consultants

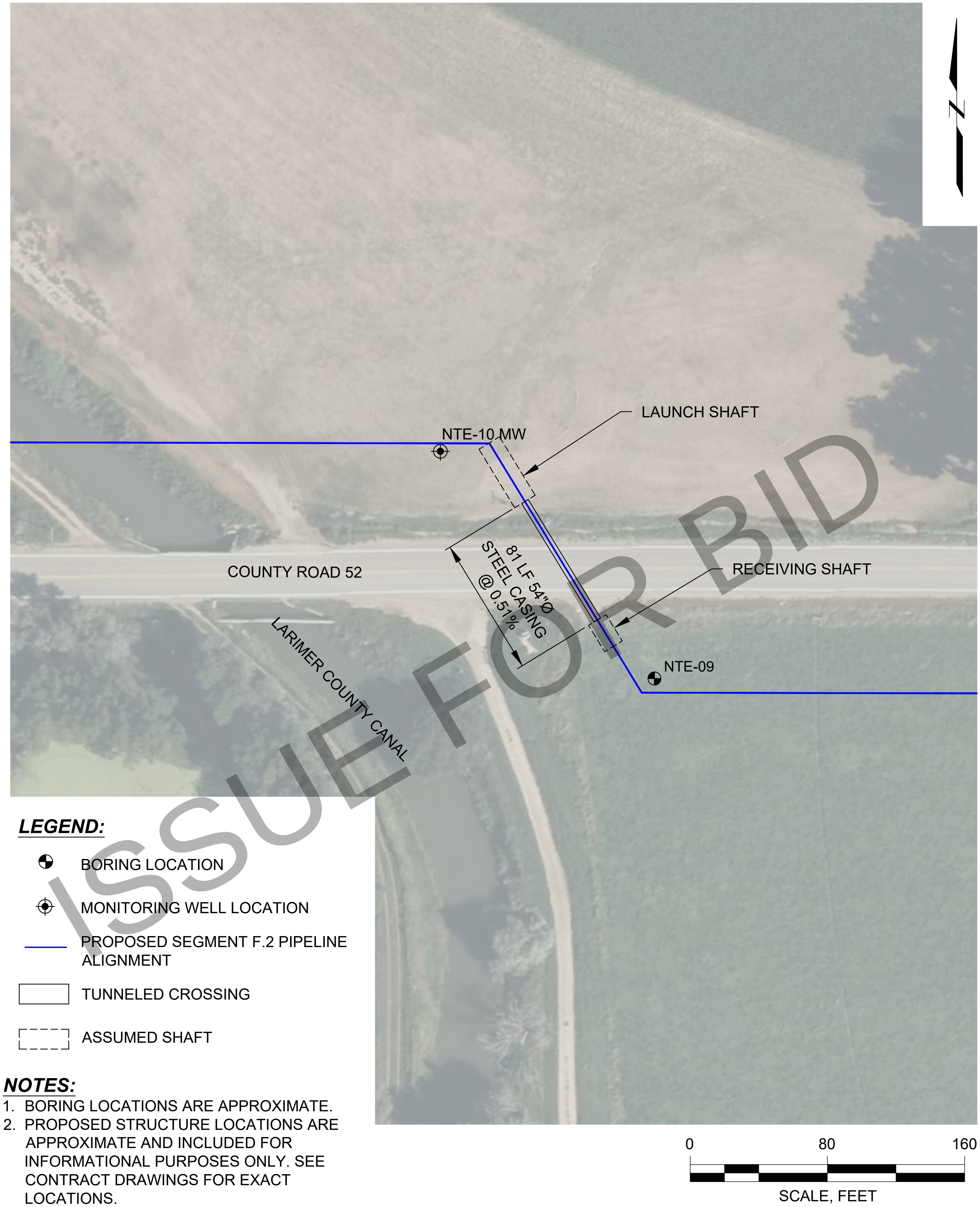
Project 2505320

SITE MAP
I-25 CROSSING
SEGMENT F.2

August 2026

Fig. 1.1

Figure 1.2 Site Map (CR 52 Crossing)



LEGEND:

- ◐ BORING LOCATION
- ⊕ MONITORING WELL LOCATION
- — PROPOSED SEGMENT F.2 PIPELINE ALIGNMENT
- ▭ TUNNELED CROSSING
- ⬚ ASSUMED SHAFT

NOTES:

1. BORING LOCATIONS ARE APPROXIMATE.
2. PROPOSED STRUCTURE LOCATIONS ARE APPROXIMATE AND INCLUDED FOR INFORMATIONAL PURPOSES ONLY. SEE CONTRACT DRAWINGS FOR EXACT LOCATIONS.

Thornton Raw Waterline Segment F.2

HDR Engineering, Inc. Denver, Colorado

GEI Consultants

Project 2505320

SITE MAP
CR 52 CROSSING
SEGMENT F.2

August 2026

Fig. 1.2

2. Geology and Subsurface Conditions

2.1. Regional Geology

The geologic conditions in the area are characterized by surficial materials consisting of eolian deposits including loess, Piney Creek Alluvium, and Broadway Alluvium. These soils overlie sandstone, shale, and claystone bedrock of the Pierre Shale. The project site is located within the Colorado Piedmont section of the Great Plains Physiographic Province. The piedmont, being an erosional inlier, consists of arid plains that are lower than the foothills to the west and slightly lower than the Great Plains to the east. During periods of uplift of the Rocky Mountains, younger sedimentary rock units were eroded and transported by streams and rivers to the piedmont. As rivers have historically meandered, alluvium was deposited in a broad swath across the plain, with wind sorting and re-distributing these materials as eolian deposits including loess. Tributary creeks and streams drain towards the rivers and re-distribute both eolian and alluvial deposits.

Groundwater in the region is heavily influenced by the Rocky Mountains to the west and the local rivers, creeks, and drainages. Groundwater generally flows west to east from the foothills with more localized flow towards and along waterbodies. Northern Colorado has semi-confined, unconfined, and perched aquifers within surficial sediments and confined and semi-confined aquifers in bedrock. The historically meandering and braided easterly-flowing rivers have significant influence on the local groundwater levels and hydrogeology.

More specifically, geologic mapping of the Boulder-Fort Collins-Greeley area (Colton, 1978) indicates the site is underlain primarily by upper Holocene-aged eolian clay, silt, and sand with some local channel deposits consisting of upper Holocene-aged Piney Creek alluvium. The eolian deposits are described as light-brown, reddish-brown, and olive-gray clay, silt (loess), and fine sand. Eolian deposits in the vicinity of the Project site likely consist primarily of loess with a thickness of between 3 and 15 feet. The Piney Creek alluvium is described as dark gray sandy to gravelly alluvium that underlies terraces whose surfaces are 10 to 20 feet above the nearby flood plain. The thickness of the alluvium is described as 0 to 20 feet.

Bedrock in the vicinity of the project site is mapped as the Upper Transition Member of Cretaceous-aged Pierre Shale consisting of friable sandstone and soft shaly sandstone containing thin-bedded sandy shale and calcareous sandstone concretions. The thickness of the unit is approximately 2,000 feet.

Specific to the Project site, the unconfined aquifer groundwater levels are generally higher in the immediate vicinity of waterbodies such as rivers, creeks, and irrigation ditches and decreases with distance away from waterbodies.

2.2. Subsurface Investigations

2.2.1. Field Investigations

GEI performed geotechnical subsurface investigations for the project tunnels between January and July of 2025. Field investigations consisted of geotechnical borehole drilling (“borings”). In general, borings were performed at either end of each tunnel alignment as near to the anticipated shaft locations as access allowed. In general, GEI collected Modified California and split spoon samples. Exploration data from these investigations are presented in the GDR. Many of the geologic terminology used in this GBR are further described and summarized in the GDR.

A geotechnical laboratory testing program was performed on selected samples and the results assisted in classification and assessment of applicable engineering properties for encountered subsurface materials. GEI designed the laboratory testing program. Details of the procedures used for conducting the field work and laboratory testing, and the factual results of the subsurface investigations and laboratory testing performed for this project are summarized in the GDR. Summaries of geotechnical data encountered during the investigation or provided by laboratory testing are embedded within this report. All bedrock testing was performed on Modified California samples rather than rock core; as such, baselined bedrock strength values may be higher than results presented in the laboratory testing results.

2.2.2. Literature Review

In addition to the field investigation, GEI performed a review of available literature, including historic aerial photography for each tunnel location and subsurface data from the United States Geological Survey (USGS), and other public entities. Specific documents reviewed for pertinent data include:

- GEI reviewed historical aerial imagery through Google Earth and Historic Aerials (historicaerials.com). Images dating from the 1960s through present were reviewed for each tunnel crossing. GEI identified no relevant feature changes that would affect tunnel construction.

