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REPORT OF GEOTECHNICAL EXPLORATION

Spruce Bog Warming Project

Marcell Experimental Forest
Marcell, Minnesota

Report No. 07-05001

Date:

December 20, 2011

Prepared For:

Ms. Angela Shillings
UT-Batelle, LLC for the U.S. Department of Energy
c/o Oak Ridge National Laboratory
1 Bethel Valley Road, Building 7001
Oak Ridge, Tennessee 37831

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Ms. Angela Shillings
UT-Batelle, LLC for the U.S. Department of Energy
c/o Oak Ridge National Laboratory
1 Bethel Valley Road, Building 7001
Oak Ridge, Tennessee 37831

RE: Report of Geotechnical Exploration
Spruce Bog Warming Project
Marcell Experimental Forest
Marcell, Minnesota
Report No. 07-05001

Dear Ms. Shillings:

Following your acceptance of our proposal and the subcontract agreement we have completed the geotechnical exploration for this project. In this report we present our results of the field and laboratory testing, and our recommendations regarding the geotechnical aspects of the project. We are submitting 10 copies of this report to you; this report is the instrument of service defined in our proposal.

We have enjoyed working with you on this phase of the project. If you have questions regarding this report or if we can be of further assistance, please contact us.

Sincerely,

American Engineering Testing, Inc.

Taryn J. Kuusisto, EIT
Staff Engineer
tkuusisto@amengtest.com

William Kwasny
William C. Kwasny, PE
Principal Engineer
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SIGNATURE PAGE

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Attn: Ms. Angela Shillings

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Principal Engineer
Registered Professional Engineer, Minnesota
License No. 11427

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

Print Name: William C. Kwasny

Signature: Kwasny

Date: 12-20-2011 License #: 11427

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1.0 INTRODUCTION

The Oak Ridge National Laboratory (ORNL) will conduct studies of the effects of climate change on wetland soils in the Marcell Experimental forest in Marcell, Minnesota. Information about the structures that will be used in these studies was provided to us by Ms. Kathy Huczko of ORNL.

The project will consist of building 24 octagonal, open-topped chambers, each approximately 50 feet in diameter and extending to about 24 feet above grade. These structures will be built of aluminum and plexiglass panels. The chambers will be subjected to wind loads, resulting in horizontal shear and overturning moments. Dr. Howard Perko, P.E., the structural engineer designing the foundations, has told us that the plan calls for support of the chambers on helical piles. While the specific axial loads and horizontal loads are not yet defined, the Statement of Work (SOW) for the project indicates the need for helical piles with design capacities in the range of 10,000 to 15,000 pounds for each structure. The applied horizontal loads are shown to be in the range of 1,500 pounds to 8,000 pounds for each structure.

Each chamber will be surrounded with a subsurface flow barrier constructed of driven, interlocking vinyl sheet piles. The plans call for these piles to be driven through the near-surface organic soils, penetrating into the underlying mineral (non-organic) soils.

Access to the chambers will be provided by four main access boardwalks, with interconnecting spurs. There is no information available as to whether these boardwalks will be for pedestrian traffic only, or whether they will be designed to carry light vehicles. These boardwalks will be supported on helical piles. There will also be ancillary scientific equipment installed within the site, supported on helical piles.

2.0 SCOPE OF SERVICES

AET's services were performed according to our proposal and subcontract agreement, which was authorized on October 10, 2011. The authorized scope is limited to the following elements:

- Arrange for the location of existing public underground utilities through the Gopher State One Call;
- Drill eight Standard Penetration Test (SPT) borings planned to depths of 30 feet;
- Visually-manually classify all of the samples, perform laboratory tests on selected soil samples, and prepare the boring logs; and
- Prepare a geotechnical report presenting boring logs, a summary of the soil and groundwater conditions, the laboratory testing results, and geotechnical engineering recommendations for earthwork foundation and design.

These services are intended for geotechnical purposes. The scope is not intended to explore for the presence or extent of environmental contamination in the soil and groundwater.

3.0 SUBSURFACE EXPLORATION AND TESTING

3.1 Field Exploration Program

ORNL specified the number and locations of the borings in the SOW dated August 27, 2011. After the program was reviewed with AET, the final number of borings was determined to be eight, planned to be drilled to depths of 30 feet. When we found loose soils at 30 feet in some borings, we recommended drilling all of the borings to 40 feet.

The US Forest Service directed our drill crew to select general boring locations along each transect based on drill rig accessibility. The Forest Service then determined the boring locations by GPS and gave us the coordinates, along with the surface elevation of the Bog in National Geodetic Vertical

Datum (NGVD). The approximate boring locations and the coordinates are shown on Figure 1 in Appendix A of this report, while the elevation of the bog was used for the boring logs.

We drilled the borings with a CME 45 rig mounted on a tracked Bombardier carrier. We used 3-1/4 inch ID hollow stem augers and the mud rotary method to advance the boreholes, sampling by the split-barrel method (ASTM D1586). Our crew kept field logs noting the methods of drilling and sampling, along with the Standard Penetration values (N-values, "blows per foot"), preliminary soils classifications, and observed the groundwater levels. Upon completion of the drilling we backfilled each borehole with bentonite chips in bentonite slurry to comply with the regulations of the Minnesota Department of Health.

4.0 LABORATORY TESTING

The laboratory testing was initiated by a geologist examining each sample to assess the major and minor soil components, while noting the color, degree of saturation, and lenses or seams found in the samples. Selected samples were tested for moisture content, unconfined compressive strength (by hand penetrometer), and pH levels. The results of these tests are shown on the respective logs; the column WC indicates the moisture content, the column q_p indicates the hand penetrometer reading, and the column pH indicates the pH level.

The geologist visually-manually classified each sample based on texture and plasticity in accordance with the Unified Classification System (ASTM D2488). The capital letters in parentheses following the written soil descriptions on the boring logs are the estimated group symbols based on this system. A chart describing the Unified System is included in Appendix A.

The geologist grouped the soils by type into the strata shown on the logs. These strata lines are approximate, and the actual transitions may be gradual or abrupt in the horizontal and vertical directions.

5.0 SITE CONDITIONS

5.1 Surface Features/Topography/Geology

The site of the project is a natural wetland. There have been no known structures on the site. The topography is relatively level and flat, varying by only a few inches among the borings. The surface vegetation consisted of typical wetland growth, along with shrubs and tamarack trees. There were shallow puddles among the boring locations.

