Appendix E. Embankment Sample Report

PLEASE NOTE

A sample foundations report is included here for reference. It is provided as an example of content, format, and organization representative of a typical Foundation Investigation and Recommendation Report for an embankment. As site conditions vary widely, the investigation means and methods, and report content (including recommendations), may differ for other projects. Note that the selection and inclusion of this report as a sample does not imply that it is guaranteed to be free of errors. Please contact the Foundations Unit with any questions when interpreting a geotechnical report issued by this office or if you have any questions with respect to preparing geotechnical reports for MnDOT. The information presented here is intended for use as a resource by geotechnical engineering professionals. MnDOT makes no warranty as to the suitability of engineering reports in the style of this sample report, for other geotechnical needs, purposes, clients, or projects. NOTE: SPT boring logs, cross sections or CPT logs typically included at the end of the Foundation Investigation and Recommendation Report have been removed for this example.

Minnesota Department of Transportation
Office of Materials & Road Research
1400 Gervais Avenue, Maplewood, MN 55109

Memo

TO: Tom Highum, Project Manager
District 3, Baxter

FROM: Rich Lamb, Foundations Project Engineer RAL
Foundations Unit

Concur: Gary Person, Foundations Engineer
Foundations Unit

DATE: June 10, 2010

SUBJECT: SP 0503-75 TH 23 Roadway Embankment
Station 336+00 – 351+00 TH 23 WB
Located near Foley
Subsurface Investigation and Geotechnical Recommendations

Project Summary

This letter is in response to a request by the District to provide Foundation Recommendations for a segment of roadway embankment to be constructed just south of Foley on proposed westbound TH 23. The proposed embankment in this area passes through a low, swampy area and initial District auger borings revealed the presence of potentially deep organic deposits. This new embankment is part of the widening of TH 23 from two to four lanes from the junction of TH 95 to the junction of TH 25 in Foley.

Subsurface Investigation

The Foundations Unit mobilized several times to the site with several types of equipment in an effort to determine the depth and lateral extent of the swamp deposits in the area. Eleven Standard Penetration Test (SPT) borings, forty-eight Cone Penetration Test (CPT) soundings and fourteen Flat Plate Dilatometer (DMT) soundings were taken from October 2009 to April 2010. In addition, two Resistivity Surveys were performed by our Geology Unit in the fall of 2009 to get an initial idea on the swamp deposit limits. A copy of the boring and sounding logs is included with this report.

The foundation soils at the site consist of layers and seams of sand with variable depth layers of organic material, silty clays and clayey soils. Organic material was found to depths of almost 40 ft. in some areas. Water was measured between elevations 1010-1015 during normal drilling operations. Please refer to the attached boring and sounding logs for a more complete description of the foundation soils.

