GEOTECHNICAL EXPLORATION AND ENGINEERING REVIEW

MVH - FF New Greenhouse
Fergus Falls, Minnesota

NTI Project No. 21.FGO.11938

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Unearthing confidence™

May 4, 2021

State of Minnesota
309 Administrative Building
50 Sherburne Ave
St. Paul, MN 55155

Attn: Mr. Paul Gannon

Subject: Geotechnical Exploration and Engineering Review
Proposed MVH - FF New Greenhouse
Fergus Falls, Minnesota
NTI Project No. 21.FGO.11938

In accordance with your request and subsequent April 5, 2021 authorization, Northern Technologies, LLC (NTI) conducted a Geotechnical Exploration for the above referenced project. Our services included advancement of exploration borings and preparation of an engineering report with recommendations developed from our geotechnical services. Our work was performed in general accordance with our proposal of March 31, 2021 and our Master Contract Number 167673/T#2002A with the State of Minnesota.

Soil samples obtained at the site will be held for 60 days at which time they will be discarded. Please advise us in writing if you wish to have us retain them for a longer period. You will be assessed an additional fee if soil samples are retained beyond 60 days.

We appreciate the opportunity to have been of service on this project. If there are any questions regarding the soils explored or our review and recommendations, please contact us at your convenience at (701) 232-1822.

Northern Technologies, LLC

Daniel Gibson

Dan Gibson, P.E.
Senior Engineer

Josh Holmes, P.E.
Engineer

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TABLE OF CONTENTS
GEOTECHNICAL EXPLORATION AND ENGINEERING REVIEW

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Contents Page

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1.0 EXECUTIVE SUMMARY

We briefly summarize below our geotechnical recommendations for the proposed project. The summary must be read in complete context with our report.

We conclude you may support the proposed MVH - FF New Greenhouse (Greenhouse) by founding of standard perimeter strip and spread column footings or the proposed Frost Protected Shallow Foundation (FPSF) on competent, non-organic natural soil(s) or engineered fill, as recommended within our report.

- Foundations may be proportioned using the maximum net allowable soil bearing pressures of Table 2.
- Our exploration indicates topsoil extends to approximately 0.5 feet at project borings. You should anticipate similar but variable depth of topsoil across the project. We recommend additional evaluation during site stripping and excavation to confirm removal of unsuitable soils from below project construction.
- ***While we did not encounter measurable ground water during or at the completion of drilling operations at the borings, select soil samples recovered during our exploration program were moist.*** The moisture content of lens soils and the host clays can vary annually and per recent precipitation. While unlikely, such soils and other regional dependent conditions may produce ground water entry of project excavations. We direct your attention to other report sections and appendices concerning ground water issues and subsurface drainage recommendations.
- Through material composition, clay soils have a tendency to swell with absorption of moisture. This is especially true for fat clays (CH) or silty fat clays (CH-MH) due to increased montmorillonite mineral content. ***Clay soils on this site consist of lean clay (CL) soils which have a lesser swell potential; however, we recommend measures are taken during construction to minimize moisture change of the native soils.*** The attachment presented within the appendices provides a brief description of the swell process of clay and provides limited recommendation(s) for reducing this risk on your project. Note a major attribute contributing to swell of clays is absorption of moisture under reduced confinement. Continuous drainage of site excavations is necessary to reduce swelling impacts to your project.

2.0 INTRODUCTION

2.1 Site / Project Description

The proposed Greenhouse is to be constructed within greenspace to the northwest of the existing MVH located at 1821 N Park St in Fergus Falls, Minnesota. The 21 foot by 31 foot Greenhouse will consist of a concrete frost protected slab, nominal 30 inch CMU walls, and pre-engineered greenhouse structure above.

2.2 Scope of Services

The purpose of this report is to present a summary of our geotechnical exploration and provide generalized opinions and recommendations regarding the soil conditions and design parameters for founding of the project. Our "scope of services" was limited to the following:

1. Explore the project subsurface by means of two (2) standard penetration borings extending to maximum depth of 14.9 feet, and conduct laboratory tests on representative samples to characterize the engineering and index properties of the soils.
2. Prepare a report presenting our findings from our field exploration, laboratory testing, and engineering recommendations for footing depths, allowable bearing capacity, estimated settlements, floor slab support, excavation, engineered fill, backfill, compaction and potential construction difficulties related to excavation, backfilling and drainage.

3.0 EXPLORATION PROGRAM RESULTS

3.1 Exploration Scope

Site geotechnical drilling occurred on April 19, 2021 with individual borings advanced at approximate locations as presented on the diagram within the appendices. NTI located the borings relative to existing site features and determined the approximate elevation of the borings relative to the temporary benchmark (TBM), the finished floor of existing building (reference boring diagram). The elevation of the TBM, as assigned by NTI, is 200.0 feet.

3.2 Surface Conditions

The property for the proposed Greenhouse is currently vacant greenspace. We assume this area has not been previously developed and does not include demolition material from prior occupancy or from other off site locations. Surface drainage appears to flow generally north, south, and west towards lower elevation based on Google Earth imagery. The elevation change between borings is less than one foot.

3.3 Subsurface Conditions

Please refer to the boring logs within the appendices for a detailed description and depths of stratum at each boring. The boreholes were backfilled with auger cuttings or abandoned using high solids bentonite or neat cement grout per state statute. Minor settlement of infill soil will occur with Owner responsible for final closure of the boreholes. The general geologic origin of retained soil samples is listed on the boring logs. The upper portion of the soil profile for each boring was sampled using auger flights and is approximate.

The overall subsurface soil profile at the borings consists of approximately 0.5 feet of topsoil underlain by rather stiff Stagnation Moraine/Glacial Drift soils which extend to the termination depth of the borings (maximum 14.9 feet). The SM/GD soils are comprised of lean clay with trace amounts of sand and gravel having varying color, moisture content, and unit weight. Additional comment on the evaluation of recovered soil samples is presented within the report appendices.

3.4 Ground Water Conditions

The drill crew observed the borings for ground water and noted cave-in depth of borings, if any, during and at the completion of drilling activities. These observations and measurements are noted on the boring logs.