The geology of the soil within our depth of drilling is found in deposition as coarse alluvium from wastage of the latter stages of the Wisconsinan glaciation, overlain by organic soils that developed in post-glacial times.

5.2 Soil Conditions

The general soil profile depicted by the boring logs consists of approximately 5.5 to 13 feet of swamp deposits underlain by naturally-occurring fine and coarse glacial alluvium. The swamp deposits consist of very soft, compressible fibric and hemic peat, organic silt, and organic clay with high moisture contents and low N-values (blow counts) of 1 or less. The fine alluvium consists of very soft to firm sandy silty clay, sandy silt, and lean clay with sand; the coarse alluvium consists of very loose to medium dense sand, silty sand, silty clayey sand, and sand with gravel. The soils were loose to medium dense; to a depth of about 30 to 35 feet the N-values in the coarse alluvium were less than 9.

Based on the N-values from our borings, we recommend using a seismic site rating of F, following Section 1613.5.2 of the International Building Code 2009.

5.3 Water Level Measurements

Groundwater was encountered in seven of the eight borings; no groundwater was encountered in boring T1W. The sands we encountered in the borings are relatively permeable, and therefore it is our opinion that our measurements are a reasonable indication of the groundwater conditions on the date of drilling. A discussion of the water level measurement methods is presented in the Exploration/Classification Procedures in Appendix A.

The hydrostatic groundwater level will vary in elevation seasonally and annually depending on the local amount of precipitation, runoff, and infiltration.

6.0 REVIEW AND RECOMMENDATIONS

6.1 Discussion

Based on the soil conditions found in our borings and our understanding of the structures that are to be built, we concur with the plan to use helical pile foundations. The type(s) of piles to be used and the allowable pile design capacities will depend on the manufacturer whose pile is specified or chosen, because of the proprietary nature of the helical pile industry. It is common that contracts for helical pile installation are issued as design-build projects because of the differences in helical pile design among the manufacturers.

An important issue in building the structure for this project will be accessing the locations where the piles are to be installed. We used a drill rig on a tracked Bombardier carrier to access the borings, and we believe that we did not break into the very soft and weak organic soils because of a surficial root mat about 1 foot thick, and because we did virtually no turning of the carrier. That is, we drove as straight as we could into and out of the boring locations. The contractor on this project should be advised that he must be careful when driving equipment into the site to avoid tearing or breaking through the root mat, to prevent his equipment from becoming mired.

6.2 Pile Construction

We recommend the use of triple helix piles of a type that can develop the required vertical capacity. Dr. Howard Perko, P.E., has told us that concrete will not be brought into the site, so piles installed by the "pull down" method cannot be used.

For preliminary planning, we estimate that the piles would have to be installed to depths of approximately 40 feet below the existing grades to develop the required capacity. Because of the variability in the soil conditions, the actual depths of penetration may be deeper than 40 feet. The installation should be observed and documented by a geotechnical engineer to verify that the proper torque and pile capacity have been achieved. In our opinion, it would be appropriate to perform one pile load test in accordance with ASTM D1143 for this project. The responsibility to install and conduct this test should be included with the contractor's scope.

6.3 Soil Corrosivity

The pH tests indicate that the organic soils that exist to as deep as 13 feet below grade on this site are acidic, with values in the range of 3.9 to 5.8 (average value: 4.4). These soils can aggressively attack unprotected steel.

Given the location of the project, we recommend protecting the helical piles by galvanization in accordance with ASTM A153. In our opinion, active corrosion protection by sacrificial anodes may not be applicable on this site since extreme pile longevity would not be required.

Once the materials for the piles have been specified, the designers can then calculate the potential metal loss, and the effects of the metal loss, following the procedures in the National Bureau of Standards Circular No. 569, *Underground Corrosion* (Romanoff, M., 1957).

6.4 Lateral Capacity

It is our opinion that the soft, weak organic soils found on this site will provide essentially no lateral resistance for the helical piles to resist shearing forces and overturning moments. Thus, the piles should be designed as having an unbraced section from the surface to an average depth of 10 feet. The necessary lateral resistance should be provided by installing battered helical piles (anchors) connected to the vertical piles and/or the structural frames of the chambers.

It is our understanding that there will be no pile caps or grade beams in the design of the chambers. Thus, no lateral resistance will be available other than that from the battered piles.

6.5 Subsurface Flow Barriers

We understand that the subsurface flow barriers will be constructed with driven interlocking vinyl sheeting. There will be no vertical loads on these piles, so they would probably be driven a few feet into the non-organic soils to provide the needed support.

In our opinion, it may be necessary for the contractor to cut "slots" into and through the surficial root mat where the vinyl piles are to be driven, in order that they are driven plumb and in proper alignment.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 Groundwater

We encountered groundwater at depths as shallow as 2 inches in the borings. Thus, in constructing the foundations it is likely that groundwater will be encountered. This may require dewatering.

7.2 Equipment Selection/Soil Disturbance

The soils on this site are susceptible to disturbance by construction equipment, and workers' foot traffic. The responsibility to properly select construction equipment and methods to avoid disturbing the soils on this site lies solely with the contractor. A note to this effect should be included in the project specifications.

7.3 Construction Safety

All excavations on this project must comply with the requirements of OSHA 29 CFR, Part 1926, Subpart P, "Excavations and Trenches." This document states that excavation safety is solely the responsibility of the contractor; the decisions regarding safe slopes on the project are to be made by the contractor's "competent person." Reference to this OSHA requirement should be included in the job specifications. The responsibility to provide safe working conditions on the site, for earthwork, chamber construction, or any associated operations, is not borne in any manner by American Engineering Testing, Inc.

7.4 Construction Testing

We recommend that a construction testing program be carried out to determine that the piles have been installed to adequate bearing. This should include at least one static load test which should be written in to the project specifications.

We welcome the opportunity to provide the observation and testing services for this project.

8.0 GENERAL QUALIFICATIONS

This report has been prepared based on the soil and groundwater conditions found in our borings. This report is intended solely for this project at the specific locations discussed. If there are any changes in size, scope, structural loads, use or nature from those outlined in the Introduction of this report, or if our understanding of the project is incomplete or incorrect, it is necessary that you contact us so we can review our recommendations to determine they are applicable. If we are not given the opportunity to review any changes in the design, then the recommendations in this report will not be valid.