- GEI reviewed the USGS Geologic Maps available for the tunnel crossings to identify the mapped deposits and bedrock formations. This aided in identifying the geologic processes that shaped the present-day subsurface conditions for each tunnel.

Relevant observations or construction considerations are noted in the GBR text for each tunnel where findings were applicable, and baselines were developed accordingly.

2.2.3. Relevant Historic Tunnel Projects

Data, observations, and design elements from nearby completed tunneling projects aided in developing this GBR. GEI relied on experience designing tunnels crossing I-25 and roadways near the I-25 corridor of northern Colorado in similar geologic conditions to supplement the geotechnical data, geologic behavior, and develop the baselines included herein. Of immediate relevance are the Greeley Waterline I-25 Widening and NEWT III Pipeline I-25 Tunnel projects that were designed and constructed in 2018 and 2023, respectively. The separate I-25 crossings for the relevant projects were of similar lengths, diameters, subsurface conditions, tunneling techniques, third parties, and design constraints. Specifically, both of the relevant projects were completed using microtunnel tunneling techniques through a non-cohesive material below groundwater. Both projects were completed successfully and with no impact to the I-25 pavement surface or right-of-way. Relevant observations or construction considerations are noted in the GBR text where findings were applicable, and baselines were developed accordingly.

2.3. Geologic Units

GEI's geotechnical test borehole reports, observations and literature review were used to create the geologic profiles associated with each tunnel. Geologic units that will be encountered in tunnel and shaft excavation include cohesive soils, non-cohesive soils, and bedrock. The sections below discuss the geologic and geotechnical characteristics of these materials. Index properties, material sizes, and volumetric percentages of material, including features specific to each crossing are described in each tunnel's respective section of the GBR. Specific modifications to the general baselines presented in Section 2.3 may be included in each individual tunnel section if it modifies the baselines presented within this section. Baselines for ground behavior included in this report are derived based on Tunnelman's classification system, which is included for reference in Appendix A at the end of this report.

2.3.1. Cohesive Soil

Cohesive soil to be encountered in shaft and tunnel excavations consists of lean clay (CL), lean clay with sand (CL), sandy lean clay (CL), and clayey sand (SC). Cohesive soil generally consists of native materials and imported fill with greater than 30% fines (clay and silt passing a No. 200 sieve) and exhibits a cohesive (plastic) behavior as determined by either laboratory Atterberg limits testing or visual-manual field observation, with the former procedure taking precedence over the latter. Cohesive soil will be encountered above and below groundwater. The table below provides the baseline conditions of cohesive soil.

Table 2-1. Baseline Conditions of Cohesive Soil

Tunnelman's Classification		Grain Size Distribution (% Composition)	Stickiness (% of Excavation)			Soil Abrasivity	Blow Counts (Blow/Foot; ASTM D3550)
Above Groundwater	Below Groundwater		High	Medium	Low		
Slow Raveling	Squeezing	Gravel Avg: 2 (Range: 0-10) Sand Avg: 40 (Range: 10-60) Fines Avg: 58 (Range: 40-90)	70	15	15	Low	Avg: 9 Range: 0-21

Cohesive soil has a low to high potential (as defined by Hollman and Thewes, 2012) to create problems with adhesion and/or clogging equipment with the in-situ moisture content. Precipitation, nuisance water, or added moisture from construction (e.g. lubrication fluids) have the potential to create higher stickiness conditions. Hollman and Thewes suggest that the stickiness of fines, if present, can be determined based on the consistency index and plasticity index of the clay. The consistency index is a function of the natural moisture content, the liquid limit, and the plasticity index. A graphical plot of clogging potential from Hollman and Thewes (2012) is shown in Figure 2.1.

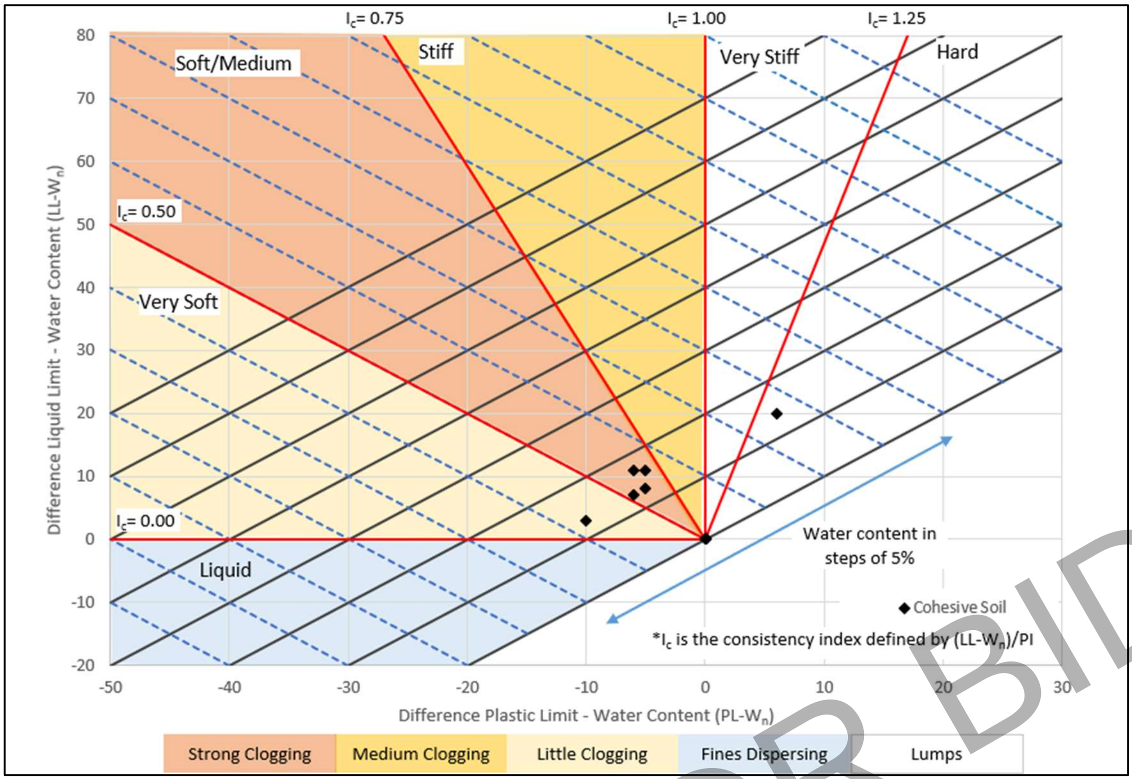


Figure 2.1 **Cohesive Soil Clogging Potential Chart (Hollman and Thewes, 2012)**

Cohesive soil has a low potential for excessive steel wear. Soil abrasivity is known to affect the wear and replacement rate of steel excavating components. Soil abrasivity is a function of the nature of the soil (e.g. mineralogy, quartz content, abrasiveness, rounding, compaction, and grain size distribution), soil moisture content, soil conditioning during excavation, and rate of excavation (Jakobsen, et al, 2013). Soil abrasivity was estimated based on mineral percentages of quartz-rich sand.

For bidding and baseline purposes, cobbles, boulders, or other obstructions, including natural or artificial singular features greater than three inches will not be encountered.

2.3.2. Non-Cohesive Soil

Non-cohesive soil to be encountered in shaft and tunnel excavations consists of clayey sand with gravel (SC), poorly-graded sand (SP), poorly-graded sand with clay and gravel (SP-SC), and well-graded sand with clay and gravel (SW-SC). Non-cohesive soil generally consists of native materials with less than 30% fines (clay and silt passing a No. 200 sieve) and exhibits a non-cohesive (non-plastic) behavior as determined by either laboratory Atterberg limits testing or visual-manual field observation, with the former procedure taking precedence over the latter. Non-cohesive soil will be encountered above and below groundwater. The table below provides the baseline conditions of the non-cohesive soil.

Table 2-2. Baseline Conditions of Non-Cohesive Soil

Tunnelman's Classification		Grain Size Distribution (% Composition)	Stickiness (% of Excavation)			Soil Abrasivity	Blow Counts (Blow/Foot; ASTM D3550)
Above Groundwater	Below Groundwater		High	Medium	Low		
Fast Raveling	Flowing	Gravel Avg: 22 (Range: 10-40) Sand Avg: 69 (Range: 45-80) Fines Avg: 9 (Range: 5-23)	0	0	100	High	Avg: 24 Range: 2-49

Non-cohesive soil has a low potential to create problems with adhesion and/or clogging equipment with the in-situ moisture content and a high potential for excessive steel wear based on estimations of mineral percentages of quartz-rich sand.