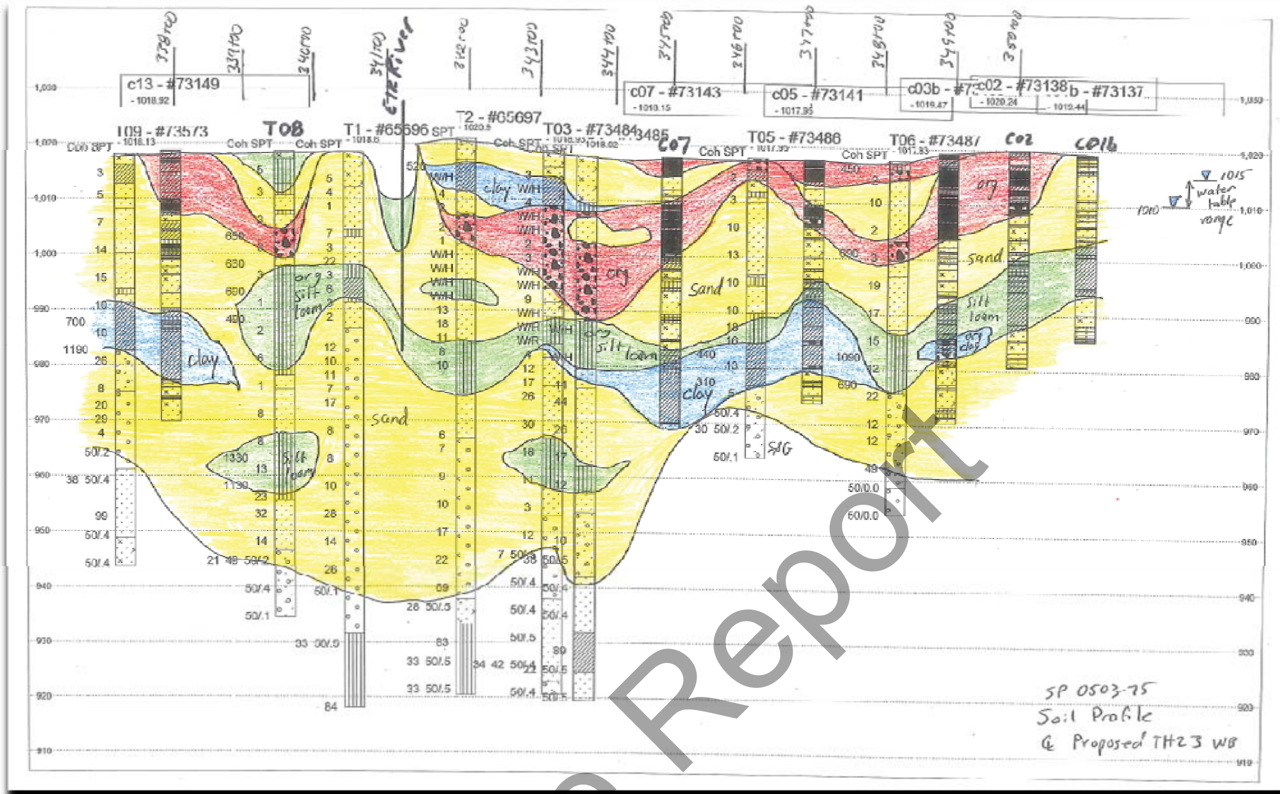


Figure 1: Soil Profile

Lab Testing Results

Routine lab tests showed that the organic soils may be classified as organic and highly organic Silt Loam. This material has organic contents ranging from 10-20% and moisture contents of 80-130%. In addition to these simple tests, fourteen one dimensional consolidation tests were performed on representative samples of the organic and silty soils. These tests revealed that the organic material is highly compressible but will drain quickly as a result of numerous sand and silt seams found throughout.

Material	e_0	C_c	C_r	C_v (ft^2/day)
horg Silt Loam	2.4	1.0	0.15	0.1 – 0.4
org Silt Clay	1.6	0.5	0.01	1

Table 1: Consolidation Test Results (averages)

Geotechnical Analysis

Our Geotechnical analysis for this project consisted of looking at the following:

- Embankment Settlement, including both primary and secondary settlement and time rate of primary and secondary settlement
- Global Stability

Embankment Settlement

Embankment settlement was computed assuming 9-12 ft. of fill, an embankment top width of 50 ft. and 1:4 side slopes. In addition, a unit weight of fill of 120 pcf was used in the analysis. Based on these assumptions and utilizing the results from the consolidation tests, we estimate that the organic and silty clayey soils will experience 1-2 ft. of primary settlement and as much as 1-4 in. of secondary consolidation long after the project is completed. Our estimate for time rate of settlement for primary consolidation is 2-6 months whereas the secondary compression may occur over a period of several decades.

Surcharge Option

In an effort to decrease the primary consolidation period, a soil surcharge was considered to be added to the proposed embankment. As an initial design, a 5 ft. surcharge was selected and analyzed for primary and secondary settlement. As expected, the additional fill material will reduce the waiting period for the target settlement and also take out most of the long term settlement.

Partial Excavation Option

In addition to a soil surcharge, we considered digging out some of the organic material to reduce the overall settlement of the new embankment. Initially, a complete dig option was considered for this project, whereby all of the organic soils would be completely removed and replaced with granular material. However, this option was considered very costly, as it would require deep sheet piling and extensive dewatering efforts. As a compromise, we are recommending removing the top 8-10 ft. of material to reduce the overall settlements of the embankments.

Assuming a partial excavation as mentioned above, revised settlement calculations were then performed. The results are shown on the following table.

Station	Fill Ht. (ft.)	computed primary settlement	Estimated range of Primary Settlement	Time for Primary Settlement	Time for Primary Settlement with 5' Surcharge	Secondary Settlement	Time for Secondary Settlement	Assumptions
337+00	10	8.1 in.	6-8 in.	30 days	10 days	1 in.	50 years	no digging
339+00	12	25.5 in.	18-24 in.	60 days	30 days	2-4 in.	50 years	no digging
		20 in.	16-20 in.					dig 10 ft.
344+00	10	25.8 in.	18-24 in.	80 days	30 days	2-4 in.	50 years	no digging
		20 in.	16-20 in.					dig 10 ft.
348+00	9	5.8 in.	4-6 in.	180 days	60 days	0.5 in.	50 years	dig 3.5 ft.

Table 2: Revised Settlement Estimates with Excavation/Surcharge Option

Slope Stability Analysis

A preliminary slope stability analysis was also performed to see if an embankment could be constructed over the poor foundation soils without any ground improvement. The results showed that the slopes would be marginally stable if loaded quickly. However, the foundation soils will drain and gain strength if they are loaded slowly enough and provide for stable embankment. As evidence of this, the existing embankment has been stable for decades after being constructed over the same materials.