We determined the soil and groundwater conditions at eight locations on the site. The conditions we describe and discuss in this report are pertinent only at the borings under the environment at the time of our field exploration. Variations in the subsurface conditions were encountered, and it is highly likely that additional variations exist that cannot be determined from our borings or from our site reconnaissance. These variations would not become apparent until excavation and construction is started on the site. No warranty, express or implied, is presented in this report with respect to the soil and groundwater conditions on this site.

9.0 ASTM STANDARDS

When we refer to an ASTM Standard in this report, we mean that our services were performed in general accordance with that standard. Compliance with any other standards referenced within the specified standard is neither inferred nor implied.

10.0 STANDARD OF CARE

We have endeavored to provide our engineering services for this project in accordance with the local standard of practice for geotechnical engineers. Other than this, no warranty, express or implied, is intended.

Appendix A

AET Project No. 07-05001

Geotechnical Field Exploration and Testing
Boring Log Notes
Unified Soil Classification System
Figure 1 – Boring Locations
Subsurface Boring Logs

A.1 FIELD EXPLORATION

The subsurface conditions at the site were explored by performing eight (8) standard penetration test borings between November 28 and December 1, 2011. The locations of the borings appear on Figure 1, preceding the Subsurface Boring Logs in this appendix.

A.2 SAMPLING METHODS

A.2.1 Split-Spoon Samples (SS) - Calibrated to N_{60} Values

Standard penetration (split-spoon) samples were collected in general accordance with ASTM: D1586 with one primary modification. The ASTM test method consists of driving a 2-inch O.D. split-barrel sampler into the in-situ soil with a 140-pound hammer dropped from a height of 30 inches. The sampler is driven a total of 18 inches into the soil. After an initial set of 6 inches, the number of hammer blows to drive the sampler the final 12 inches is known as the standard penetration resistance or N-value. Our method uses a modified hammer weight, which is determined by measuring the system energy using a Pile Driving Analyzer (PDA) and an instrumented rod.

In the past, standard penetration N-value tests were performed using a rope and cathead for the lift and drop system. The energy transferred to the split-spoon sampler was typically limited to about 60% of its potential energy due to the friction inherent in this system. This converted energy then provides what is known as an N_{60} blow count.

The newest drill rigs incorporate an automatic hammer lift and drop system, which has higher energy efficiency and subsequently results in lower N-values than the traditional N_{60} values. By using the PDA energy measurement equipment, we are able to determine actual energy generated by the drop hammer. With the various hammer systems available, we have found highly variable energies ranging from 55% to over 100%. Therefore, the intent of AET's hammer calibrations is to vary the hammer weight such that hammer energies lie within about 60% to 65% of the theoretical energy of a 140-pound weight falling 30 inches. The current ASTM procedure acknowledges the wide variation in N-values, stating that N-values of 100% or more have been observed. Although we have not yet determined the statistical measurement uncertainty of our calibrated method to date, we can state that the accuracy deviation of the N-values using this method is significantly better than the standard ASTM Method.

A.2.2 Disturbed Samples (DS)/Spin-up Samples (SU)

Sample types described as "DS" or "SU" on the boring logs are disturbed samples, which are taken from the flights of the auger. Because the auger disturbs the samples, possible soil layering and contact depths should be considered approximate.

A.2.3 Sampling Limitations

Unless actually observed in a sample, contacts between soil layers are estimated based on the spacing of samples and the action of drilling tools. Cobbles, boulders, and other large objects generally cannot be recovered from test borings, and they may be present in the ground even if they are not noted on the boring log.

Determining the thickness of "topsoil" layers is usually limited, due to variations in topsoil definition, sample recovery, and other factors. Visual-manual description often relies on color for determination, and transitioning changes can account for significant variation in thickness judgment. Accordingly, the topsoil thickness presented on the log should not be the sole basis for calculating topsoil stripping depths and volumes. If more accurate information is needed relating to thickness and topsoil quality definition, alternate methods of sample retrieval and testing should be employed.

A.3 CLASSIFICATION METHODS

Soil descriptions shown on the boring log are based on the Unified Soil Classification (USC) system. The USC system is described in ASTM: D2487 and D2488. Where laboratory classification tests (sieve analysis or Atterberg Limits) have been performed, accurate classifications per ASTM: D2487 are possible. Otherwise, soil descriptions shown on the boring log are visual-manual judgments. Charts are attached which provide information on the USC system, the descriptive terminology, and the symbols used on the boring log.

Visual-manual judgment of the AASHTO Soil Group is also noted as a part of the soil description. A chart presenting details of the AASHTO Soil Classification System is also attached.

The boring log includes descriptions of apparent geology. The geologic depositional origin of each soil layer is interpreted primarily by observation of the soil samples, which can be limited. Observations of the surrounding topography, vegetation, and development can sometimes aid this judgment.

A.4 WATER LEVEL MEASUREMENTS

The ground water level measurements are shown at the bottom of the boring log. The following information appears under "Water Level Measurements" on the log:

- Date and Time of measurement
- Sampled Depth: lowest depth of soil sampling at the time of measurement
- Casing Depth: depth to bottom of casing or hollow-stem auger at time of measurement
- Cave-in Depth: depth at which measuring tape stops in the borehole
- Water Level: depth in the borehole where free water is encountered
- Drilling Fluid Level: same as Water Level, except that the liquid in the borehole is drilling fluid

The true location of the water table at the boring location may be different than the water levels measured in the boreholes. This is possible because there are several factors that can affect the water level measurements in the borehole. Some of these factors include: permeability of each soil layer in profile, presence of perched water, amount of time between water level readings, presence of drilling fluid, weather conditions, and use of borehole casing.

A.5 LABORATORY TEST METHODS

A.5.1 Water Content Tests
Conducted per AET Procedure 01-LAB-010, which is performed in general accordance with ASTM: D2216 and AASHTO: T265.

A.5.2 Atterberg Limits Tests
Conducted per AET Procedure 01-LAB-030, which is performed in general accordance with ASTM: D4318 and AASHTO: T89, T90.

A.5.3 Sieve Analysis of Soils (thru #200 Sieve)
Conducted per AET Procedure 01-LAB-040, which is performed in general conformance with ASTM: D6913, Method A.

A.5.4 Particle Size Analysis of Soils (with hydrometer)
Conducted per AET Procedure 01-LAB-050, which is performed in general accordance with ASTM: D422 and AASHTO: T88.

A.5.5 Unconfined Compressive Strength of Cohesive Soil
Conducted per AET Procedure 01-LAB-080, which is performed in general accordance with ASTM: D2166 and AASHTO: T208.