Cobbles in non-cohesive soil are anticipated based on the GDR and regional geology at the project location. For bidding and baseline purposes, the Contractor shall assume:

- A maximum cobble volume ratio of 10%;
- 90% of cobbles will have a maximum dimension of 6 inches, and 10% will have a maximum dimension between 6 inches and 12 inches;
- Cobbles will have a maximum unconfined compressive strength (UCS) of 15,000 psi and maximum Cerchar Abrasivity Index (CAI) of 4.0;
- Cobbles will be sub-angular to sub-rounded;
- Cobbles will be isolated throughout non-cohesive soil.

For bidding and baseline purposes, boulders, or other obstructions, including natural or artificial singular features greater than 12 inches will not be encountered.

2.3.3. Bedrock

Bedrock to be encountered in shaft and tunnel excavations consists of interbedded sandstone, and clayey sandstone. Bedrock is undifferentiated in this GBR due to similarity in Baseline Conditions affecting construction. The bedrock at depths relevant to the excavations is classified as extremely weak rock to weak rock for ISRM field strength estimate procedures (ISRM, 2007) above and below groundwater. Unconfined Compressive Strength (UCS) laboratory tests were performed on intact samples that resulted in values between 11 psi and 128 psi, however stronger localized clasts and beds are possible given regional project experience and will be encountered as baselined below. These stronger bedrock zones have additional cementation that significantly increases both bedrock hardness and strength. Additionally, the International Society for Rock Mechanics provides a guideline for compressive strength ranges based on the relative strength of bedrock as determined in the field and assisted in compressive strength baseline determination (ISRM, 2007).

These values are higher than as tested based on geotechnical drilling performance and GEI's experience with bedrock in the project vicinity. The table below provides the baseline conditions of bedrock.

Table 2-3. General Baseline Conditions of Bedrock

Tunnelman's Classification	Stickiness (% of Excavation)			Abrasivity	UCS (% of Excavation: psi)
Above and Below Groundwater	**High**	**Medium**	**Low**		
Firm[1]	0	25	75	Moderate	95%: 150 maximum 5%: 2,000 maximum

Notes:
1. Though bedrock is a rock unit, classification in accordance with Tunnelman's Ground Classification for Soils is more representative of ground behavior.

Bedrock in the region is known to exhibit swelling characteristics with moisture variations; however, swelling rock is not anticipated during tunnel excavation. Bedrock has a low potential to create problems with adhesion and/or clogging equipment with the in-situ moisture content. A graphical plot of clogging potential from Hollman and Thewes (2012) is shown in Figure 2.2.

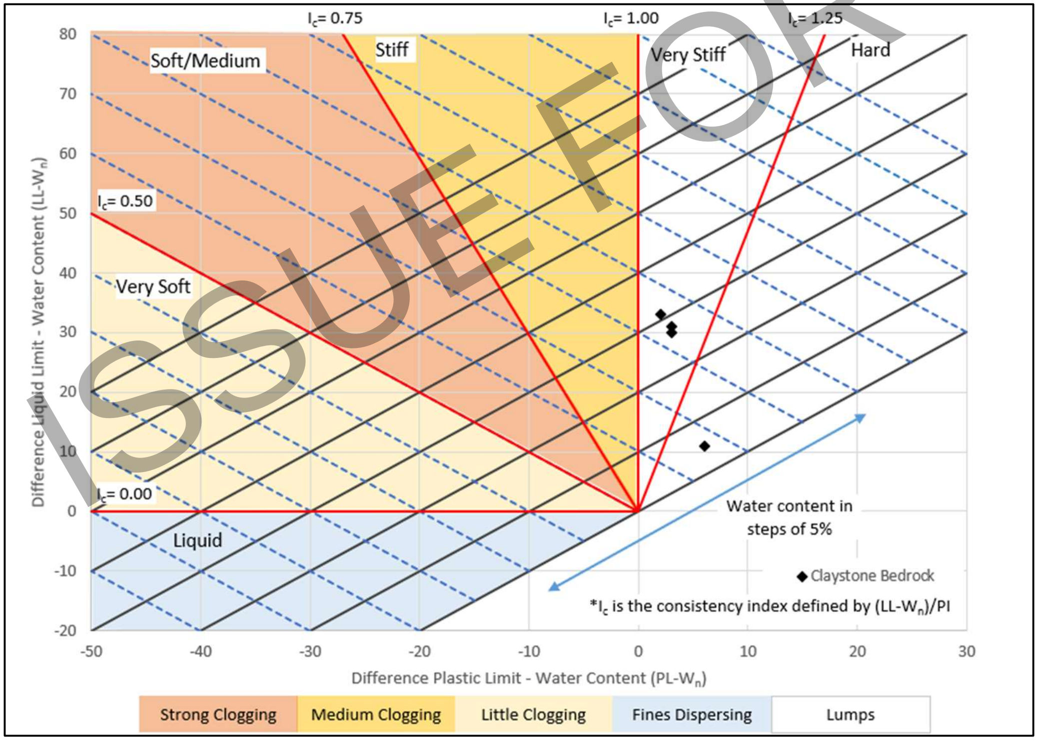


Figure 2.2: Bedrock Clogging Potential Chart (Hollman and Thewes, 2012)

2.4. Groundwater

Groundwater was encountered throughout the project geotechnical investigation. The baseline groundwater elevations for each tunnel are shown in each respective section.

The Contractor should anticipate that local variations in hydraulic conductivity and aquifer characteristics will be encountered. Fluctuations in groundwater levels may occur due to variations in seasonal fluctuations, stormwater runoff, rainfall, temperature, site development, and other factors not evident at the time these measurements were made. With respect to construction dewatering design, the cohesive soil is problematic in that frequent layers of lower hydraulic conductivity material with a high percentage of fines can hinder dewatering. In addition, shallow bedrock specifically at the CR 52 crossing location will hinder groundwater drawdown. Excavations with significant proportions of cohesive material or bedrock should anticipate lower inflow rates and dewatering design should be for planned accordingly. Tunnel and shaft-specific requirements for dewatering and groundwater management are discussed in each respective tunnel-specific section herein.

The hydraulic conductivity of the geologic units varies with fines content, void ratio and particle size. The Contractor should be aware that horizontal hydraulic conductivity in these deposits is significantly greater (from 5x to 10x) than vertical hydraulic conductivity. For baseline purposes, the hydraulic conductivity of the materials found onsite is as follows in the table below:

Table 2-4. Baseline Hydraulic Conductivity of Materials

Geologic Unit	Horizontal Hydraulic Conductivity (cm/s)	
	Baseline	Range
Cohesive Soil	$1x10^{-4}$	$1x10^{-6}$ to $1x10^{-3}$
Non-cohesive Soil	$1x10^{-1}$	$1x10^{-3}$ to $1x10^{-1}$
Bedrock	$1x10^{-5}$	$1x10^{-6}$ to $1x10^{-3}$

3. Tunnels

Per specification 31 71 00, the allowable tunneling techniques and initial support methods for the tunnels associated with the project are provided in the table below.

Table 3-1. Tunnel Summary

Tunnel	Length (LF)	Initial Support Minimum Diameter (inch)	Allowable Tunneling Techniques			Allowable Initial Support
			TBM	MTBM	Guided Auger Boring	Casing Pipe
I-25	295	54		X		X
CR 52	81	54	X	X	X	X

3.1. Interstate 25 (I-25) Crossing

This tunnel crosses beneath Interstate 25 and local utilities. The total tunnel length is 295 feet at a slope of 0.44% down from West to East. A 42-inch-diameter steel carrier pipe will be installed within a 54-inch-minimum-diameter steel casing pipe. The launch shaft is planned on the east side of I-25 within a fenced commercial lot without existing structures, and the receiving shaft is planned on the west side of I-25 within an agricultural lot without existing structures. The baseline geologic profile is shown in Figure 3.1.

3.1.1. Subsurface Characteristics and Ground Behavior

The soil characteristics and ground conditions described in this section constitute the baseline geotechnical conditions to be anticipated during construction of the shafts and tunnel. Geologic baselines include percent by volume of material anticipated to be encountered, groundwater elevation, and potential for obstructions. Baseline values and discussion pertinent to the geologic conditions from which the baselines are derived are provided below.