Geotechnical Recommendations

Based on review of the existing conditions and proposed construction, we recommend the following:

1. The upper 7-10 ft. of material below the existing ground below proposed TH 23 WB should be excavated down to elevation 1010. This excavation applies from Stations 335+50 to 351+00.
2. Place a geosynthetic separator (3733 Type V) at the bottom of the excavation as shown on the attached typical section.
3. Place and compact alternating layers of Select Granular Borrow (3149.2B2) and geosynthetic reinforcement (3733 Type V1) for three layers as shown on the attached

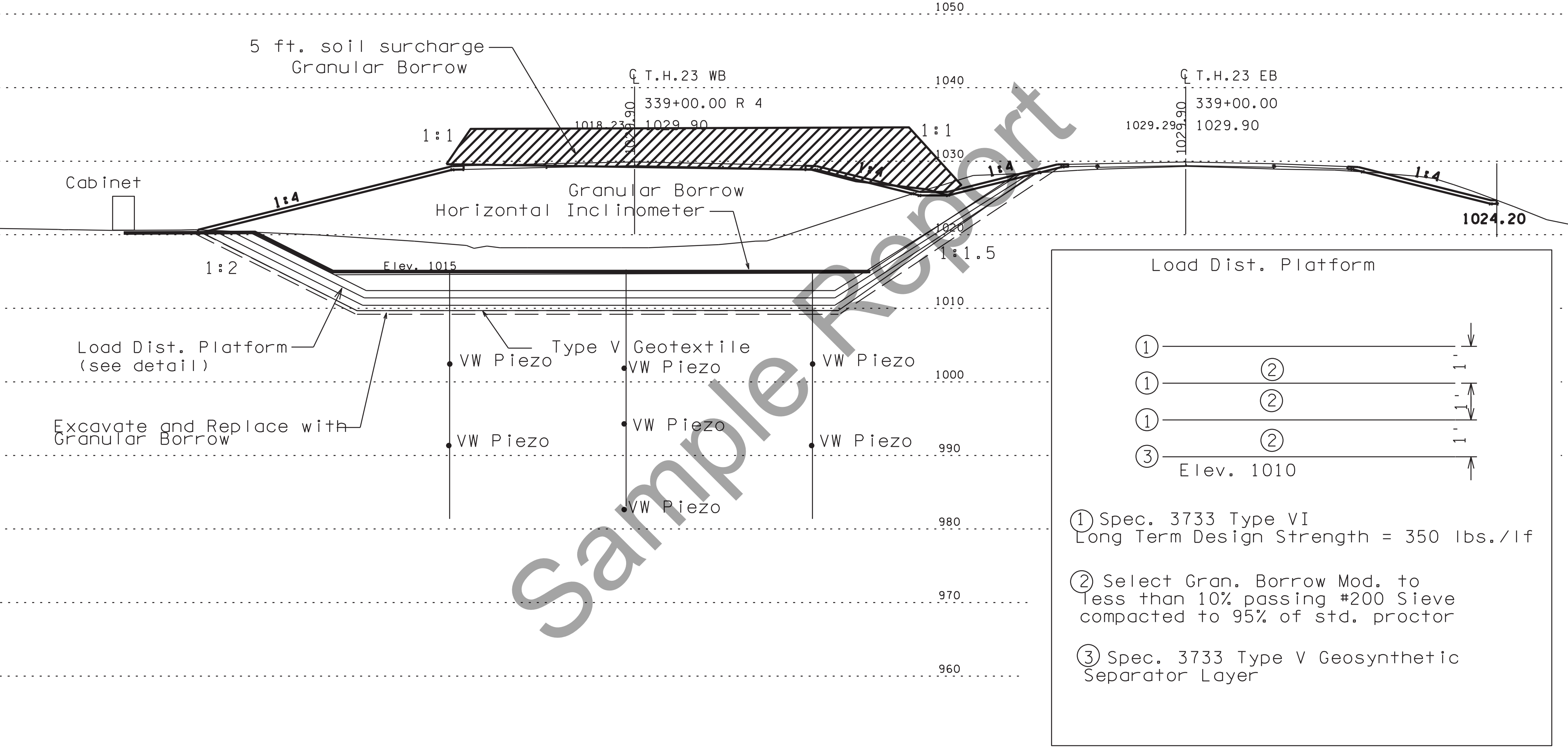
typical section. The Select Granular Borrow should be compacted to 95% of Standard Proctor. The Type VI geosynthetic reinforcement should have a minimum long term design strength of 350 lbs./ft.

4. Place 2 ft. of Granular Borrow (3149.2B1) and compact to 95% of Standard Proctor.
5. Install Geotechnical Instrumentation including piezometers and settlement gages as shown on the attached typical section. Please note that piezometers and settlement gage system should be installed at five cross sections as shown on the attached instrumentation plan.
6. Place Granular Borrow fill in 2 ft. lifts for remaining fill height. In between lifts, observe a minimum waiting period of 1 week to allow underlying cohesive soils to drain and gain strength. Actual settlement waiting period between lifts should be determined by Engineer based on results of Geotechnical Instrumentation.
7. Place additional 5 ft. surcharge fill above top of final pavement grade in similar fashion (2 ft. lifts and waiting periods).
8. Monitor embankment settlement over a period of 3-6 months before removing surcharge fill and paving roadway.
9. Please note that some dewatering efforts may be required to successfully excavate to the required depths and place the specified geosynthetic materials.