A.6 TEST STANDARD LIMITATIONS

Field and laboratory testing is done in general conformance with the described procedures. Compliance with any other standards referenced within the specified standard is neither inferred nor implied.

A.7 SAMPLE STORAGE

Unless notified to do otherwise, we routinely retain representative samples of the soils recovered from the borings for a period of 30 days.

BORING LOG NOTES

DRILLING AND SAMPLING SYMBOLS

Symbol	Definition
B,H,N:	Size of flush-joint casing
CA:	Crew Assistant (initials)
CAS:	Pipe casing, number indicates nominal diameter in inches
CC:	Crew Chief (initials)
COT:	Clean-out tube
DC:	Drive casing; number indicates diameter in inches
DM:	Drilling mud or bentonite slurry
DR:	Driller (initials)
DS:	Disturbed sample from auger flights
FA:	Flight auger; number indicates outside diameter in inches
HA:	Hand auger; number indicates outside diameter
HSA:	Hollow stem auger; number indicates inside diameter in inches
LG:	Field logger (initials)
MC:	Column used to describe moisture condition of samples and for the ground water level symbols
N (BPF):	Standard penetration resistance (N-value) in foot (see notes)
NQ:	NQ wireline core barrel
PQ:	PQ wireline core barrel
RD:	Rotary drilling with fluid and roller or drag bit
REC:	In split-spoon (see notes) and thin-walled tube sampling, the recovered length (in inches) of sample. In rock coring, the length of core recovered (expressed as percent of the total core run). Zero indicates no sample recovered.
REV:	Revert drilling fluid
SS:	Standard split-spoon sampler (steel; 1d" is inside diameter; 2" outside diameter); unless indicated otherwise
SU	Spin-up sample from hollow stem auger
TW:	Thin-walled tube; number indicates inside diameter in inches
WASH:	Sample of material obtained by screening returning rotary drilling fluid or by which has collected inside the borehole after "falling" through drilling fluid
WH:	Sampler advanced by static weight of drill rod and 140-pound hammer
WR:	Sampler advanced by static weight of drill rod
94mm:	94 millimeter wireline core barrel
▼:	Water level measured in borehole prior to abandonment
▽:	Interim water level measurement or estimated water level based on sample appearance

TEST SYMBOLS

Symbol	Definition
CONS:	One-dimensional consolidation test
DEN:	Dry density, pcf
DST:	Direct shear test
E:	Pressuremeter Modulus, tsf
HYD:	Hydrometer analysis
LL:	Liquid Limit, %
LP:	Pressuremeter Limit Pressure, tsf
OC:	Organic Content, %
PERM:	Coefficient of permeability (K) test; F - Field; L - Laboratory
PL:	Plastic Limit, %
q_p:	Pocket Penetrometer strength, tsf (approximate)
q_c:	Static cone bearing pressure, tsf
q_u:	Unconfined compressive strength, psf
R:	Electrical Resistivity, ohm-cms
RQD:	Rock Quality Designation of Rock Core, in percent (aggregate length of core pieces 4" or more in length as a percent of total core run)
SAblows per	Sieve analysis
TRX:	Triaxial compression test
VSR:	Vane shear strength, remoulded (field), psf
VSU:	Vane shear strength, undisturbed (field), psf
WC:	Water content, as percent of dry weight
%-200:	Percent of material finer than #200 sieve

STANDARD PENETRATION TEST NOTES

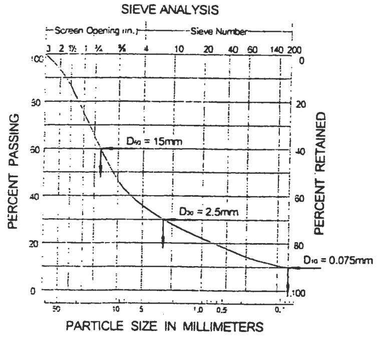
The standard penetration test consists of driving the sampler with a 140 pound hammer and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), permitted in ASTM:D1586, the blows for each complete 6" increment and for each partial increment is on the boring log. For partial increments, the number of blows is shown to the nearest 0.1' below the slash.

The length of sample recovered, as shown on the "REC" column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM:D1586 is encountered) whereas the length of sample recovered is for the entire sampler drive (which may even extend more than 18").

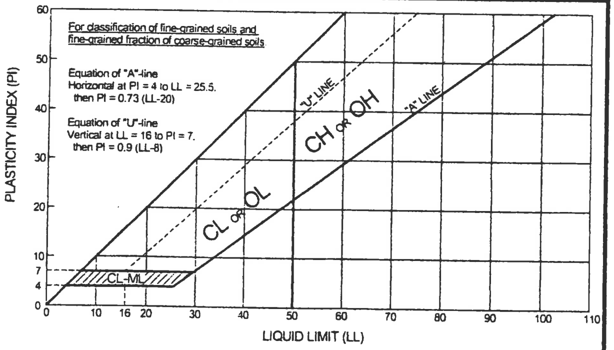
UNIFIED SOIL CLASSIFICATION SYSTEM
ASTM Designations: D 2487, D2488

AMERICAN ENGINEERING TESTING, INC.

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]	GW	Well graded gravel[F]
			$Cu < 4$ and/or $1 > Cc > 3$[E]	GP	Poorly graded gravel[F]
		Gravels with Fines more than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel[F.G.H]
			Fines classify as CL or CH	GC	Clayey gravel[F.G.H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]	SW	Well-graded sand[I]
			$Cu < 6$ and $1 > Cc > 3$[E]	SP	Poorly-graded sand[I]
		Sands with Fines more than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand[G.H.I]
			Fines classify as CL or CH	SC	Clayey sand[G.H.I]
Fine-Grained Soils 50% or more passes the No. 200 sieve (see Plasticity Chart below)	Silts and Clays Liquid limit less than 50	inorganic	$PI > 7$ and plots on or above "A" line[J]	CL	Lean clay[K.L.M]
			$PI < 4$ or plots below "A" line[J]	ML	Silt[K.L.M]
		organic	$\frac{\text{Liquid limit–oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OL	Organic clay[K.L.M.N] Organic silt[K.L.M.O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K.L.M]
			PI plots below "A" line	MH	Elastic silt[K.L.M]
		organic	$\frac{\text{Liquid limit–oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OH	Organic clay[K.L.M.P] Organic silt[K.L.M.Q]
Highly organic soil			Primarily organic matter, dark in color, and organic in odor	PT	Peat[R]



$C_u = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{2.5^2}{0.075 \times 15} = 5.6$



Plasticity Chart

Notes

[A] Based on the material passing the 3-in (75-mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols:
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D] Sands with 5 to 12% fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E] $Cu = D_{60} / D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot is hatched area, soils is a CL-ML silty clay.