3.1.2. Geologic Units (Tunnel Specific)

Borings NTE-17-MW, NTE-18-MW and NTE-23 were used to create the Baseline Geologic Profile shown in Figure 3.1, however boring NTE-17-MW was completed approximately 350 feet to the east of the proposed launch shaft location due to restricted site access at the time of the investigation, and is not shown on the figures. Geologic units that will be encountered in tunnel and shaft excavations consist of cohesive soil and non-cohesive soil. The sections below discuss the geologic and geotechnical characteristics of these units.

3.1.2.1. Cohesive Soil

Cohesive soil will be encountered within the shaft excavations and tunnel excavation at the I-25 crossing. At the I-25 crossing, Cohesive soil consists of lean clay with varying amounts of sand (CL) and clayey sand (SC). Cohesive soil will be encountered above groundwater.

3.1.2.2. Non-Cohesive Soil

Non-cohesive soil will be encountered in both shaft and tunnel excavations at the I-25 crossing. Non-cohesive soil to be encountered in the shafts and tunnel excavations consists of poorly graded sand with varying amounts of clay (SP-SC, SW-SC, SP), and clayey sand with gravel (SC). Non-cohesive soil will be encountered above and below groundwater.

3.1.3. Groundwater

Groundwater was encountered during drilling of all three borings. Monitoring wells were installed at both borings NTE-17-MW and NTE-18-MW and depth to water was periodically measured thereafter. Shaft and tunnel construction will encounter groundwater. The baseline groundwater elevation is shown in Figure 3.1.

The local aquifer at the site is unconfined within surficial deposits. Unconfined aquifers are highly influenced by storm water runoff and infiltration, storm events, and drought conditions; however, this is accounted for in the baseline groundwater elevation. Section 2.4 discusses the baseline hydraulic conductivities of materials found onsite.

3.1.4. Construction Considerations (Tunnel Specific)

This section discusses the methods GEI anticipates will be used by the Contractor during construction of the shafts and tunnel at the I-25 crossing.

3.1.4.1. Shafts

Two construction shafts (launch and receiving shafts) will be required for the tunnel. Due to available space for equipment and staging and industry preference for mining uphill, the anticipated direction of tunnel excavation is from East to West such that the launch shaft will be on the East and the receiving shaft will be on the West side of the interstate.

The shafts will be excavated in Cohesive soil and Non-Cohesive soil. These materials are anticipated to be excavated with conventional equipment and will not require the use of blasting or hydraulic rock breaker attachments. The individual geologic unit discussions in Section 2.3 include the baselines regarding ground behavior. The table below presents baseline excavation relative volumes of each geologic unit that will be encountered during shaft excavations.

Table 3-2. Baseline Shaft Excavation Volumes by Geologic Unit (I-25 Crossing)

Geologic Unit	Shaft Excavation Volume (%)	
	Launch	Receiving
Cohesive Soil	50	55
Non-cohesive Soil	50	45

Unless watertight shaft systems are used, dewatering will be necessary for successful construction and use of the shafts. Deep wells are likely to be effective in this ground. The Contractor is also encouraged to plan for a means of handling precipitation, internal nuisance or construction water as necessary, such as sump pumps.

A variety of ground support methods can be successful in this ground. Best practice in the baselined ground conditions will be to provide support as soon as practical after excavation in stages or concurrent with excavation. Possible non-watertight shoring methods include slide rail, sheet piles, soldier piles and lagging, and liner plates. Possible watertight shoring methods include secant pile shaft and gasketed sheet piles. A concrete floor (mud mat) may be useful in controlling groundwater inflow through the non-cohesive soil and bottom instability at the shafts. If a watertight shaft is used in lieu of dewatering, a structural shaft invert plug is recommended to counteract upwelling pressures, as groundwater is baselined above the excavation bottom.

3.1.4.2. Tunnel

Microtunneling is the only method of tunnel excavation considered viable for the tunnel excavation at the I-25 crossing due to the groundwater table located above the tunnel excavation, relatively high permeability non-cohesive material to be encountered during tunnel excavation, and the importance of reducing risk of settlement to the traveling public. Initial Support must employ a jacked steel casing. A steel carrier pipe will be installed in a second pass and the annulus will be backfill grouted.

Other techniques for tunnel excavation such as guided auger boring or ramming are considered unfeasible due to groundwater levels and the planned length and diameter of the tunnel being beyond the acceptable risk tolerance for these techniques. A TBM or other open-faced techniques do not provide suitable control of groundwater and face stability.

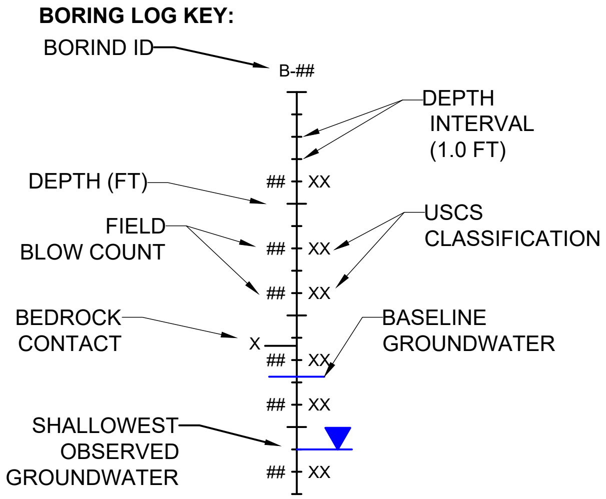
The tunnel will be excavated within Non-Cohesive soil. The table below presents baseline excavation volumes of each geologic unit that will be encountered during tunnel excavation. The baselines specific to subsurface characteristics and ground behavior are included in Section 2.3.

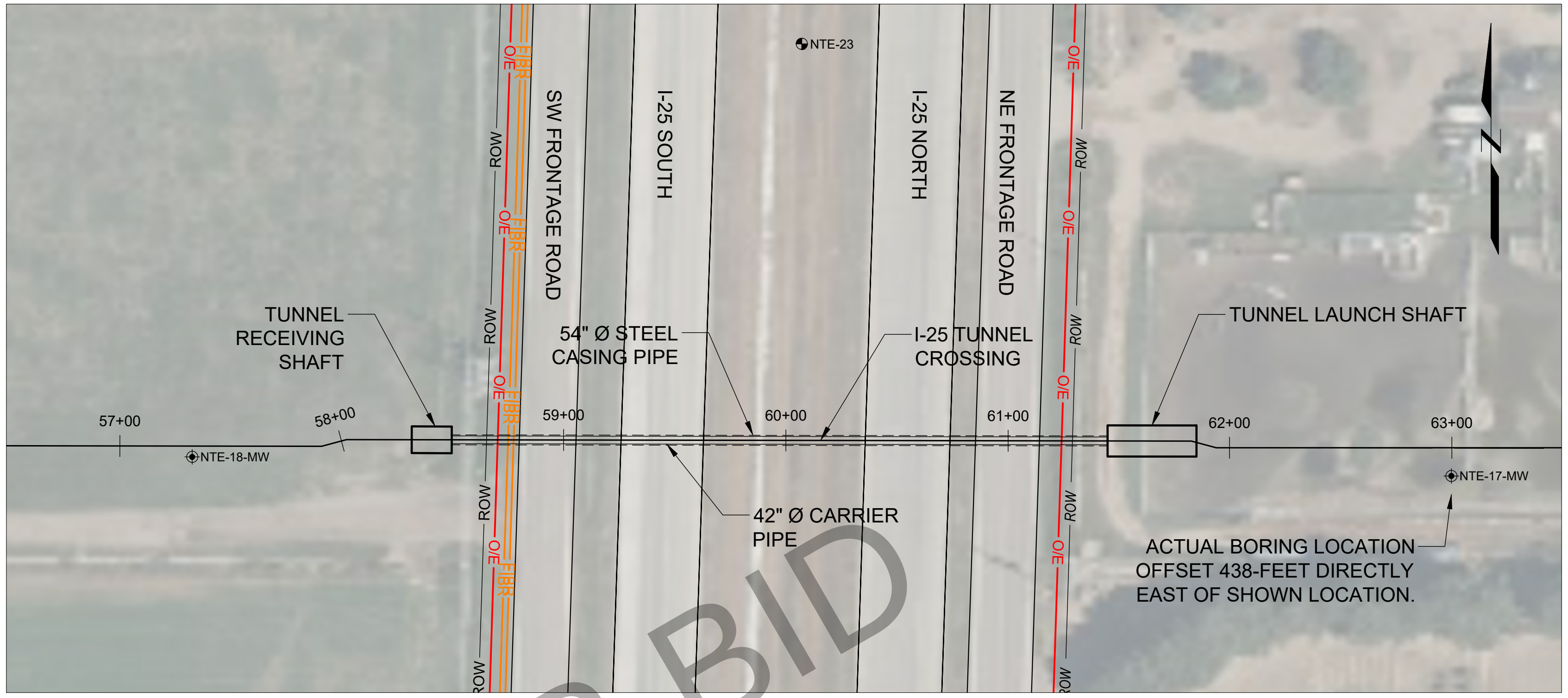
Table 3-3. Baseline Tunnel Excavation Volumes by Geologic Unit (I-25 Crossing)

Geologic Unit	Tunnel Excavation Volume (%)
Cohesive Soil	5
Non-cohesive Soil	95

With pipe jacking a MTBM (Microtunnel Boring Machine), a properly selected jacking frame will be sufficient to install the casing pipe under tolerable jacking loads in the baselined ground conditions and for the length and diameter of the proposed tunnel using construction best-practices. While the Contractor is responsible for selecting means and methods appropriate to the ground conditions and tunnel layout within the limitations set by the contract documents, use of an Intermediate Jacking Station (IJS) is not anticipated for this tunnel, but may be considered by the Contractor.