Attachments:
Boring/Sounding Plan
Geotechnical Typical Section
Geotechnical Cross Sections
Geotechnical Instrumentation Plan and Location Details
SPT Boring Logs
CPT Sounding Logs
DMT Sounding Logs

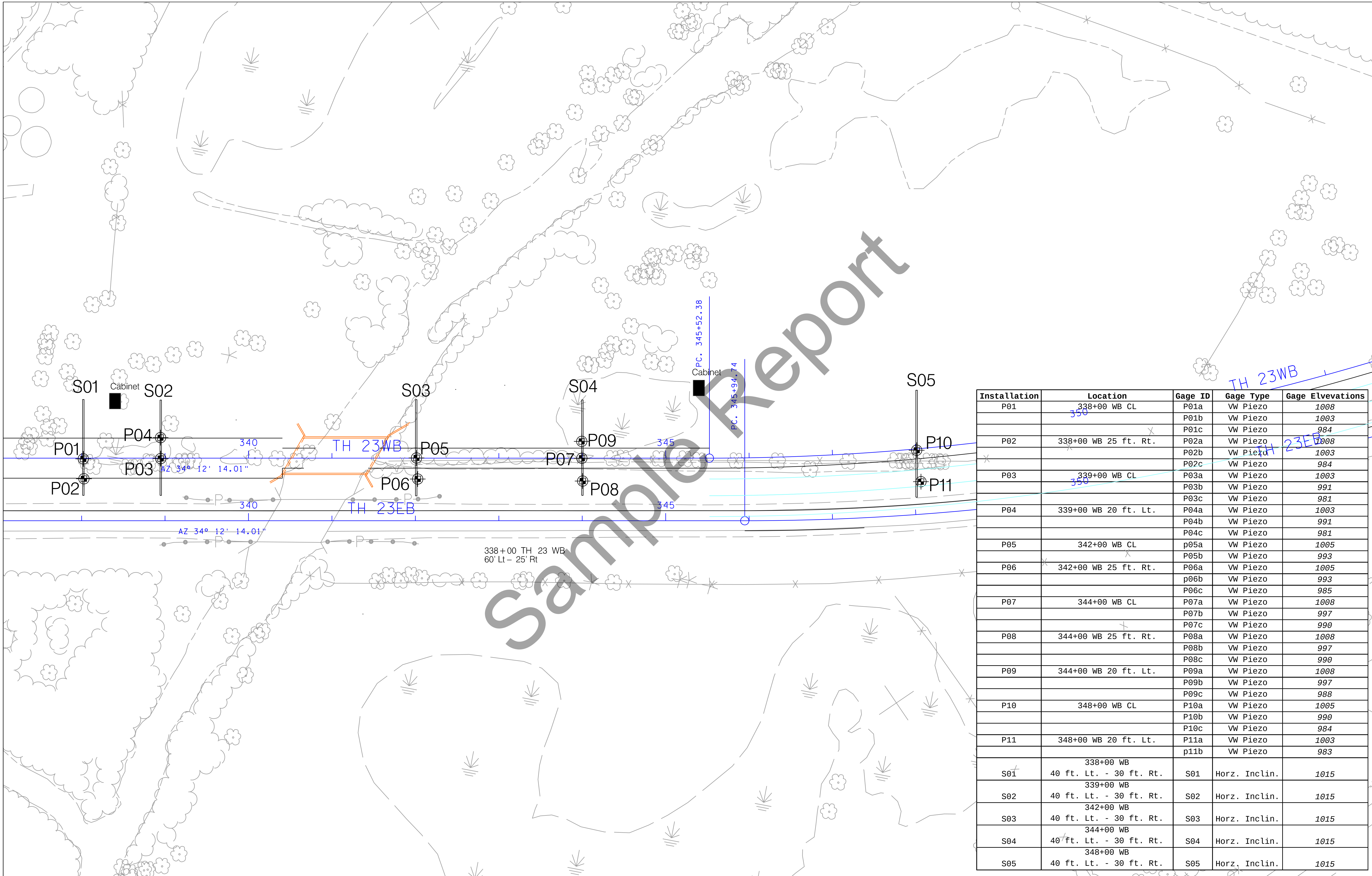
cc: G. Engstrom
T. Kempenich
C. DeMenge
A. Pitan, K. Molnau