While we did not encounter measurable ground water during or at the completion of drilling operations at the borings, select soil samples recovered during our exploration program were moist. The moisture content of lens soils and the host clays can vary annually and per recent precipitation. While unlikely, such soils and other regional dependent conditions may produce ground water entry of project excavations. We direct your attention to other report sections and appendices concerning ground water issues and subsurface drainage recommendations.

3.5 Laboratory Test Program

Our analysis and recommendations of this report are based upon our interpretation of the standard penetration resistance determined while sampling soils, hand penetrometer test results obtained during classification of retained soils, and experience with similar soils from other sites near the project. The results of such tests are summarized on the boring logs or attached test forms.

4.0 ENGINEERING REVIEW AND RECOMMENDATIONS

The following recommendations are based on our present knowledge of the project. We ask that you or your design team notify us immediately if significant changes are made in building size, location or design as we would need to review our current recommendations and provide modified or different recommendations with respect to such change(s).

4.1 Project Scope

We understand the Greenhouse will include a FPSF consisting of an insulated slab support of above grade construction. We anticipate interior column loads (if any) will not exceed 30 kips and wall loads will not exceed 4 kips per lineal foot (klf). We anticipate the project will include a modest 1 to 1 ½ foot increase in grade to elevate the Greenhouse and promote drainage from the structure. Our assessment of project soils, opinions, and report recommendations are based directly on application of estimated structural loads to site soils.

4.2 Site Preparation

Project construction, as proposed, will involve stripping of the site and implementation of corrective grading. We recommend removal of all topsoil and/or any unsuitable material(s) encountered during advancement of project excavations. Our field exploration indicates removal of topsoil should result in excavations extending to approximately 0.5 feet below existing grade. Additional excavation will be necessary to achieve frost protection of footing construction and construction of the FPSF.

We recommend that you oversize all earthwork improvements and excavations where fill materials are placed below foundations. The minimum excavation oversize should extend per the requirements outlined on the diagram within the report appendices.

You should pump seepage from excavations continuously until the Geotechnical Engineer of Record or their designated representative determines such seepage no longer impacts the bearing soils, engineered fill system, backfill system or soils and concrete placement.

The Geotechnical Engineer of Record or their designated representative should review project excavations to verify removal of unsuitable material(s) and adequate bearing support of exposed soils. All such observations should occur prior to the placement of engineering fill, or construction of footings and floor slabs.

Engineered fill for overall corrective earthwork and for support of project perimeter footings should consist of native, non-organic clay or non-frost susceptible fill. Engineered fill placed interior to and above the base of perimeter frost footings or below the FPSF should consist of granular soils which comply with the material properties listed for granular fill placement below floor slab construction. We recommend draining of granular soils placed below the structure.

Unless otherwise directed by the report, you should temper engineered fill for correct moisture content and then place and compact individual lifts of engineered fill to criteria established within the appendices.

4.3 Foundations

The following bearing recommendations are based on our understanding of the project. You should notify us of any changes made to the project size, location, design, or site grades so we can assess how such changes impact our recommendations. We assume foundation elements will impose maximum vertical loads as previously noted within this report.

In our opinion, you may support the proposed Greenhouse by founding of spread footings or a FPSF on competent, non-organic native soils, or engineered fill, providing such construction complies with the criteria established within this report.

You should support exterior foundations at a common elevation within soils of the same strata layer. All perimeter footings should be supported by cohesive soils to limit migration of seepage interior to the building perimeter or provide drainage of the granular section as needed. You may design footings using the Table 1 maximum net allowable soil bearing pressures.

Table 1: Recommended Maximum Net Allowable Soil Bearing Pressure [1]

Location	***Criteria***
Frost Protected Shallow Foundation (FPSF): Supported on natural soils or engineered fill and adequate rigid insulation to prevent frost heave.	Maximum of 2,500 psf
Perimeter Strip Footings, Perimeter Columns: Supported on natural soils or engineered fill below depth of frost penetration, and at an elevation as referenced within this report.	Maximum of 2,500 psf
Interior Strip Footings: Supported on natural, competent soils and/or engineered fill at a depth which provides no less than 6 inches of clearance between the top of footing and underside of floor slab (for sand cushion).	Maximum of 2,500 psf
Interior Column Footings: Supported on natural, competent soils and/or engineered fill at a depth which provides no less than 6 inches of clearance between the top of footing and underside of floor slab (for sand cushion).	Maximum of 3,000 psf

1. Maximum net allowable soil bearing pressure recommendations predicated on footing design and construction complying with recommendations presented within this report. To minimize local failure of supporting soils, it is our opinion footing construction should comply with the International Building Code (IBC) requirements.

Construction should extend footing to sufficient depth below ground (exposed slab) surface as protection against frost action. For this project, you should extend at-grade footing construction within permanently heated areas (60^0 Fahrenheit or above) to no less than 5 feet below final grades as protection against frost action. Similarly, you should extend at-grade footings to a minimum of 7 feet below the exterior ground surface in areas lacking permanent heat. Intermediate founding of footings between the two referenced depths may be necessary for construction within areas with moderate temperature and/or intermittent heating. ***Frost protected shallow foundations may be designed based on an Air Freezing Index of 3279 °F or 3391°F for 50 year (98%) and 100 year (99%) returns, respectively, per the NOAA - National Climatic Data Center.***

We previously noted clay soils have risk of swell with absorption of moisture. This is especially true when excess runoff, pooled within excavations is absorbed by clay soils. Partially constructed foundations, foundation of reduced confining load, and more importantly, lightly loaded on-grade floor construction may heave due to clay soil swell. You should maintain constant automated subsurface drainage of the construction site to reduce this risk of heaved foundations.

(If part of construction) Foundation walls with unbalanced earthen fill will experience lateral loading from retained soils. You may model this lateral loading as an equivalent earth pressure applied to the foundation wall providing site geometric and related conditions complies with the parameters supporting such modeling. We recommend use of the Table 2 "at-rest" equivalent fluid earth pressures for establishing lateral loading of foundations walls with unbalanced earthen fill.

Table 2: Retained Soil - Equivalent Fluid Weight / Coefficient of Friction

Soil Type	***"At Rest" Condition*** (pcf) [1]	***"Active" Condition*** (pcf) [1]	***"Passive Condition*** (pcf) [1]	***Coefficient of Friction*** [2]
Lean Clay (CL)	95	80	140	0.30
Sand (SP, SP-SM)	62	42	250	0.50

1 The recommendations for equivalent fluid weight based solely on assumed conditions with respect to sloping ground and/or presence of surcharge load. We caution design professional that actual loads imparted to the foundation will be dependent on soil conditions, site geometric considerations and surcharge loads imparted to the structure.