Figure 3.1 Baseline Geologic Profile (I-25 Crossing)





BASELINE GEOLOGIC UNTS:
- 🟨 COHESIVE SOIL
- 🟫 NON-COHESIVE SOIL
- ⬜ BEDROCK

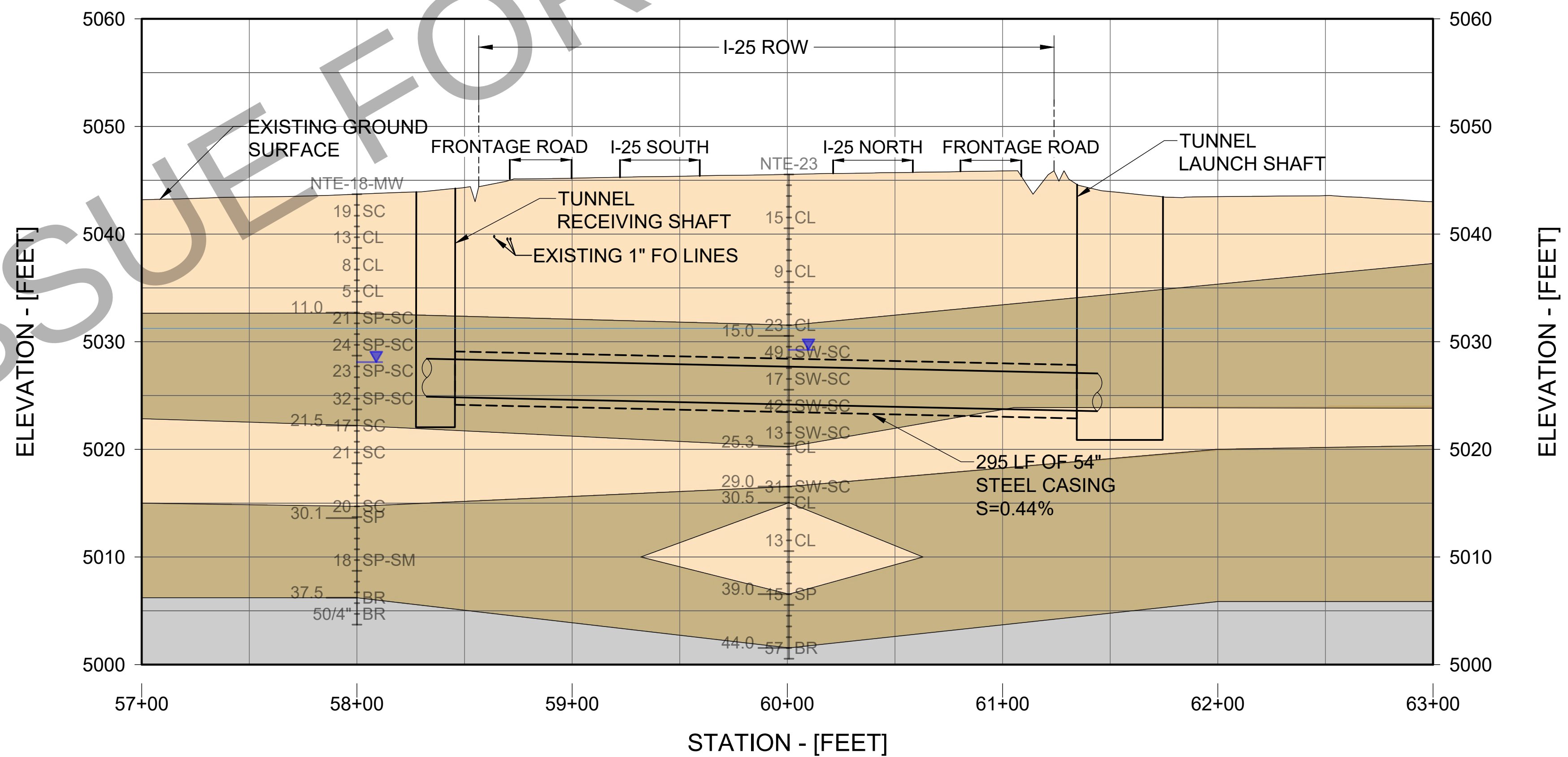
LINE TYPES AND SYMBOLS LEGEND:
- ——— CARRIER PIPE
- – – – – CASING PIPE
- ——— BASELINE GROUNDWATER DEPTH
- ◕ GEOTECHNICAL BORING
- ⊕ MONITORING WELL

BORING OFFSETS FROM TUNNEL ALIGNMENT		
BORING ID	OFFSET (FT)	OFFSET DIRECTION
NTE-17-MW	550	EAST
NTE-23	175	NORTH
NTE-18-MW	200	WEST

SHAFT DEPTHS[1,2]	
SHAFT	APPROXIMATE DEPTH (FT)
LAUNCH	23.6
RECEIVING	22

[1] NOTE: SHAFTS ASSUMED TO EXTEND 2-FEET BELOW CASING PIPE INVERT

[2] SHAFT DEPTH BASED ON SURVEY INFORMATION FROM HDR.



NOTES:
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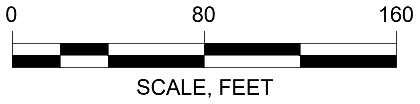


Geotechnical Baseline Report
Thornton Water Project - Segment F.2
Fort Collins, Colorado

HDR Engineers, Inc.
Denver, Colorado

GEI Consultants

Project 2505320

I-25 Crossing Geologic Cross Section

August, 2026

Fig. 3.1

3.2. CR 52 Crossing

This tunnel crosses beneath CR 52 and local utilities. The total tunnel length is 81 feet at a slope of 0.51% down from South to North. A 42-inch-diameter steel carrier pipe will be installed within a 54-inch-minimum-diameter steel casing pipe. The launch and receiving shafts are planned within undeveloped land. The baseline geologic profile is shown in Figure 3.2.

3.2.1. Subsurface Characteristics and Ground Behavior

The soil characteristics and ground conditions described in this section constitute the baseline geotechnical conditions to be anticipated during construction of the shafts and tunnel. Geologic baselines include percent by volume of material anticipated to be encountered, groundwater elevation, and potential for obstructions. Baseline values and discussion pertinent to the geologic conditions from which the baselines are derived are provided below.

3.2.2. Geologic Units (Tunnel Specific)

Borings NTE-9 and NTE-10-MW were used to create the Baseline Geologic Profile shown in Figure 3.2. Geologic units that will be encountered in tunnel and shaft excavations consist of cohesive soil and bedrock. The sections below discuss the geologic and geotechnical characteristics of these units.

3.2.2.1. Cohesive Soil

Cohesive soil will be encountered within the shaft excavations but not within the tunnel excavation at the CR 52 crossing. Cohesive soil consists of lean clay with varying amounts of sand (CL) and clayey sand (SC). Cohesive soil will be encountered above and below groundwater.

3.2.2.2. Bedrock

Bedrock to be encountered within the tunnel and shaft excavations at the CR 52 crossing consists of interbedded sandstone, clayey sandstone, and shale. Bedrock will be encountered below groundwater.

3.2.3. Groundwater

Groundwater was encountered during drilling of both borings at the CR 52 crossing. A monitoring well was installed at boring NTE-10-MW and depth to water was periodically measured thereafter. Shaft and tunnel construction will encounter groundwater. The baseline groundwater elevation is shown in Figure 3.2.