[K] If soil contains 15 to 29% plus No. 200 add "with sand" or "with gravel", whichever is predominant.

[L] If soil contains ≥30% plus No. 200, predominantly sand, add "sandy" to group name.

[M] If soil contains ≥30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI≥4 and plots on or above "A" line.

[O] PI<4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.

[R] Fiber Content description shown below.

ADDITIONAL TERMINOLOGY NOTES USED BY AET FOR SOIL IDENTIFICATION AND DESCRIPTION

Grain Size

Term	Particle Size
Boulders	Over 12"
Cobbles	3" to 12"
Gravel	#4 sieve to 3"
Sand	#200 to #4 sieve
Fines (silt & clay)	Pass #200 sieve

Gravel Percentages

Term	Percent
A Little Gravel	3% - 14%
With Gravel	15% - 29%
Gravelly	30% - 50%

Consistency of Plastic Soils

Term	N-Value, BPF
Very Soft	less than 2
Soft	2 - 4
Firm	5 - 8
Stiff	9 - 15
Very Stiff	16 - 30
Hard	Greater than 30

Relative Density of Non-Plastic Soils

Term	N-Value, BPF
Very Loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	Greater than 50

Moisture/Frost Condition
(MC Column)

D (Dry):	Absense of moisture, dusty, dry to touch.
M (Moist):	Damp, although free water not visible. Soil may still have a high water content (over "optimum").
W (Wet/ Waterbearing):	Free water visible intended to describe non-plastic soils. Waterbearing usually relates to sands and sand with silt.
F (Frozen):	Soil frozen

Layering Notes

Laminations:	Layers less than ½" thick of differing material or color.
Lenses:	Pockets or layers greater than ½" thick of differing material or color.

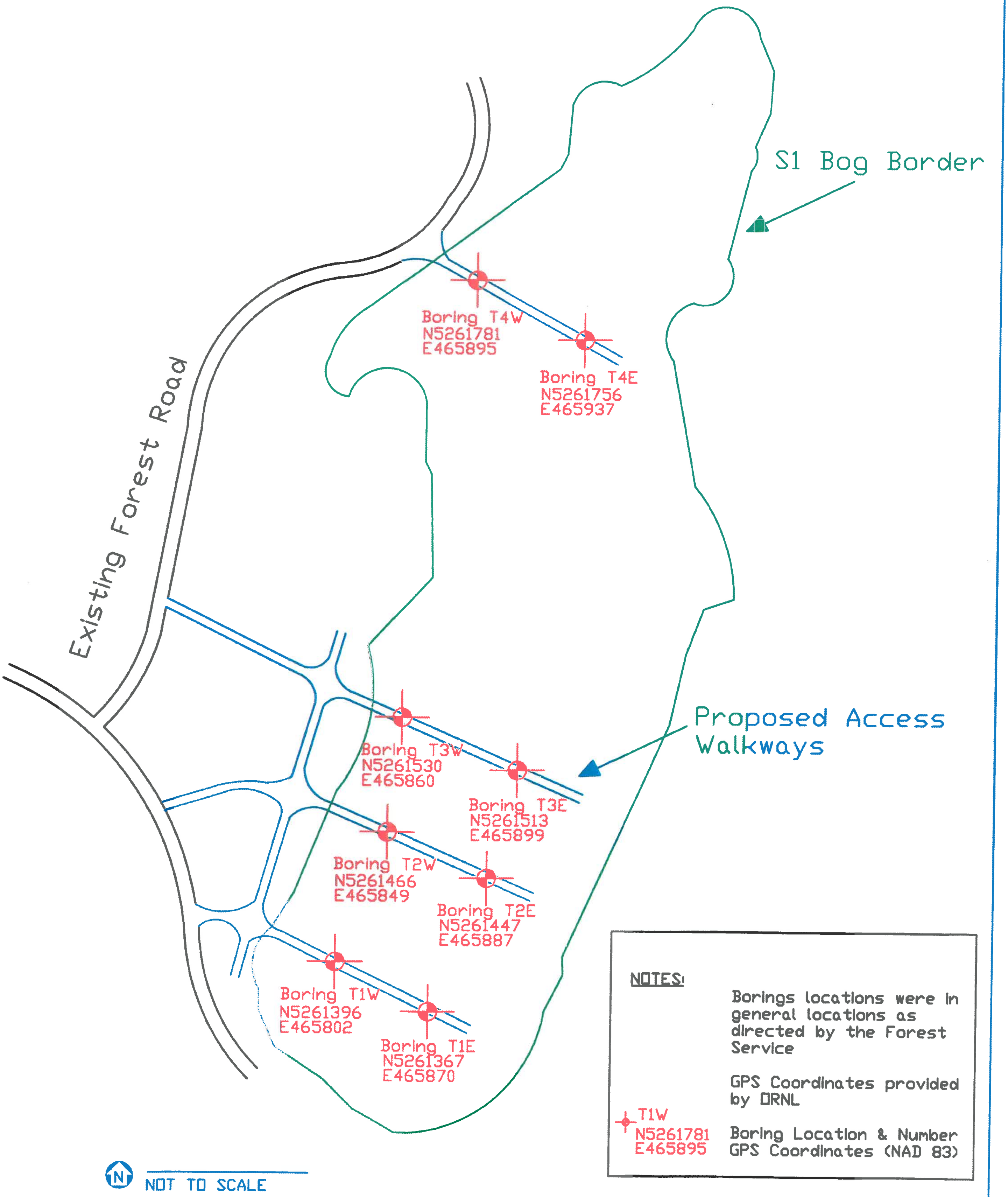
Fiber Content of Peat

Term	Fiber Content (Visual Estimate)
Fibric Peat:	Greater than 67%
Hemic Peat:	33 – 67%
Sapric Peat:	Less than 33%

Organic/Roots Description (if no lab tests)

Soils are described as *organic*, if soil is not peat and is judged to have sufficient organic fines content to influence the soil properties. *Slightly organic* used for borderline cases.

With roots:	Judged to have sufficient quantity of roots to influence the soil properties.
Trace roots:	Small roots present, but not judged to be in sufficient quantity to significantly affect soil properties.