2 The determination of resistance to sliding determined based on multiplication of the respective coefficient of friction by the effective vertical stress occurring at the elevation of interest.

4.4 Bearing Factor of Safety and Estimate of Settlement

We estimate native soils provide a nominal 3 factor of safety against localized bearing failure when construction complies with report criteria and recommendations, and you design structure footings using the Table 1 maximum net allowable soil bearing recommendation(s).

We also estimate that footings designed with the Table 1 maximum net allowable soil bearing pressure recommendations and loaded per report assumptions may experience long term, total settlement of less than 3/4 inch. Likewise, project footings may experience differential settlement on the order of 25 to 50 percent of total settlement with greatest movement occurring between adjacent footings of greatest load variation.

Furthermore, total and differential movement of footings and floor slabs could be significantly greater than the above estimates if you support construction on frozen soils, the moisture content of the bearing soils significantly changes from insitu conditions, and snow or ice lenses are incorporated into site earthwork.

4.5 Slab-on-Grade Floors

Our borings indicate poor soils within the project interior and recommend removal of all unsuitable soils and materials as previously recommended for structure footings. We conclude construction of at-grade floors will require fill placement interior to the structure perimeter for the FPSF.

Due to use of a FPSF, fill placement for the floor slab should consist of granular fill, providing such fill has 100 percent material passing the 1 inch sieve opening, no more than 50 percent materials passing the No. 40 U.S. Sieve opening, and no more than 5 percent material passing the No. 200 U.S. Sieve opening. The granular fill should be tempered for moisture, should be placed and then compacted per the criteria established within the appendices.

Design of the floor slab may be based on an estimated subgrade reaction modulus (k) of 100 lbs/in^3. While it is our opinion that you reinforce floor slab construction, such need should be determined by the Structural Engineer of Record.

All interior at-grade floors with impervious or near impervious surfacing such as, but not limited to, paint, hardening agent, vinyl tile, ceramic tile, or wood flooring, should include provision for installation of a vapor barrier system. Historically, vapor barrier systems can consist of many different types of synthetic membrane and can be placed either below sand cushion materials or at the underside of the concrete floor. All such issues are contentious and have both positive and negative aspects associated with long term performance of floor. We recommend you follow ACI 302 for guidance on the need and location for installing vapor barrier below the project floor slab.

When possible, you should isolate floor slabs from other building components. It is our opinion such isolation should include installation of a ½ inch thick expansion joint between the floor and walls, and/or columns to minimize binding between construction materials. This construction should also include application of a compatible sealant after curing of the floor slab to reduce moisture penetration though the expansion joint. As a minimum, you should install bond breaker to isolate and reduce binding between building components.

We previously noted risk of heave of on-grade floor slab construction if exposed clay soils are allowed to absorb moisture [from runoff or precipitation]. We direct your attention to the appendices for further discussion on the Swelling of Clay Soils.

4.6 Exterior Backfill & Subsurface Drainage

Exterior fill placement around the foundation and associated final grading adjacent to the building can significantly impact the performance of a structure. ***We understand the project will not include basement construction or foundation walls which retain soils.***

While not necessarily required for this project, you should install subsurface drainage at the base of basement foundation walls, retaining walls, and at-grade foundation walls to limit moisture accumulation within granular soils placed below interior floors. We anticipate placement of drain tile at the base of any granular section below floor slabs and the FPSF. The native clays should be graded to direct flow to the drain tile system.

As a general guideline, such drainage consists of a geotextile and coarse drainage encased slotted or perforated pipe extending to sump basin(s). We recommend that exterior drainage be separated from interior drainage to reduce risk of cross flow and moisture infiltration below structure interior. The project Architect and/or Structural Engineer of Record should determine actual need for subsurface drainage.

Exterior backfill of at-grade foundations walls should consist of native, non-organic soils for at-grade construction. Placement of exterior backfill against at-grade foundation walls should be performed concurrent with interior backfill to minimize differential loading, rotation and/or movement of the wall system.

You should limit placement of exterior backfill against below grade foundations until lateral restraint of the foundation walls has been installed to the satisfaction of the Structural Engineer. Final grading of exterior backfill should provide sufficient grade for positive drainage from structure. We presented within other report section recommendations for final grading.

4.7 Surface Drainage

You should maintain positive drainage during and after construction of project and eliminate ponding of water on site soils. We recommend you include provisions within construction documents for positive drainage of site. You should install sumps at critical areas around project to assist in removal of seepage and runoff from site. We present recommendations for sump construction within the appendices.

You should maintain the moisture content of site clays as close to existing as possible as excessive changes can cause shrinkage or expansion of the soil, and lead to distress of construction.

We understand sidewalks, curbing, pavements, and lawn will direct drainage from structure. You should grade exterior to slope from building(s). We recommend that you provide a 5 percent gradient within 10 feet of building for drainage from lawn, and 2 percent minimum gradient from building for drainage of sidewalks / pavements. All pavements should drain to on-site storm collection, municipal collection system, or roadside ditching.

You should direct roof runoff from building by a system of interior roof and scupper drains, or rain gutters, down spouts and splash pads. It is our opinion interior roof drains plumbed directly to the storm water piping system provide the most favorable method of conveying drainage from the roof as interior drains do not freeze or discharge runoff onto exterior sidewalks and pavements.

4.8 Utilities

Placement of underground utilities typically includes granular bedding for support of piped systems. Placement of granular soils within underground utility construction promotes migration of subsurface moisture towards and below the bearing stratum of footing construction. This, in turn, can lead to moisture uptake by native clays producing heave of construction, loss of shear strength and/or differential settlement of footing and floors.

Therefore, we recommend that you eliminate placement of all granular bedding soils within 10 feet of project excavations creating a zone where cohesive soils or lean concrete (i.e. controlled density fill) is used for all soil replacement within utility trenches. This “zone of control” should significantly reduce moisture migration below the project foundations. All clay bedding fill within this zone should be placed and compacted as recommended for utility trench backfill.