The local aquifer at the site is unconfined within surficial deposits. Unconfined aquifers are highly influenced by storm water runoff and infiltration, storm events, and drought conditions; however, this is accounted for in the baseline groundwater elevation. Section 2.4 discusses the maximum baseline hydraulic conductivity of materials found onsite.

3.2.4. Construction Considerations (Tunnel Specific)

This section discusses the methods GEI anticipates will be used by the Contractor during construction of the shafts and tunnel at the CR 52 crossing.

3.2.4.1. Shafts

Two construction shafts (launch and receiving shafts) will be required for the tunnel. Due to available space for equipment and staging and industry preference for mining uphill, the anticipated direction of tunnel excavation is from north to south such that the launch shaft will be on the north side and the receiving shaft will be on the south side of the roadway.

The shafts will be excavated in cohesive soil and bedrock. For baseline purposes, the Contractor shall account for a minimum of 2 concretions with a maximum dimension of 2-feet to be encountered in each shaft excavation. These materials are anticipated to be excavated with conventional equipment and will not require the use of blasting or hydraulic rock breaker attachments. The individual geologic unit discussions in Section 2.3 include the baselines regarding ground behavior. The table below presents baseline excavation relative volumes of each geologic unit that will be encountered during shaft excavations.

Table 3-4. Baseline Shaft Excavation Volumes by Geologic Unit (CR 52 Crossing)

Geologic Unit	Shaft Excavation Volume (%)	
	Launch	Receiving
Cohesive Soil	50	40
Bedrock	50	55

Water management systems internal to the shafts such as sumps are anticipated to be sufficient for construction at this location. Deep wells are unlikely to be effective in this ground due to the relatively low hydraulic conductivities and shallow bedrock. The Contractor is also encouraged to consider handling precipitation, internal nuisance or construction water as necessary.

A variety of ground support methods can be successful in this ground. Best practice in the baselined ground conditions will be to provide support as soon as practical after excavation in stages or concurrent with excavation. Possible methods include trench boxes, slide rail, sheet piles, soldier piles and lagging, and liner plates with dewatering. Bedrock may prove difficult for driving/raising sheet piles depending on how deep the piles are advanced below the shaft bottoms. A concrete floor (mud mat) may be useful in providing water resistant and structurally sound working surface at the shaft bottoms.

3.2.4.2. Tunnel

Three methods of tunnel excavation are considered viable for the tunnel excavation including guided auger boring, TBM, and MTBM. If the Contractor elects to use guided auger boring, a machine suitable for the baselined ground conditions should be selected, such as certain models manufactured by McLaughlin. Use of a MTBM with a pressurized face is permitted, though is it unlikely to be necessary when considered with the other open face, non-pressurized methods listed. Initial Support must employ a jacked steel casing. A steel carrier pipe will be installed in a second pass and the annulus will be backfill grouted.

Other techniques for tunnel excavation such as guided ramming or shield mining are considered unfeasible due to baseline ground conditions and the planned length and diameter of the tunnel being beyond the acceptable risk tolerance for these techniques.

The tunnel will be excavated within bedrock. The table below presents baseline excavation volumes of each geologic unit that will be encountered during tunnel excavation. The baselines specific to subsurface characteristics and ground behavior are included in Section 2.3.

Table 3-5. Baseline Tunnel Excavation Volumes by Geologic Unit (CR 52 Crossing)

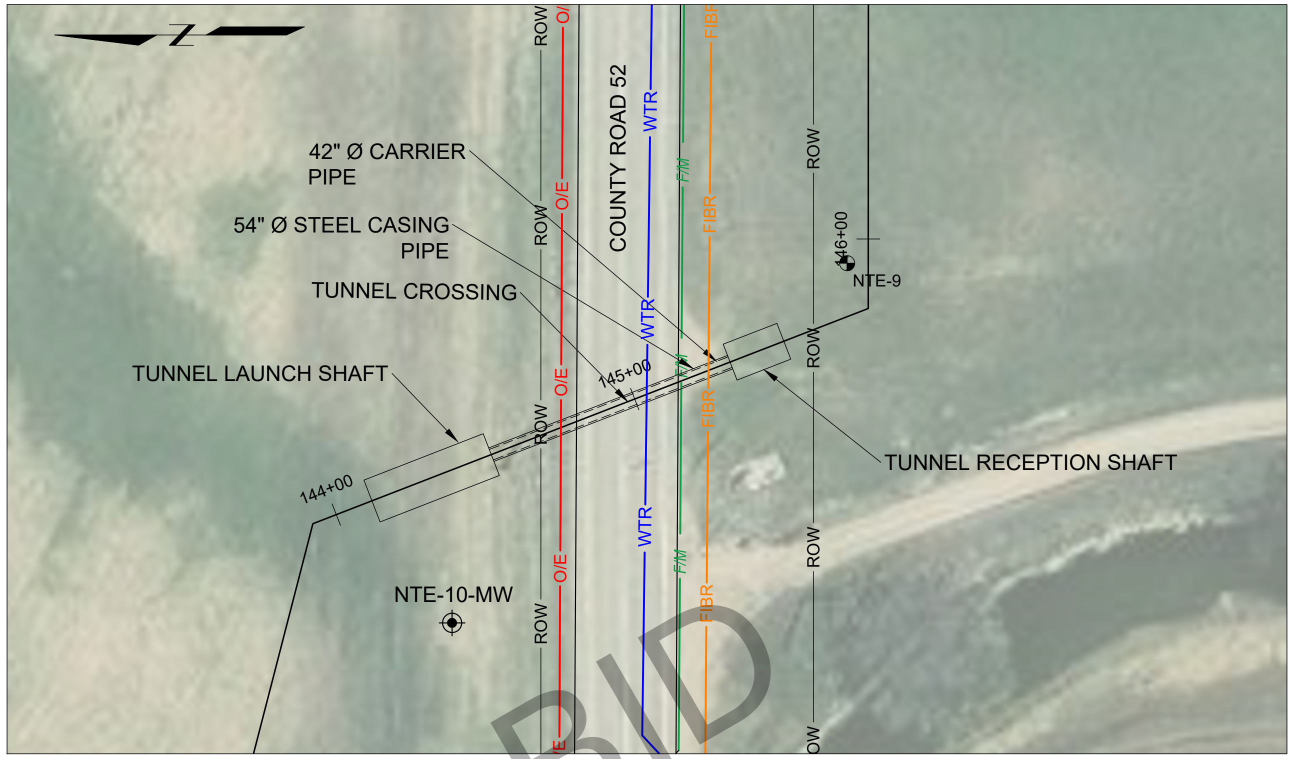
Geologic Unit	Tunnel Excavation Volume (%)
Bedrock	100

For baseline purposes, the Contractor shall account for a maximum of 2 concretions with a maximum dimension of 2-feet to be encountered in the tunnel excavation. Based on the Contractor's cutting head selection, hydraulic rock breakers may be required.

With pipe jacking a TBM, guided auger bore, or MTBM, a properly selected jacking frame will be sufficient to install the casing pipe under tolerable jacking loads in the baselined ground conditions and for the length and diameter of the proposed tunnel using construction best-practices. While the Contractor is responsible for selecting means and methods appropriate to the ground conditions and tunnel layout within the limitations set by the contract documents, use of an Intermediate Jacking Station (IJS) is not anticipated for this tunnel.

If guided auger boring is utilized, machinery should be tooled and equipped to excavate bedrock with baselined engineering properties provided in Section 3. This may include use of a steerable head or specially designed pilot tube and augers capable of excavating the non-displaceable bedrock. If a pilot tube and augers are used, the Contractor should assume a minimum of two full-length upsizings will be required to install the casing to the design alignment: one upsizing from the pilot tube to a casing between 12 - 18 inches, and one upsizing from the 12 – 18 inch casing to a 36-42 inch casing. Additional upsizings are at the discretion of the Contractor.