NOTES:

Borings locations were in general locations as directed by the Forest Service

GPS Coordinates provided by ORNL

T1W N5261781 E465895	Boring Location & Number GPS Coordinates (NAD 83)

FIGURE NO. 1	PROJECT NO. 07-05001 DRAWN BY: TJK CHECKED BY: WCK DATE: 12/06/2011	APPROXIMATE BORING LOCATIONS	Spruce Bog Warming Project Marcell Experimental Forest Marcell, Minnesota	AMERICAN ENGINEERING TESTING, INC.

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261367, E465870

AET JOB NO: **07-05001**

LOG OF BORING NO. **T1E (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

SURFACE ELEVATION: ~1351.7

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	pH	PL	q_p
	PEAT, fibric, dark brown (PT)										
1			1	W	SS/SU	0	629				
2											
3			1	W	SS	0					
4											
5			*WH	W	SS	0					
6		SWAMP DEPOSIT									
7			*WH	W	SS	0					
8											
9			*WH	W	SS	0					
10											
11	PEAT, hemic, dark brown (PT)		*WH	W	SS	12	1268		5.8		
12											
13	ORGANIC SILT WITH SAND, trace roots, grayish brown (OL)		*WH	W	SS	11	448				
14	SAND, fine grained, trace roots, gray, wet, very loose (SP)										
15			2	W	SS	14					
16											
17											
18											
19	SILTY SAND, fine grained, gray, wet (SM)	COARSE ALLUVIUM									
20	SAND, fine grained, gray, wet, very loose (SP)		3	W	SS	12					
21											
22											
23											
24											

DEPTH:	DRILLING METHOD
0-14'	3.25" HSA
14'-39'	RD w/DM

BORING COMPLETED: **11/29/11**

DR: **LA** LG: **TD** Rig: **83R**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
11/29/11		14.0	19.0	16.0	--	13.0
		2.0	--	2.0	--	0.2

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
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SUBSURFACE TEST BORING LOG

N5261367, E465870

AET JOB NO: **07-05001** LOG OF BORING NO. **T1E (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION		GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
								WC	DD	pH	PL	q_p
	SAND, fine grained, gray, wet, very loose (SP) *(continued)*			4	W	SS	12					
26			COARSE ALLUVIUM *(continued)*									
27												
28	SAND, a little gravel, fine to medium grained, gray, wet, very loose (SP)											
29												
30				4	W	SS	10					
31												
32												
33	SAND, fine grained, gray, wet, loose to medium dense (SP)											
34												
35				9	W	SS	12					
36												
37												
38												
39												
40				17	W	SS	14					
41	**END OF BORING AT 41.0 FEET** *Boring backfilled with bentonite grout* ***WH = Weight of Hammer**											

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SUBSURFACE TEST BORING LOG

N5261396, E465802

AET JOB NO: **07-05001** LOG OF BORING NO. **T1W (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	SURFACE ELEVATION: ~1351.7 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	pH	PL	qp
	ROOT MASS	SWAMP DEPOSIT									
1	PEAT, fibric, dark brown (PT)		*WH	W	SS/SU	0			3.9		
2											
3			2	W	SS	0					
4											
5			*WH	W	SS	18	900	6			
6											
7			1	W	SS	24	526				
8	ORGANIC TO SLIGHTLY ORGANIC SILT, trace roots, gray (OL-ML)										
9			*WH	W	SS	17	98				
10	SANDY SILTY CLAY, gray, very soft to soft (CL-ML)	FINE ALLUVIUM									<0.25
11			2	W	SS	16	22				0.25
12											
13			2	W	SS	14	20				0.25
14											
15	CLAYEY SAND, gray, wet (SC)										
16	SAND, fine to medium grained, gray to brown, wet, loose to medium dense (SP)	COARSE ALLUVIUM	6	W	SS	12					0.75
17											
18											
19											
20			10	W	SS	9					
21											
22											
23											
24											

DEPTH:	DRILLING METHOD
0-14½'	**3.25" HSA**
14½'-39'	**RD w/DM**

BORING COMPLETED: **11/28/11**

DR: **LA** LG: **TD** Rig: **83R**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
11/28/11	**1100**	**2.0**	**--**	**2.0**	**--**	**None**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
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TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261396, E465802

AET JOB NO: **07-05001**

LOG OF BORING NO. **T1W (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION		GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
								WC	DD	pH	PL	q_p
	SAND, fine to medium grained, gray to brown, wet, loose to medium dense (SP) *(continued)*		COARSE ALLUVIUM *(continued)*	6	W	SS	8					
26												
27												
28												
29												
30				11	W	SS	10					
31												
32												
33	SAND, fine to medium grained, gray, wet, medium dense, a little gravel below about 38 feet (SP)											
34												
35				13	W	SS	9					
36												
37												
38												
39												
40				13	W	SS	9					
41	**END OF BORING AT 41.0 FEET** *Boring backfilled with bentonite grout*											

***WH = Weight of Hammer**

AMERICAN
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TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261447, E465887

AET JOB NO: **07-05001**

LOG OF BORING NO. **T2E (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

SURFACE ELEVATION: **~1351.7**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	pH	PL	q_p
	ROOT MASS			▼							
1	PEAT, fibric, dark brown (PT)			W	SU		1317		4.0		
3			*WH	W	SS	0					
5			*WH	W	SS	4	600				
7		SWAMP DEPOSIT	*WH	W	SS	5	748				
9			1	W	SS	19	871				
10	ORGANIC SILT, dark grayish brown (OL)										
11			*WH	W	SS	19	115 45				
12	SILTY CLAYEY SAND, gray, wet, very loose (SC-SM)										
13			*WH	W	SS	17	20				
15	SAND, fine grained, gray, wet, loose (SP)	COARSE ALLUVIUM	8	W	SS	14					
19	SAND, fine to medium grained, gray to grayish brown, wet, loose to medium dense (SP)										
20			9	W	SS	9					

DEPTH:	DRILLING METHOD
0-14'	3.25" HSA
14'-39'	RD w/DM

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
11/30/11	900	2.0	--	2.0	--	0.3

BORING COMPLETED: **11/30/11**

DR: **LA** LG: **TD** Rig: **83R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