In lieu of placing clay soils within the above referenced "zone of control", alternate means of interception and blockage of drainage along site utilities may be provided to minimize moisture migration into and below structure foundation and floors.

Wetter soils from depth should be placed in the lower portion of utility trench construction while dryer soils from near ground surface should be placed in upper most portion of trench fill. You should temper the utility trench fill for correct moisture content and then place and compact individual lifts of trench fill to criteria established within the report appendices.

There is a high probability that fine and coarse alluvium laminations occur within site soils and may be present along utility trench excavations. Such formations and other regional dependent soil conditions may be water bearing. While it is our opinion small pumps should handle seepage resulting from utility construction, we caution that interception of a major water bearing stratum may result in significantly greater seepage into utility excavations. Therefore, we recommend that you include provisions within construction document for pumping of seepage from utility excavations.

4.9 Vegetation

Vegetation planting near structures can result in a change in soil moisture content from moisture uptake by the plants or excessive watering of plantings. The resulting change in soil moisture contributes to lateral earth pressure development and frost related heave of local soils. You should eliminate planting of trees or shrubs within 10 feet of the structures as a cautionary measure to reduce the seasonal fluctuation of soil moisture. ***As a minimum, we recommend that you establish a plan to control and limit watering of planting within 10 feet of the structures. Such review and control is necessary to minimize the moisture change of the native clays.***

5.0 CONSTRUCTION CONSIDERATIONS

5.1 Excavation Stability

Excavation depth and sidewall inclination should not exceed those specified in local, state or federal regulations. Excavations may need to be widened and sloped, or temporarily braced, to maintain or develop a safe work environment. Also, contractors should comply with local, state, and federal safety regulations including current OSHA excavation and trench safety standards. Temporary shoring must be designed in accordance with applicable regulatory requirements.

5.2 Engineered Fill & Winter Construction

The Geotechnical Engineer of Record or their designated representative should observe and evaluate excavations to verify removal of uncontrolled fills, topsoil and/or unsuitable material(s), and adequacy of bearing support of exposed soils. Such observation should occur prior to construction of foundations or placement of engineered fill supporting excavations.

Engineered fill should be evaluated by above designated representative for moisture content, mechanical analysis and/or Atterberg limits prior to placement. You should temper engineered fill for correct moisture content and then place and compact individual lifts of engineered fill to criteria established within the appendices.

Frozen soil should never be used as engineered fill or backfill, nor should you support foundations on frozen soils. Moisture freezing within the soil matrix of fine grained and/or cohesive soils produces ice lenses. Such soils gain moisture from capillary action and, with continued growth, heave with formation of ice lenses within the soil matrix. Foundations constructed on frozen soils settle at or after thaw of ice lenses.

You should protect excavations and foundations from freezing conditions or accumulation of snow, and remove frozen soils, snow, and ice from within excavations, fill section or from below proposed foundations. Replacement soils should consist of similar materials as those removed from the excavation with moisture content, placement and compaction conforming to report criteria.

5.3 Operation of Project Sumps

We previously noted the importance of removal of seepage and runoff from project excavations. You should install and continuously operate sumps, temporary subsurface drainage pipe, and/or collection manifold and vacuum wells for removal of seepage and runoff from project. We present recommendations for project sumps in the appendices.

6.0 CLOSURE

Our conclusions and recommendations are predicated on observation and testing of the earthwork directed by Geotechnical Engineer of Record. Our opinions are based on data assumed representative of the site. However, the area coverage of borings in relation to the entire project is very small. For this and other reasons, we do not warrant conditions below the depth of our borings, or that the strata logged from our borings are necessarily typical of the site. Deviations from our recommendations by plans, written specifications, or field applications shall relieve us of responsibility unless our written concurrence with such deviations has been established.

This report has been prepared for the exclusive use of State of Minnesota for specific application to the proposed MVH - FF New Greenhouse in Fergus Falls, Minnesota. Northern Technologies, LLC has endeavored to comply with generally accepted geotechnical engineering practice common to the local area. Northern Technologies, LLC makes no other warranty, expressed or implied.

Northern Technologies, LLC

Dan Gibson, P.E.
Senior Engineer

Josh Holmes, P.E.
Engineer

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a Duly Licensed Professional Engineer under the Laws of the State of Minnesota.

Daniel T. Gibson, P.E.
Date: 5/4/2021 Reg. No. 48076

Attachments

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APPENDIX A

GEOTECHNICAL EVALUATION OF RECOVERED SOIL SAMPLES

We visually examined recovered soil samples to estimate distribution of grain sizes, plasticity, consistency, moisture condition, color, presence of lenses and seams, and apparent geologic origin. We then classified the soils according to the Unified Soil Classification System (ASTM D2488). A chart describing this classification system and general notes explaining soil sampling procedures are presented within the appendices.

The stratification depth lines between soil types on the logs are estimated based on the available data. Insitu, the transition between type(s) may be distinct or gradual in either the horizontal or vertical directions. The soil conditions have been established at our specific boring locations only. Variations in the soil stratigraphy may occur between and around the borings, with the nature and extent of such change not readily evident until exposed by excavation. These variations must be properly assessed when utilizing information presented on the boring logs.

We request that you, your design team or contractors contact NTI immediately if local conditions differ from those assumed by this report, as we would need to review how such changes impact our recommendations. Such contact would also allow us to revise our recommendations as necessary to account for the changed site conditions.

FIELD EXPLORATION PROCEDURES

Soil Sampling – Standard Penetration Boring:

Soil sampling was performed according to the procedures described by ASTM D-1586. Using this procedure, a 2 inch O.D. split barrel sampler is driven into the soil by a 140 pound weight falling 30 inches. After an initial set of six inches, the number of blows required to drive the sampler an additional 12 inches is recorded (known as the penetration resistance (i.e. "N-value") of the soil at the point of sampling. The N-value is an index of the relative density of cohesionless soils and an approximation of the consistency of cohesive soils.

Soil Sampling – Power Auger Boring:

The boring(s) was/were advanced with a 6 inch nominal diameter continuous flight auger. As a result, samples recovered from the boring are disturbed, and our determination of the depth, extend of various stratum and layers, and relative density or consistency of the soils is approximate.