Figure 3.2 Baseline Geologic Profile (CR 52 Crossing)



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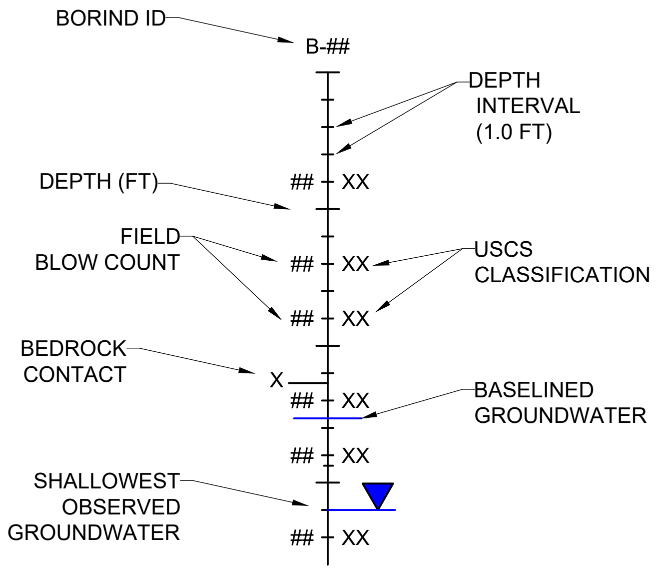
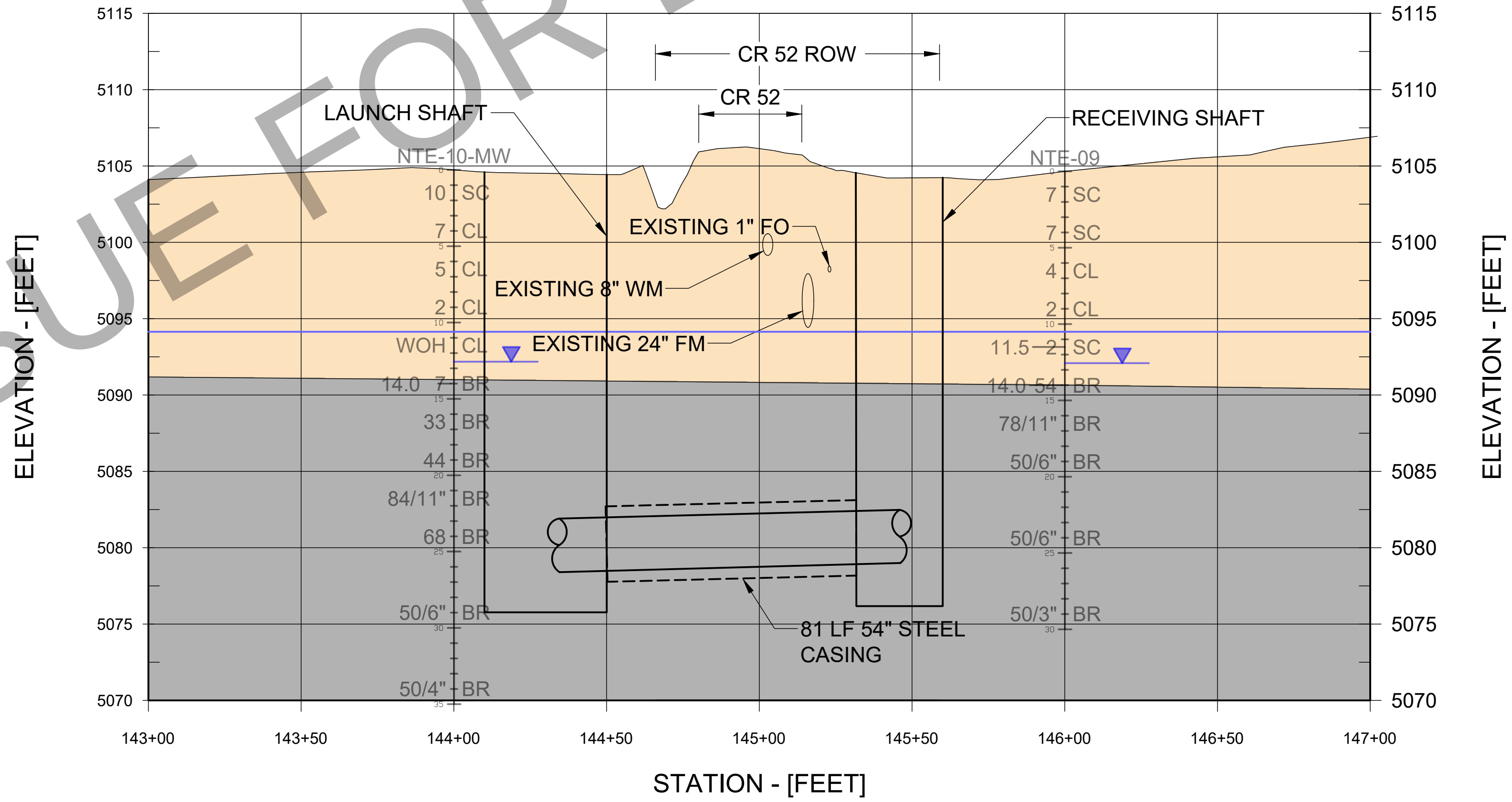


BASELINE GEOLOGIC UNTS:

🟧 COHESIVE SOIL
⬛ BEDROCK

LINE TYPES AND SYMBOLS LEGEND:

—— CARRIER PIPE
- - - - - - CASING PIPE
—— BASELINE GROUNDWATER DEPTH
◐ GEOTECHNICAL BORING
⌖ MONITORING WELL



BORING OFFSETS FROM TUNNEL ALIGNMENT		
BORING ID	OFFSET (FT)	OFFSET DIRECTION
NTE-09	80	SOUTHEAST
NTE-10-MW	70	NORTHWEST

SHAFT DEPTHS[1][2]	
SHAFT	APPROXIMATE DEPTH (FT)
LAUNCH	28.8
RECEIVING	28.0

[1] NOTE: SHAFTS ASSUMED TO EXTEND 2-FEET BELOW CASING PIPE INVERT
[2] SHAFT DEPTH BASED ON SURVEY INFORMATION FROM HDR.

NOTES:

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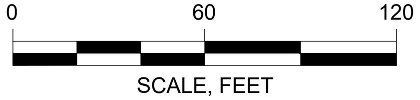

Geotechnical Baseline Report
Thornton Water Project - Segment F.2.
Fort Collins, CO

HDR Engineers, Inc.
Denver, CO

GEI Consultants

CR-52 GEOLOGIC CROSS SECTION

Project 2505320
August, 2026
Fig. 3.2

FAWAZ, DYLAN B:\Working\HDR\2505320 Thornton Segment F\06_DESIGN\Drawings\Thornton Segment F.2 CR 52 Crossing Plan and Profile.dwg - 8/01/2026

4. General Construction Considerations

The following sections discuss general methods GEI anticipates will be used by Contractors during construction of project shafts and tunnels. Discussed methods are not intended to dictate construction means and methods, but rather to provide GEI's opinion of various challenges to reasonable construction methods based on our experience and general practice. Within the limitations provided in the Specifications and this GBR, the Contractor is ultimately responsible for selecting shaft and tunnel excavation methods, shaft and tunnel support systems, and groundwater control plans. Of primary importance is the integrity of infrastructure, including roadways, utilities surrounding the tunnel, and other surrounding buildings and infrastructure. Existing utilities must also be crossed without damage as shown on the Contract Drawings. The Contractor's means and methods must be designed around protecting critical infrastructure while still meeting other project requirements such as safety and schedule.

The Contractor should notify and coordinate with all affected third parties in advance of shaft and tunnel construction. Third party reviews of the Contractor's construction plans and submittals may be performed, and the Contractor should allow time to address third party concerns and requirements.

4.1. Shafts

A minimum of two construction shafts (launching and receiving shafts) will be required for each tunnel. Due to available space for equipment and staging and industry preference for mining uphill, the anticipated direction of tunnel excavation is from down slope to up slope. The optimal sizing and layout of each shaft will be at the Contractor's discretion; however, it is assumed launch shafts will have approximate dimensions of 40 feet long (parallel to alignment) by 14 feet wide (perpendicular to alignment) with a depth extending to two feet below the tunnel inverts. This assumes the Contractor will use 20-foot-long jacking pipe segments. Smaller shafts are possible if the Contractor elects to use 10-foot-long jacking pipe segments. It is assumed receiving shafts will be used to recover mining equipment and place manholes connecting tunneled sections with open-cut sections. Receiving shafts are assumed to have approximate dimensions of 18 feet long by 12 feet wide with a depth extending to two feet below the alignment invert. If alternate sizing is used by the Contractor, the contractor shall notify the engineer for the relevant scaled baselines.

Shaft ground support methods are described in each tunnel section. Shaft construction will need to resist loads from the soils and bedrock such that movements of ground surface, roads, and existing utilities are kept within specified tolerances. Additional loading conditions/requirements are presented by traffic (i.e. HS-20 loading). Methods commonly employed include trench boxes, slide rail, sheet piles, secant piles, soldier piles and lagging, liner plates, ring beams, and other erected support.