Ground Improvement
Typical Section
338+00 -west abut
east abut -351+00



SP 0503-75 TH 23
Geotechnical Instrumenation Plan

Installation	Location	Gage ID	Gage Type	Gage Elvevations
P01	338+00 WB CL	P01a	VW Piezo	*1008*
		P01b	VW Piezo	*1003*
		P01c	VW Piezo	*984*
P02	338+00 WB 25 ft. Rt.	P02a	VW Piezo	*1008*
		P02b	VW Piezo	*1003*
		P02c	VW Piezo	*984*
P03	339+00 WB CL	P03a	VW Piezo	*1003*
		P03b	VW Piezo	*991*
		P03c	VW Piezo	*981*
P04	339+00 WB 20 ft. Lt.	P04a	VW Piezo	*1003*
		P04b	VW Piezo	*991*
		P04c	VW Piezo	*981*
P05	342+00 WB CL	p05a	VW Piezo	*1005*
		P05b	VW Piezo	*993*
P06	342+00 WB 25 ft. Rt.	P06a	VW Piezo	*1005*
		p06b	VW Piezo	*993*
		P06c	VW Piezo	*985*
P07	344+00 WB CL	P07a	VW Piezo	*1008*
		P07b	VW Piezo	*997*
		P07c	VW Piezo	*990*
P08	344+00 WB 25 ft. Rt.	P08a	VW Piezo	*1008*
		P08b	VW Piezo	*997*
		P08c	VW Piezo	*990*
P09	344+00 WB 20 ft. Lt.	P09a	VW Piezo	*1008*
		P09b	VW Piezo	*997*
		P09c	VW Piezo	*988*
P10	348+00 WB CL	P10a	VW Piezo	*1005*
		P10b	VW Piezo	*990*
		P10c	VW Piezo	*984*
P11	348+00 WB 20 ft. Lt.	P11a	VW Piezo	*1003*
		p11b	VW Piezo	*983*
S01	338+00 WB 70 ft. Lt. - 30 ft. Rt.	S01	Horz. Inclin.	*1015*
S02	339+00 WB 70 ft. Lt. - 30 ft. Rt.	S02	Horz. Inclin.	*1015*
S03	342+00 WB 70 ft. Lt. - 30 ft. Rt.	S03	Horz. Inclin.	*1015*
S04	344+00 WB 70 ft. Lt. - 30 ft. Rt.	S04	Horz. Inclin.	*1015*
S05	348+00 WB 70 ft. Lt. - 30 ft. Rt.	S05	Horz. Inclin.	*1015*



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		p06b	VW Piezo	*993*
		P06c	VW Piezo	*985*
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P11	348+00 WB 20 ft. Lt.	P11a	VW Piezo	*1003*
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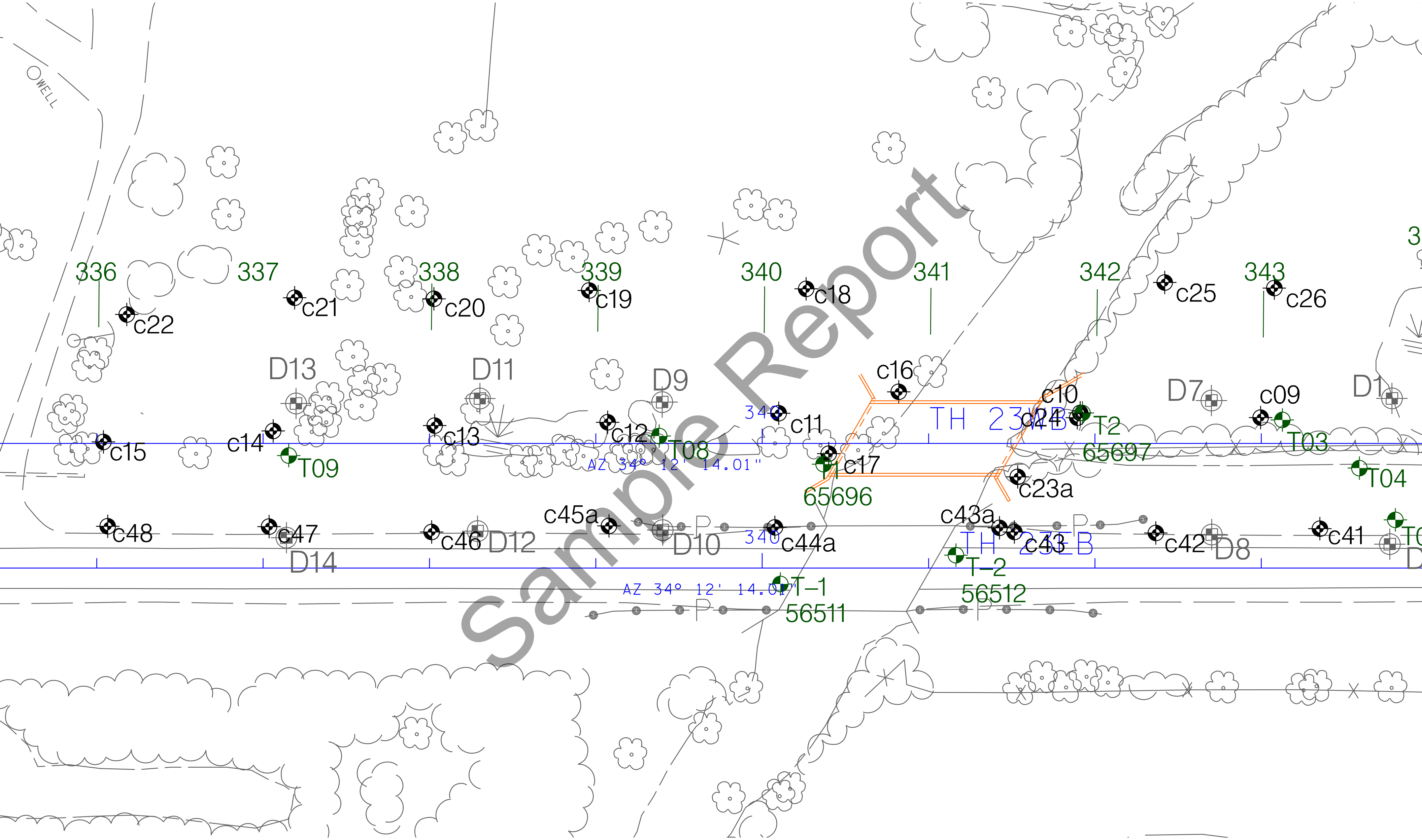
S05	348+00 WB 40 ft. Lt. - 30 ft. Rt.	S05	Horz. Inclin.	*1015*