Soil Classification:

Soil samples were visually and manually classified in general conformance with ASTM D-2488 as they were removed from the sampler(s). Representative fractions of soil samples were then sealed within respective containers and returned to the laboratory for further examination and verification of the field classification. In addition, select samples were submitted for laboratory tests. Individual sample information, identification of sampling methods, method of advancement of the samples and other pertinent information concerning the soil samples are presented on boring logs and related report attachments.

General Notes

DRILLING & SAMPLING SYMBOLS		LABORATORY TEST SYMBOLS	
SYMBOL	**DEFINITION**	**SYMBOL**	**DEFINITION**
C.S.	Continuous Sampling	W	Moisture content-percent of dry weight
P.D.	2-3/8" Pipe Drill	D	Dry Density-pounds per cubic foot
C.O.	Cleanout Tube	LL, PL	Liquid and plastic limits determined in accordance with ASTM D 423 and D 424
3 HSA	3 ¼" I.D. Hollow Stem Auger	Q_u	Unconfined compressive strength-pounds per square foot in accordance with ASTM D 2166-66
4 FA	4" Diameter Flight Auger		
6 FA	6" Diameter Flight Auger		
2 ½ C	2 ½" Casing		
4 C	4" Casing		**Additional insertions in Qu Column**
D.M.	Drilling Mud	Pq	Penetrometer reading-tons/square foot
J.W.	Jet Water	S	Torvane reading-tons/square foot
H.A.	Hand Auger	G	Specific Gravity – ASTM D 854-58
NXC	Size NX Casing	SL	Shrinkage limit – ASTM 427-61
BXC	Size BX Casing	pH	Hydrogen ion content-meter method
AXC	Size AX casing	O	Organic content-combustion method
SS	2" O.D. Split Spoon Sample	M.A.*	Grain size analysis
2T	2" Thin Wall Tube Sample	C*	One dimensional consolidation
3T	3" Thin Wall Tube Sample	Q_c*	Triaxial Compression
			* See attached data Sheet and/or graph

Water Level Symbol

Water levels shown on the boring logs are the levels measured in the borings at the time and under the conditions indicated. In sand, the indicated levels can be considered reliable ground water levels. In clay soils, it is not possible to determine the ground water level within the normal scope of a test boring investigation, except where lenses or layers of more pervious water bearing soil is present and then a long period of time may be necessary to reach equilibrium. Therefore, the position of the water level symbol for cohesive or mixed soils may not indicate the true level of the ground water table. The available water level information is given at the bottom of the log sheet.

Descriptive Terminology

DENSITY		CONSISTENCY	
TERM	**"N" VALUE**	**TERM**	**"N" VALUE**
Very Loose	0-4	Soft	0-4
Loose	5-8	Medium	5-8
Medium Dense	9 – 15	Rather Stiff	9 – 15
Dense	16 – 30	Stiff	16 – 30
Very Dense	Over 30	Very Stiff	Over 30

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon.

Relative Proportions

TERMS	RANGE
Trace	0-5%
A little	5-15%
Some	15-30%
With	30-50%

Particle Sizes

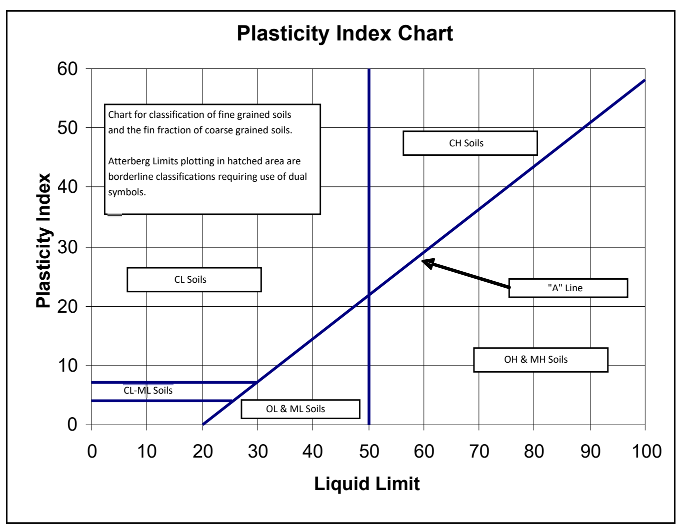
Boulders		Over 3"
Gravel -	Coarse	¾" – 3"
	Medium	#4 – ¾"
Sand -	Coarse	#4 - #10
	Medium	#10 - #40
	Fine	#40 - #200
Silt and Clay		Determined by plasticity characteristics.

Note: Sieve sizes are U.S. Standard.

Classification of Soils for Engineering Purposes

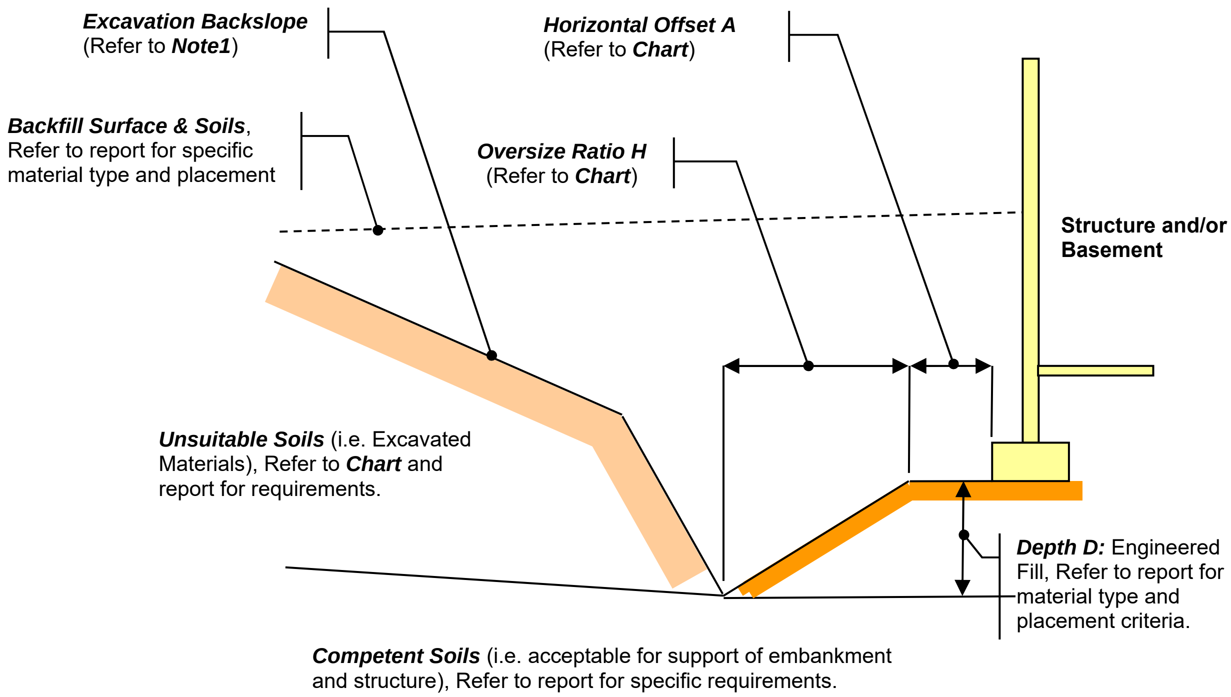
ASTM Designation D-2487 and D 2488 (Unified Soil Classification System)