SUBSURFACE TEST BORING LOG

N5261447, E465887

AET JOB NO: **07-05001** LOG OF BORING NO. **T2E (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	DD	pH	PL	q_p
	SAND, fine to medium grained, gray to grayish brown, wet, loose to medium dense (SP) *(continued)*		8	W	SS	9					
26											
27		COARSE ALLUVIUM *(continued)*									
28											
29											
30			6	W	SS	11					
31											
32											
33											
34											
35			4	W	SS	12					
36											
37											
38											
39											
40			11	W	SS	12					
	END OF BORING AT 40.5 FEET *Boring backfilled with bentonite grout*										

***WH = Weight of Hammer**

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261466, E465849

AET JOB NO: **07-05001**

LOG OF BORING NO. **T2W (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	SURFACE ELEVATION: ~1351.7 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	DD	pH	PL	q_p
	ROOT MASS	SWAMP DEPOSIT		▼							
1	PEAT, fibric, dark brown (PT)		*WH	W	SS	2					
2											
3			1	W	SS	0					
4											
5			1	W	SS	0					
6											
7			1	W	SS	6	605		4.6		
8	SANDY SILTY CLAY, gray, very soft (CL-ML)	COARSE ALLUVIUM									
9			*WH	W	SS	16	30				<0.25
10	SILTY CLAYEY SAND, gray, wet, very loose (SC-SM)										
11			1	W	SS	20	20				
12											
13			9	W	SS	24	20				
14	SAND, fine grained, gray, wet, very loose to loose (SP)										
15			1	W	SS	12					
16											
17											
18											
19											
20			8	W	SS	12					
21											
22											
23	SAND, fine to medium grained, brown to grayish brown, wet, loose (SP)										
24											

DEPTH:	DRILLING METHOD
0-14'	3.25" HSA
14'-39'	RD w/DM

WATER LEVEL MEASUREMENTS						
DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
11/29/11	1400	2.0	--	2.0	--	0.3

BORING COMPLETED: **11/29/11**

DR: **LA** LG: **TD** Rig: **83R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
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SUBSURFACE TEST BORING LOG

N5261466, E465849

AET JOB NO: **07-05001**

LOG OF BORING NO. **T2W (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	DD	pH	PL	q_p
	SAND, fine to medium grained, brown to grayish brown, wet, loose (SP) *(continued)*		6	W	SS	9					
26		COARSE ALLUVIUM *(continued)*									
27											
28											
29											
30			5	W	SS	10					
31											
32											
33	SILT WITH SAND, gray, wet (ML)	FINE ALLUVIUM									
34	SANDY SILT, gray, wet, medium dense (ML)										
35			11	W	SS	14					
36	SILTY SAND, fine grained, gray, wet (SM)										
37											
38	SAND WITH GRAVEL, fine to medium grained, gray, wet, medium dense (SP)	COARSE ALLUVIUM									
39											
40			26	W	SS	3					
	END OF BORING AT 40.5 FEET *Boring backfilled with bentonite grout*										

***WH = Weight of Hammer**

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261513, E465899

AET JOB NO: **07-05001** LOG OF BORING NO. **T3E (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	SURFACE ELEVATION: ~1351.7 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	pH	PL	q_p
	ROOT MASS			▼							
1	PEAT, fibric, dark brown (PT)			W	SU		995				
2											
3			1	W	SS	0					
4		SWAMP DEPOSIT									
5			*WH	W	SS	12	730		4.4		
6											
7			*WH	W	SS	12	818				
8											
9	SANDY SILTY CLAY, trace roots, gray (CL-ML)	FINE ALLUVIUM	1	W	SS	18	20				
10	SILTY SAND, fine grained, gray, wet (SM)										
11	SAND, fine grained, gray, wet, very loose to medium dense (SP)	COARSE ALLUVIUM	3	W	SS	16					
12											
13											
14											
15			1	W	SS	7					
16											
17											
18											
19											
20			5	W	SS	12					
21											
22											
23											
24											

DEPTH:	DRILLING METHOD
0-14'	**3.25" HSA**
14'-39'	**RD w/DM**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
12/1/11	**800**	**2.0**	**--**	**2.0**	**--**	**0.4**

BORING COMPLETED: **12/1/11**

DR: **LA** LG: **TD** Rig: **83R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

AMERICAN
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TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261513, E465899

AET JOB NO: **07-05001**

LOG OF BORING NO. **T3E (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION		GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
								WC	DD	pH	PL	q_p
	SAND, fine grained, gray, wet, very loose to medium dense (SP) *(continued)*		COARSE ALLUVIUM *(continued)*	8	W	SS	10					
26												
27												
28												
29												
30				13	W	SS	11					
31												
32												
33												
34												
35				13	W	SS	13					
36												
37	SAND WITH GRAVEL, fine to medium grained, gray, wet (SP)											
38												
39	SAND WITH SILT, fine to medium grained, gray, wet, very dense (SP-SM)											
40				53	W	SS	8					
	END OF BORING AT 40.5 FEET *Boring backfilled with bentonite grout*											

***WH = Weight of Hammer**

AMERICAN
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TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261530, E465860

AET JOB NO: **07-05001**

LOG OF BORING NO. **T3W (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	SURFACE ELEVATION: ~1351.7 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	pH	PL	q_p
	PEAT, fibric, dark brown (PT)			▼							
1				W	SU		695		3.9		
2											
3		SWAMP DEPOSIT	*WH	W	SS	0					
4											
5	ORGANIC CLAY, trace roots, grayish brown (OL)		1	W	SS	10	80				
6	LEAN CLAY WITH SAND, a little gravel, trace roots, grayish brown, firm (CL)										
7			9	W	SS	8	18				0.75
8	LEAN CLAY WITH SAND, grayish brown, very soft (CL)	FINE ALLUVIUM									
9			3	W	SS	14	23				<0.25
10											
11	SILTY SAND, fine grained, gray, wet, very loose (SM)		3	W	SS	18	18				
12											
13											
14											
15			4	W	SS	13					
16											
17	SAND, fine to medium grained, brown to gray, wet, loose (SP)	COARSE ALLUVIUM									
18											
19											
20			6	W	SS	16					
21											
22											
23											
24											

DEPTH:	DRILLING METHOD
0-10'	**3.25" HSA**
10'-39'	**RD w/DM**

BORING COMPLETED: **11/30/11**

DR: **LA** LG: **TD** Rig: **83R**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
11/30/11	**1400**	**2.0**	**--**	**2.0**	**--**	**0.5**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
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TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261530, E465860