WELL
336
337
338
339
340
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c21
c20
c19
c18
c25
c26
D13
D11
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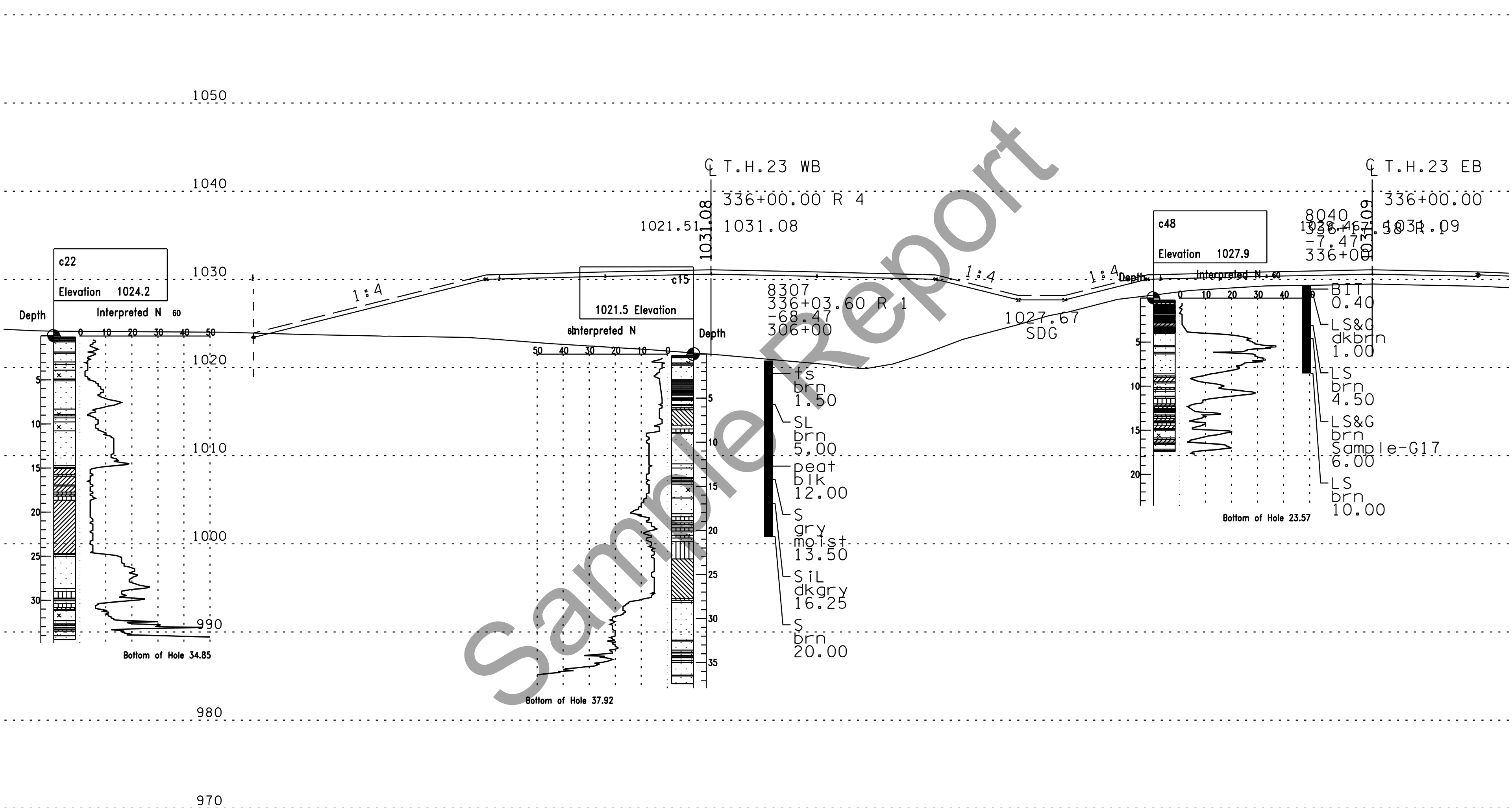
c16
c10
c09
D7
D1
c15
c14
T09
c13
c12
T08
340
c11
AZ 34° 12' 14.01"
TH 23WB
c24
T2
65697
T03
c17
65696
c23a
T04
c48
c47
c46
D12
c45a
D10
340
c44a
c43a
c43
TH 23EB
c42
D8
c41
D14
T-2
T-1
56511
56512
P
Sample Report