Major Divisions			Group Symbols	Typical Names	Classification Criteria		
Coarse Grained Soils More than 50% retained on No. 200 sieve *	***Gravels*** 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	**GW**	Well –graded gravels and gravel-sand mixtures, little or no fines.	***Classification on basis of percentage of fines.*** Less than 5% passing No. 200 Sieve: GW, GP, SW, SP More than 12% passing No. 200 Sieve: GM, GC, SM, SC From 5% to 12% passing No. 200 Sieve: Borderline Classification requiring use of duel symbols.	$C_u = D_{60} / D_{10}$ greater than 4. $C_z = (D_{30})^2 / (D_{10} \times D_{60})$ between 1 & 3.	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines.		Not meeting both criteria for GW materials.	
		Gravels with Fines	**GM**	Silty gravels, gravel-sand-silt mixtures.		Atterberg limits below “A” line, or P.I. less than 4.	Atterberg limits plotting in hatched area are *borderline* classifications requiring use of dual symbols.
			GC	Clayey gravels, gravel-sand-clay mixtures.		Atterberg limits above “A” line with P.I. greater than 7.	
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean Sands	**SW**	Well-graded sands and gravelly sands, little or no fines.		$C_u = D_{60} / D_{10}$ greater than 6. $C_z = (D_{30})^2 / (D_{10} \times D_{60})$ between 1 & 3.	
			SP	Poorly-graded sands and gravelly sands, little or no fines.		Not meeting both criteria for SW materials.	
		Sands with Fines	**SM**	Silty sands, sand-silt mixtures.		Atterberg limits below “A” line, or P.I. less than 4.	Atterberg limits plotting in hatched area are *borderline* classifications requiring use of dual symbols.
			SC	Clayey sands, sand-clay mixtures.		Atterberg limits above “A” line with P.I. greater than 7.	
Fine Grained Soils More than 50% passes No. 200 sieve *	***Silts and Clays*** Liquid Limit of 50% or less		**ML**	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.			
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.			
			OL	Organic silts and organic silty clays of low plasticity.			
	Silts and Clays Liquid Limit greater than 50%.		**MH**	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.			
			CH	Inorganic clays of high plasticity, fat clays.			
			OH	Organic clays of medium to high plasticity.			
	Highly Organic Soils		**Pt**	Peat, muck and other highly organic soils.			



Excavation Oversize

Excavation oversize facilitates distribution of load induced stress within supporting soils. Unless otherwise superseded by report specific requirements, all construction should conform to the minimum oversize and horizontal offset requirements as presented within the diagram and associated chart.



Definitions

Oversize Ratio H: The ratio of the horizontal distance divided by the engineered fill depth (i.e. # Horizontal / Depth D). Refer to Chart for specific requirements.

Horizontal Offset A: The horizontal distance between the outside edge of footing or critical position and the crest of the engineered fill section. Refer to Chart for specific requirements.

Note 1: Excavation depth and sidewall inclination should not exceed those specified in local, state or federal regulations including those defined by Subpart P of Chapter 27, 29 CFR Part 1926 (of Federal Register). Excavations may need to be widened and sloped, or temporarily braced, to maintain or develop a safe work environment.

Condition	Unsuitable Soil Type	Horizontal Offset A	Oversize Ratio H
Foundation Unit Load equal to or less than 3,000 psf.	SP, SM soils, CL & CH soils with cohesion greater than 1,000 psf	2 feet or width of footing, whichever is greater	Equal to or greater than Depth D
Foundation Unit Load greater than 3,000 psf	SP, SM soils, CL & CH soils with cohesion less than 1,000 psf	5 feet or width of footing, whichever is greater	Equal to or greater than Depth D
Foundation Unit Load equal to or less than 3,000 psf.	Topsoil or Peat	2 feet or width of footing, whichever is greater	Equal to or greater than two (2) time Depth D
Foundation Unit Load greater than 3,000 psf	Topsoil or Peat	5 feet or width of footing, whichever is greater	Equal to or greater than two (2) time Depth D

APPENDIX B

GROUND WATER ISSUES

The following presents additional comment and soil specific issues related to measurement of ground water conditions at your project site.

Note that our ground water measurements, or lack thereof, will vary depending on the time allowed for equilibrium to occur in the borings. Extended observation time was not available during the scope of the field exploration program and, therefore, ground water measurements as noted on the boring logs may or may not accurately reflect actual conditions at your site.

Seasonal and yearly fluctuations of the ground water level, if any, occur. Perched ground water may be present within sand and silt lenses bedded within cohesive soil formations. Groundwater typically exists at depth within cohesive and cohesionless soils.

Documentation of the local ground water surface and any perched ground water conditions at the project site would require installation of temporary piezometers and extended monitoring due to the relatively low permeability exhibited by the site soils. We have not performed such ground water evaluation due to the scope of services authorized for this project.

We anticipate pumps installed within temporary sumps should control subsurface seepage from perched conditions. However, we caution such seepage from such formations and any water entry from excavations below the ground water table may be heavy and will vary based on seasonal and annual precipitation, and ground related impacts in the vicinity of the project.