AET JOB NO: **07-05001**

LOG OF BORING NO. **T3W (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	DD	pH	PL	q_p
	SAND, fine to medium grained, brown to gray, wet, loose (SP) *(continued)*	COARSE ALLUVIUM *(continued)*	6	W	SS	10					
26											
27											
28											
29											
30			7	W	SS	11					
31											
32											
33											
34											
35			7	W	SS	11					
36											
37	SAND WITH GRAVEL, fine to medium grained, gray, wet (SP)										
38											
39			50/0.4	W	SS	2					
	END OF BORING AT 39.4 FEET *Boring backfilled with bentonite grout*										

***WH = Weight of Hammer**

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261781, E465895

AET JOB NO: **07-05001**

LOG OF BORING NO. **T4E (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

SURFACE ELEVATION: **~1351.7**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	pH	PL	q_p
0	ROOT MASS	SWAMP DEPOSIT		▼							
1	PEAT, fibric, dark brown (PT)			W	SU		747				
3			1	W	SS	0					
5			*WH	W	SS	8	370	14			
7			2	W	SS	8	509				
8	PEAT, hemic, dark brown (PT)										
9			*WH	W	SS	9	179				<0.25
10	LEAN CLAY WITH SAND, gray, very soft to firm, trace roots above about 12 feet (CL)	FINE ALLUVIUM									
11			*WH	M	SS	18	25				
13			4	W	SS	12	21				0.5
15			4	W	SS	16	20				0.75
19	SAND, fine to medium grained, gray, wet, loose to medium dense (SP)	COARSE ALLUVIUM									
20			5	W	SS	14					

DEPTH:	DRILLING METHOD
0-14'	**3.25" HSA**
14'-39'	**RD w/DM**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
12/1/11	**1300**	**2.0**	**--**	**2.0**	**--**	**0.4**

BORING COMPLETED: **12/1/11**

DR: **LA** LG: **TD** Rig: **83R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
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SUBSURFACE TEST BORING LOG

N5261781, E465895

AET JOB NO: **07-05001** LOG OF BORING NO. **T4E (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	DD	pH	PL	q_p
	SAND, fine to medium grained, gray, wet, loose to medium dense (SP) *(continued)*	COARSE ALLUVIUM *(continued)*	6	W	SS	13					
26											
27											
28											
29											
30			7	W	SS	12					
31											
32											
33											
34											
35			16	W	SS	12					
36											
37											
38											
39											
40			15	W	SS	12					
41	**END OF BORING AT 41.0 FEET** *Boring backfilled with bentonite grout*										

***WH = Weight of Hammer**

SUBSURFACE TEST BORING LOG

N5261756, E465937

AET JOB NO: **07-05001** LOG OF BORING NO. **T4W (p. 1 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	SURFACE ELEVATION: ~1351.7 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	pH	PL	q_p
	ROOT MASS			▼							
1	PEAT, fibric, dark brown (PT)			W	SU		499				
2											
3			*WH	W	SS	0	514				
4		SWAMP DEPOSIT									
5			*WH	M	SS	12	439				
6											
7			2	W	SS	4	654				
8	PEAT, hemic, dark brown (PT)										
9	CLAYEY SAND, gray, wet (SC)		*WH	W	SS	20	171				
10											
11	SILTY SAND, fine grained, gray, wet, very loose (SM)		*WH	W	SS	20	24				
12											
13											
14	SAND, fine grained, gray, wet, very loose (SP)	COARSE ALLUVIUM									
15			2	W	SS	18					
16											
17											
18	SAND, a little gravel, fine to medium grained, grayish brown, wet, loose (SP)										
19											
20			7	W	SS	7					
21											
22											
23											
24											

DEPTH:	DRILLING METHOD
0-14'	3.25" HSA
11'-39'	RD w/DM

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
12/1/11	1600	2.0	--	2.0	--	0.3

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

BORING COMPLETED: **12/1/11**

DR: **LA** LG: **TD** Rig: **83R**

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

N5261756, E465937

AET JOB NO: **07-05001**

LOG OF BORING NO. **T4W (p. 2 of 2)**

PROJECT: **Spruce Bog Warming Project, Marcell Experimental Forest; Marcell, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	DD	pH	PL	q_p
	SAND, a little gravel, fine to medium grained, grayish brown, wet, loose (SP) *(continued)*	COARSE ALLUVIUM *(continued)*	4	W	SS	7					
26											
27											
28	SAND, medium to coarse grained, grayish brown, wet, loose (SP)										
29											
30	SAND, fine to medium grained, grayish brown, wet, loose to medium dense (SP)		9	W	SS	9					
31											
32											
33											
34											
35			10	W	SS	14					
36											
37											
38											
39											
40			12	W	SS	12					
41	**END OF BORING AT 41.0 FEET** *Boring backfilled with bentonite grout*										

***WH = Weight of Hammer**

Appendix B

AET Project No. 07-05001

Geotechnical Report Limitations and Guidelines for Use

Geotechnical Report Limitations and Guidelines for Use
AET Project No. 07-05001

B.1 REFERENCE

This appendix provides information to help you manage your risks relating to subsurface problems which are caused by construction delays, cost overruns, claims, and disputes. This information was developed and provided by ASFE[1], of which, we are a member firm.

B.2 RISK MANAGEMENT INFORMATION

B.2.1 Geotechnical Services are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared solely for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. And no one, not even you, should apply the report for any purpose or project except the one originally contemplated.

B.2.2 Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

B.2.3 A Geotechnical Engineering Report is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typically factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, always inform your geotechnical engineer of project changes, even minor ones, and request an assessment of their impact. Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.

B.2.4 Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. Do not rely on a geotechnical engineering report whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. Always contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

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[1] ASFE, 8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733 : www.asfe.org

B.2.5 Most Geotechnical Findings Are Professional Opinions

Site exploration identified subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

B.2.6 A Report's Recommendations Are Not Final

Do not overrely on the construction recommendations included in your report. Those recommendations are not final, because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual subsurface conditions revealed during construction. The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.

B.2.7 A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

B.2.8 Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

B.2.9 Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, but preface it with a clearly written letter of transmittal. In the letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need to prefer. A prebid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

B.2.10 Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their report. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. Read these provisions closely. Ask questions. Your geotechnical engineer should respond fully and frankly.

B.2.11 Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a geoenvironmental study differ significantly from those used to perform a geotechnical study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Unanticipated environmental problems have led to numerous project failures. If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. Do not rely on an environmental report prepared for someone else.