1050
1040
1030
1020
1010
1000
990
980
970
CL T.H.23 WB
336+00.00 R 4
1021.51
1031.08
CL T.H.23 EB
336+00.00
c22
Elevation 1024.2
Depth
Interpreted N 60
Bottom of Hole 34.85
c15
1021.5 Elevation
Interpreted N
Bottom of Hole 37.92
c48
Elevation 1027.9
Interpreted N 60
Bottom of Hole 23.57
1:4
8307
336+03.60 R 1
-68.47
306+00
fs
brn
1.50
SL
brn
5.00
peat
blk
12.00
S
gry
moist
13.50
SiL
dkgry
16.25
S
brn
20.00
1027.67
SDG
BIT
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LS&G
dkbrn
1.00
LS
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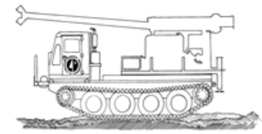
LS&G
brn
Sample-G17
6.00
LS
brn
10.00

Minnesota Department of Transportation Geotechnical Section

Boring Log Descriptive Terminology (English Units)



USER NOTES, ABBREVIATIONS AND DEFINITIONS - Additional information available in Geotechnical Manual.

This boring was made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since this boring was not taken to gather information relating to the construction of the project, the data noted in the field and recorded may not necessarily be the same as that which a contractor would desire. While the Department believes that the information as to the conditions and materials reported is accurate, it does not warrant that the information is necessarily complete. This information has been edited or abridged and may not reveal all the information which might be useful or of interest to the contractor. Consequently, the Department will make available at its offices, the field logs relating to this boring.

Since subsurface conditions outside each borehole are unknown, and soil, rock and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this boring will necessarily be the same as or similar to those shown on this log. Furthermore, the Department will not be responsible for any interpretations, assumptions, projections or interpolations made by contractors, or other users of this log.

Water levels recorded on this log should be used with discretion since the use of drilling fluids in borings may seriously distort the true field conditions. Also, water levels in cohesive soils often take extended periods of time to reach equilibrium and thus reflect their true field level. Water levels can be expected to vary both seasonally and yearly. The absence of notations on this log regarding water does not necessarily mean that this boring was dry or that the contractor will not encounter subsurface water during the course of construction.

WATER MEASUREMENT

AB .... After Bailing
AC .... After Completion
AF .... After Flushing
w/C .... with Casing
w/M .... with Mud
WSD .... While Sampling/Drilling
w/AUG .... with Hollow Stem Auger

MISCELLANEOUS

NA .... Not Applicable
w/ .... with
w/o .... with out
sat .... saturated

DRILLING OPERATIONS

AUG .... Augered
CD .... Core Drilled
DBD .... Disturbed by Drilling
DBJ .... Disturbed by Jetting
PD .... Plug Drilled
ST .... Split Tube (SPT test)
TW .... Thinwall (Shelby Tube)
WS .... Wash Sample
NSR .... No Sample Retrieved

WH .... Weight of Hammer
WR .... Weight of Rod
Mud .... Drilling Fluids in Sample
CS .... Continuous Sample

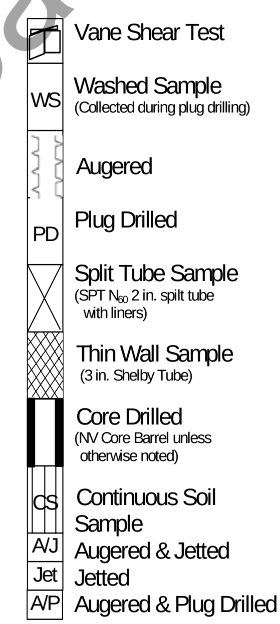
SOIL/CORE TESTS

SPT N_{60} .... ASTM D1586 Modified Blows per foot with 140 lb. hammer and a standard energy of 210 ft-lbs. This energy represents 60% of the potential energy of the system and is the average energy provided by a Rope & Cathead system.
MC .... Moisture Content
COH .... Cohesion
γ .... Sample Density
LL .... Liquid Limit
PI .... Plasticity Index
Φ .... Phi Angle
REC .... Percent Core Recovered
RQD .... Rock Quality Description (Percent of total core interval consisting of unbroken pieces 4 inches or longer)
ACL .... Average Core Length (Average length of core that is greater than 4 inches long)
Core Breaks .... Number of natural core breaks per 2-foot interval.