GEOTEXTILE FABRIC

We occasionally recommend installation of a geotextile separation fabric between the native soils and the engineered fill section below project foundations, floors and/or between the clay subgrade and aggregate base of pavement construction within the body of the report. If recommended within the body of the report, it is our opinion this geotextile should consist of a non-woven, needle punched, fabric with a minimum grab tensile strength in both directions equal to or greater than 200 lbs minimum average roll value (MARV, ASTM D 4632).

We recommend that the geotextile panels be oriented parallel with proposed aggregate placement activities and occur in such a manner that the overall number of individual panels are kept to a minimum. As placed, individual panels of geotextile should have a width equal to or greater than 12 feet. We recommend that the Contractor overlap longitudinal and butt seams of adjacent panels a minimum of 18 inches with such joints oriented to follow initial construction traffic (shingles profile with traffic).

PLACEMENT and COMPACTION OF ENGINEERED FILL

Unless otherwise superseded within the body of the Geotechnical Exploration Report, the following criteria shall be utilized for placement of engineered fill on project. This includes but is not limited to earthen fill placement to improve site grades, fill placed below structural footings, fill placed interior of structure, and fill placed as backfill of foundations.

Engineered fill placed for construction, if necessary, should consist of natural, non-organic, competent soils native to the project area. Such soils may include, but are not limited to gravel, sand, or clays with Unified Soil Classification System (ASTM D2488) classifications of GW, SP, SM, CL or CH. Use of silt or clayey silt as project fill will require additional review and approval of project Geotechnical Engineer of Record. Such soils have USCS classifications of ML, MH, ML-CL, MH-CH. Use of topsoil, marl, peat, other organic soils construction debris and/or other unsuitable materials as fill is not allowed. Such soils have USCS classifications of OL, OH, Pt.

Engineered fill, classified as clay, should be tempered such that the moisture content at the time of placement is equal to and no more than 3 percent above the optimum content for as defined by the appropriate proctor test. Likewise, engineered fill classified as gravel or sand should be tempered such that the moisture content at the time of placement is within 3 percent of the optimum content.

All engineered fill for construction should be placed in individual 8 inch maximum depth lifts. Each lift of fill should be compacted by large vibratory equipment until the in-place soil density is equal to or greater than the criteria established within the following tabulation.

	Compaction Criteria (% respective Proctor) [1]	
Type of Construction	**Clay**	**Sand or Gravel**
General Embankment Fill	95 to 100	Min. 95
Engineered Fill below Foundations	Min. 95	Min. 98
Engineered Fill below Floor Slabs	95 to 98	Min. 95
Engineered Fill placed against Foundation Walls	95 to 98	95 to 100
Engineered Fill placed as Pavement Subgrade	Min. 95	Min. 95
Engineered Fill placed as Pavement Aggregate Base	NA	Min. 98
Engineered Fill placed within Utility Trench (to within 3 feet of pavement aggregate base or final grade	Min. 95	Min. 95
Engineered Fill placed as Utility Trench Fill (within 3 feet of pavement aggregate base or final grade	Min. 98	Min. 98

Note 1 Unless otherwise required, compaction criteria shall be based on the Standard Proctor Test (ASTM D698).

Density tests should be taken during engineered fill placement to document earthwork has achieved necessary compaction of the material(s). Recommendations for interior fill placement and backfill of foundation walls are presented within other sections of this report.

SWELLING of CLAY SOILS

Swell of clay soil occurs when moderate to highly desiccated, "over consolidated", moderate to highly plastic clay absorbs moisture concurrent within removal of overburden pressure. Fat clay formations are generally known to have "moderate" to "high risk" of swelling when conditions favorable for heave occur.

Clay minerals are generally elongated bipolar charged particles aligned in plate like structures. Absorption of water by the clay minerals is driven, in part, by the electrical attraction between the bipolar mineral and the electrical charged water molecule. The electrical attraction at the molecular level is a fairly strong bond which forces separation of the clay particle into a stratified system of bonded clay and water. The resulting composite system has greatly increased volume as compared to the original clay minerals.

Major clay minerals include Kaolinite, Holloysite, Illite, Calcium Montmorillonite, Sodium Montmorillonite, and Sodium Hectorite. Mielenz and King (1955) have noted that absorption of water by clays leads to expansion or swelling and that the magnitude of swelling varied widely depending upon the type and quantity of clay mineral present, their exchangeable ions, electrolyte content of the aqueous phase, particle-size distribution, void size and distribution, the internal structure, water content, superimposed load, and possibly other factors. Research geology professor Mr. Ralph Grim [University of Illinois] collaborates free swelling of clay minerals varied widely [referenced Table 5-10].

Table 5-10
Free Swelling Data for Clay Minerals (in per cent)
(After Mielenz and King, 1955) [1]

Calcium Montmorillonite:	
Forest, Mississippi	145
Wilson Creek Dam, Colorado	95
Davis Dam, Arizona	45 - 85
Osage, Wyoming (prepared from Na-Mont.)	***125***
Sodium Montmorillonite - Osage, Wyoming	***1,400 - 1,600***
Sodium Hectorite - Hector, California	1,600 - 2,000
Illite:	
Fithian, Illinois	115 - 120
Morris, Illinois	60
Tazewell, Virginia	15
Kaolinite:	
Mesa Alta, New Mexico	5
Macon, Georgia	60
Langley, North Carolina	20
Halloysite - Santa Rita, New Mexico	70

[1] Ralph E. Grim, Table 5-10, Free Swelling Data for Clay Minerals, "Applied Clay Mineralogy", University of Illinois, Urbana, Illinois, McGraw -Hill Book Company, Inc., 1962, p 248.

As shown in referenced Table 5-10, the effective range of swell in percent varies widely from as little as 5% with Kaolinite to 2,000% with Sodium Hectorite. Of major concern, regional clay soils typically include varying concentration of montmorillonite mineral [commonly defined as smectite]. ***Note that defining the percent content and mineral type of clay soils calls for very costly and time intensive laboratory analysis. Such determination cannot be made through visual classification.***

A majority of fat clay soils have low permeability on the order of 1×10^{-8} or lower cm/sec. However, this low permeability for water flow can be moderated by silt and very fine sand lens bedded within the overall clay formation. Such lenses become wet to saturated allowing movement of ground water during periods of prolonged wet cycles [nominal 10 to 50 year cycles], allowing limited transport of aqueous minerals through the clays. This can lead to varied extent of sodium and calcium mineral exchange within the clay soil structure [through presence of gypsum].