Excavation is typically done by hydraulic excavator for shaft depths beneath approximately 20 feet, or with a mini-excavator working in combination with a bucket attached to a crane/excavator for greater depths. All excavated materials are anticipated to be rippable with conventional equipment. Blasting is not anticipated for any shaft on this project; however, the Contractor may assess the need for hydraulic rock breakers or other auxiliary equipment based on available geotechnical blow count data and rock engineering properties baselined in each tunnel section of this report. When considering handling of excavated materials, or "muck," the Contractor needs to account for potential shrinkage and bulking which are defined as the change in volume of the soil from its in-situ condition following excavation, moisture conditioning, placement or compaction.

Shaft entry/exit eyes are often zones susceptible to over-excavation and running ground, particularly as a pipe or machine is jacked through the eye transition between shafts/tunnels. Over excavation at these points is often controlled by a combination of dewatering, contact grouting of surficial materials immediately outside the shafts, and incorporating a bulkhead which exposes no more ground than is necessary for excavation equipment to pass. The Contractor should assume construction of a gasketed bulkhead for tunnel excavations below the groundwater table for MTBM installations, dewatering for other techniques below the groundwater table for other techniques, and torch-cutting a hole with an appropriate overcut for tunnel excavations above the groundwater table. Lifting/raising plates/piles, or other support members at the excavation face for the I-25 crossing tunnel will not be permitted unless they are sealed prior to lifting with a cast-in-place entry or exit wall.

4.2. Tunnels

It is important the Contractor closely monitors tunnel excavation out of the launch shaft and into the receiving shaft. These locations are often where ground loss into the shaft and over-excavation of ground occurs due to disturbance from shaft construction, which can create surface settlement and/or sinkholes. If not controlled, the settlement trough can follow the path of excavation and extend beyond the immediate vicinity of the shaft and into areas where settlement control is critical, such as the roadway.

Backfill grouting and contact grouting will be required for all tunnels as further described in the Contract Specifications. Backfill grouting involves filling the annulus between initial support and the carrier pipe with an approved grout mixture. Contact grouting involves filling the annulus created by an overcut (if any) between the initial support and native ground.

4.2.1. Tunnel Excavation Methods

Tunneling methods described in this report are generally described below. The descriptions are intended to provide justification for use of each method allowed for each tunnel by describing general applicability. The descriptions are specifically excluded from the baselines and are not intended to describe means and methods nor every practical application of these techniques. These techniques are listed in order corresponding to their general ability to control baselined ground and groundwater conditions presented above using standard and readily available equipment, from least capable to most capable. Equipment or equipment modifications are sometimes used, either at the option of the Contractor or as required by the Contract Specifications, to control specific risks associated with site-specific ground conditions. Each Contractor involved in this project has been pre-qualified for use select various techniques listed below by demonstrating proficiency and success using their select method(s).

The Contractor should be aware each of the excavation techniques is subject to project challenges and it is ultimately the Contractor's responsibility to select and perform tunnel construction best suited to their experience and capability to reduce manageable risk to affected third parties. Some of the specific challenges associated with each tunnel excavation method are described in each respective tunneling section of this report.

4.2.1.1. TBM

Excavation by TBM involves a wheeled excavator with a rotating cutting head equipped for the anticipated ground conditions. The cutting head has removeable panels and disjointed openings which limit material inflow. The TBM is propelled by a jacked casing. Excavated muck is removed from the tunnel by conveyor/bucket.

This is considered a non-pressurized, open-face technique suitable to dry/moist non-running or flowing soil or bedrock. This technique is sometimes used in combination with dewatering to promote better stability of the excavation face.

4.2.1.2. Guided Auger Bore

Guided auger boring involves excavation with a steel auger located ahead of or within a jacked steel casing. The auger teeth are equipped for the anticipated ground conditions. In bedrock such as will be encountered onsite, a specialized auger head is commonly used (e.g. “On-Target head” by McLaughlin or equivalent). An On-Target head or equivalent is steerable in baselined ground conditions and does not require a pilot tube. Auger bore systems not capable of accurate steering in both line and grade direction will require a pilot tube, which may require modifications both in cutting ability and adapters to match baselined ground density and strength. A pilot tube is pushed ahead of the auger casing to set the alignment and smaller-diameter casings (“upsizings”) may precede the final casing to prevent alignment deviation. The auger flights transmit excavated muck to the shaft where it is removed.

This is considered a non-pressurized, open-face technique suitable to dry/moist soil, cohesive soil with minimal water head, or firm bedrock. This technique is sometimes used in combination with dewatering to promote better stability of the excavation face.

4.2.1.3. MTBM

Excavation by MTBM involves a wheeled excavator with a rotating cutting head equipped for the anticipated ground conditions. The cutting head has a closed face with inflow/outflow ports. The inflow ports allow for injection of a specialized slurry, generally water, bentonite, and anti-clogging chemicals, which counteract in-situ ground pressures. The outflow ports allow for withdrawal of the slurry and excavated ground where the mixture is screened through a slurry separation plant and recycled. A surface-based operator carefully monitors slurry inflow/outflow, machine advance, and jacking loads, among other parameters, to minimize chances for over excavation. The MTBM is propelled by a jacked casing.

This is considered a pressurized, closed-face technique suitable to all ground conditions anticipated on this project. This technique prohibits worker access to the excavation face if an obstruction is encountered.

4.3. Instrumentation and Monitoring

The Contractor will be required to install, monitor, and report utility monitoring points, pavement monitoring point arrays, and surface survey points at all crossings per the Contract Drawings to assess potential ground deformation associated with tunneling. If alert threshold deformation values are reached or exceeded at any monitoring point, the Contractor will be required to perform measures to prevent further deformation. Systematic settlement analysis has been performed based on a conventional equipment overcut, and settlement in exceedance of the stipulated exceedance values is not anticipated with good Contractor practices. The Contractor should familiarize themselves with the minimum number of monitoring points, arrays, deformation values, and requirements provided in the Contract Documents.

4.4. Environmental Considerations

Measurement of subsurface gas was not completed or noted during the subsurface investigations. For baseline purposes, material encountered during shaft and tunnel excavation shall be considered “Potentially Gassy” per OSHA 3115-06R (2003).

Contaminated ground was not noted during environmental site assessments in the crossing vicinity. For baseline purposes, extra precautions or measures will not be required to handle, treat, or dispose of contaminated ground.

5. Limitations

This report was prepared in accordance with generally accepted geotechnical engineering and engineering geologic practices and principles; no warranty, express or implied is made. The subsurface conditions described in this report were based on data obtained from widely spaced exploratory borings and geotechnical laboratory testing performed by others, information provided by the client, engineering judgement, and our experience with similar subsurface conditions and projects.

This report has been prepared exclusively for our client for design, bidding, and construction purposes for the subject project. GEI is not responsible for technical interpretations by others of the data presented in this report or use of this report by others for the subject project or other projects.

The baseline values presented in this report are only intended for the proposed design and construction as understood by GEI at the time of issuing this report. If the proposed design and construction changes, GEI should be notified immediately and given the opportunity to review the proposed changes and if necessary, modify our baseline values presented herein.

An environmental assessment was not included in GEI's scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for baseline purposes. Environmental site assessments are to be conducted by others for this project.

References

References listed herein are included as information only. The Contractor may not rely upon the provided references as baseline statements in any phase of the project.

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Appendix A Tunnelman's Ground Classification Chart

Tunnelman’s Ground Classification Chart (Soil)

Classification	Behavior	Typical Soil Types
Firm	Material at the face is stable and holds a vertical face unsupported.	Hard clay, cemented sand
Slow Raveling	Material ravels from the face within hours after the ground has been exposed.	Sands with fines, fine sands above water table
Fast Raveling	Material ravels from the face within minutes after the ground has been exposed.	Sands with fines, fine sands below water table
Squeezing	Soil slowly advances into tunnel without signs of fracturing	Soft to stiff clays where the overburden pressure is higher than the soil shear strength.
Swelling	Soil moves slowly into tunnel, associated with a considerable volume increase in the ground surrounding the tunnel.	Highly overconsolidated high plasticity clays.
Cohesive Running	Preceded by brief period of raveling, soil will then “run” like a granulated sugar until the slope angle reaches its angle of repose.	Clean, fine, moist sand.
Running	Immediately upon exposure, the soil will “run” like a granulated sugar until the slope angle reaches its angle of repose.	Clean, coarse or medium sand above water table.
Flowing	Flows as a mixture of soil and water into the heading.	Silt, sand, and gravel beneath the water table without fines.