Our past observation of projects suggest the most prevalent risk of heave occurs when new, lightly loaded construction occurs over a prior shelter belt [previously forested with mature cotton wood or oaks], or farm fields previously planted in alfalfa or similar deep rooting plants. Clay soils within nominal 10 to 30 feet of ground surface at such locations typically are desiccated to varying degree from moisture uptake by plant cover.

Outside of above anomalies [excluding areas desiccated during seasonal construction exposure and areas immediately adjacent to silt or sand lens], clay soils below nominal depth 12 to 25 feet generally experience extreme slow change in moisture content seasonally, with long term [i.e. decade level event] slight to moderate change in moisture content following cyclical drought or wet cycles common to the northern prairie.

The extreme depth of clay deposits generally precludes construction of conventional frost foundations on other than soil having heave potential. Thus, the major means of reducing risk of heave to construction includes: isolation of lightly loaded floor slabs from more heavily loaded foundation element, allowing unhindered movement between walls / floor and any piped penetrations and, most importantly, providing continuous automated drainage of site during construction and permanent subsurface drainage of foundations and at-grade floors long term. ***Lacking access to moisture, heave prone clay soils will have minimal if any volume change.***

PROJECT SUMPS

The collection, control and removal of seepage and runoff from within project excavations is critical in maintaining the bearing capacity of native soils, in-place density of engineered fill and stability of embankments at project excavations.

As constructed, it is our opinion all sumps should consist of a 2 foot by 2 foot or larger plan dimension excavation(s) located adjacent to and directly exterior to the excavation oversize limit for structural engineered fill. Sump excavations should extend a minimum of 2 feet below the base of the excavation for collection of seepage and runoff.

All sumps should be lined with a non-woven, needle-punched, geotextile having a grab tensile strength equal to or greater than 70 pounds per square inch (psi). A standpipe of 12 inches in diameter or larger should be centered within the sump excavation. This pipe should include sufficient openings for entry of seepage. We recommend that the standpipe extend to the ground surface to facilitate pumping during project construction. Infill within the sump area should consist of a 1½ to ¾ inch clear rock placed between the standpipe and walls of the sump excavation.

Pumping of sump(s) should continue until completion of the construction or until the Geotechnical Engineer of Record indicates such pumping is no longer necessary for stability of the project footings and related construction. Sumps should be abandoned per methods required by the Geotechnical Engineer of Record and per Federal, State and local governmental statutes.

Discharge from sumps should be directed away from site and be disposed within storm water systems or other systems which comply with Federal, State and local governmental statute. As constructed and operated, the General Contractor should be responsible for all permits, operation and abandonment of sumps or other temporary dewatering systems.

APPENDIX C

Fergus Falls Veterans Greenhouse
Project #21.FGo11938.000
Fergus Falls, Minnesota
Legend
Soil Boring
Temporary Benchmark
TBM
SB-02
SB-01
N
100 ft
Google Earth
© 2021 Google

Northern Technologies LLC
3522 4th Ave S
Fargo, ND 58103
P: 701.232.1822 F: 701.232.1864
www.NTIgeo.com

BORING NUMBER SB-01

Long: -96° 4' 43.608"
Lat: 46° 18' 8.496"

CLIENT State of Minnesota
PROJECT NAME Fergus Falls Veterans Greenhouse
PROJECT NUMBER 21.FGO.11938.000
PROJECT LOCATION Fergus Falls, Minnesota
DATE STARTED 4/19/21 **COMPLETED** 4/19/21
GROUND ELEVATION 197.2 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Garrett Matz **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NA **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

DEPTH (ft)	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
0–0.5	TOPSOIL, ORGANIC CLAY, (OL) dark brown to black, rather stiff	196.7	AU 1									
0.5–4.0	LEAN CLAY, (CL) olive brown to light gray, rather stiff, trace sand, trace gravel	193.2	SS 2	89	3-4-6 (10)	2.9	118	18				
4.0–14.9	LEAN CLAY, (CL) brown, rather stiff, trace sand, trace gravel	182.3	SS 3	89	3-6-7 (13)	3.5	114	73				
			SS 4	100	4-6-8 (14)	3.6	117	18				
			SS 5	100	4-5-7 (12)	3.5	115	19				
			SS 6	106	5-5-7 (12)	1.7	116	19				
			SS 7	100	4-4-7/5"	4.0	115	19				

Bottom of borehole at 14.9 feet.
Borehole backfilled with auger cuttings.

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BORING NUMBER SB-02

Long: -96° 4' 43.392"
Lat: 46° 18' 8.568"

CLIENT State of Minnesota
PROJECT NAME Fergus Falls Veterans Greenhouse
PROJECT NUMBER 21.FGO.11938.000
PROJECT LOCATION Fergus Falls, Minnesota
DATE STARTED 4/19/21 **COMPLETED** 4/19/21
GROUND ELEVATION 197.8 feet **HOLE SIZE** 6 1/2 in.
DRILLING CONTRACTOR NTI
GROUND WATER LEVELS:
DRILLING METHOD 3 1/4 in H.S.A
AT TIME OF DRILLING --- No Groundwater Encountered
LOGGED BY Garrett Matz **CHECKED BY** Dan Gibson
AT END OF DRILLING ---
CAVE IN (ft) NA **FROST DEPTH (ft)** NA
AFTER DRILLING ---
NOTES

Depth (ft)	Material Description	Elevation
0–0.5	TOPSOIL, ORGANIC CLAY, (OL) black, rather stiff	197.3
0.5–14.9	LEAN CLAY, (CL) brown, rather stiff to stiff, trace sand, trace gravel	182.9

SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES
AU 1									
SS 2	89	4-4-6 (10)	2.7	120	18				
SS 3	106	3-4-7 (11)	3.6	118	17				
SS 4	94	4-6-8 (14)	3.4	118	18				
SS 5	94	4-6-7 (13)	3.2	121	17				
SS 6	106	7-8-9 (17)	3.3	119	19				
SS 7	94	5-6-10/5"	2.2	116	19				

Bottom of borehole at 14.9 feet.
Borehole backfilled with auger cuttings.