DISCONTINUITY SPACING

Fractures	Distance	Bedding
Very Close	<2 inches	Very Thin
Close	2-12 inches	Thin
Mod. Close	12-36 inches	Medium
Wide	>36 inches	Thick

DRILLING SYMBOLS



RELATIVE DENSITY

Compactness - Granular Soils	BPF
very loose	0-4
loose	5-10
medium dense	11-24
dense	25-50
very dense	>50

Consistency - Cohesive Soils	BPF
very soft	0-1
soft	2-4
firm	5-8
stiff	9-15
very stiff	16-30
hard	31-60
very hard	> 60

COLOR

blk .... Black — **wht** .... White
grn .... Green — **brn** .... Brown
orng .... Orange — **yel** .... Yellow
dk .... Dark — **lt** .... Light
IOS .... Iron Oxide Stained

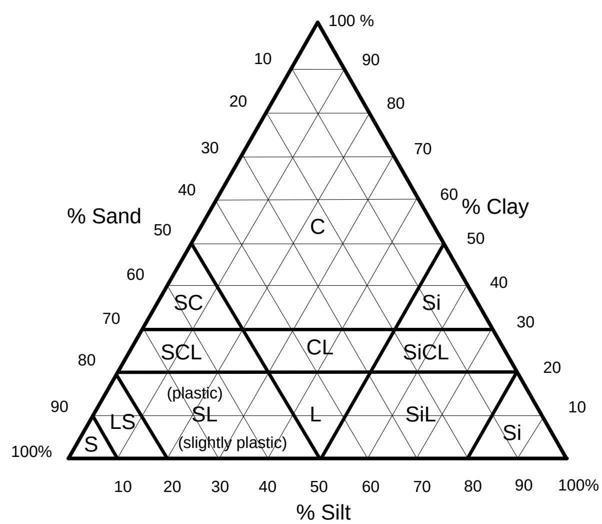
GRAIN SIZE /PLASTICITY

VF .... Very Fine — **pl** .... Plastic
F .... Fine — **slpl** .... Slightly Plastic
Cr .... Coarse

SOIL/ROCK TERMS

C .... Clay — **Lmst** .... Limestone
L .... Loam — **Sst** .... Sandstone
S .... Sand — **Dolo** .... Dolostone
Si .... Silt — **wx** .... weathered
G .... Gravel (No. 10 Sieve to 3 inches)
Bldr .... Boulder (over 3 inches)
T .... till (unsorted, nonstratified glacial deposits)

Mn/DOT Triangular Textural Soil Classification System



MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 73484

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
0503-75		**MN Trunk Highway 23**	**T03**	**1018.9** *(DTM)*

Location Benton Co. Coordinate: X=504485 Y=116789 (ft.)

Latitude (North)=45°36'18.74" Longitude (West)=94°01'56.91"

No Station-Offset Information Available

Drill Machine **207184 CME 850 Track**

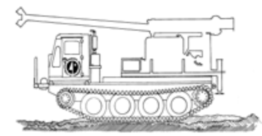
Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **3/8/10**

Depth / Elev.	Classification	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
3.0 / 1015.9	organic plastic Loam with roots, black and moist		45			%org-9.6
5.0 / 1013.9	slightly organic plastic Loam, brown and very moist	3	33			%org-2.9
10.0 / 1008.9	slightly organic Clay Loam with some roots, grays and moist	W/H	42			%org-4.3
		4	34			%org-3.0
12.5 / 1006.4	highly organic slightly plastic Silt Loam, gray-brown and moist	W/H	154			%org-21.5
25.0 / 993.9	highly organic plastic Silt Loam with a few roots and shell fragments, thin seams of Sand at 16.0'; grays and wet	W/H	70			%org-7.1
		2	89			%org-10.8
		3	122			%org-15.2
		W/H	165			%org-23.1
		W/H	94			%org-10.7
27.5 / 991.4	Sand, gray-brown and saturated	9	20			
30.0 / 988.9	Loamy Sand with some wood, gray and saturated	W/H	38			
35.0 / 983.9	organic plastic Silt Loam, gray and wet	W/H	57			%org-6.6
		W/R	49			%org-5.4
37.5 / 981.4	Sand with traces osf organic Loamy Fine Sand, grays and saturated	4	29			
42.5 / 976.4	Fine Sand with a few thin seams of slightly plastic Fine Sand Loam, light gray and wet	12	24			high Silt content
		17	28			
52.0 / 966.9	Loamy Fine Sand, light gray and saturated	26	26			
		30	25			
	Silty Clay Loam with traces if Silt, grays and moist	18	29			

Minnesota Department of Transportation
Geotechnical Section
Cone Penetration Test Index Sheet 1.0 (CPT 1.0)



USER NOTES, ABBREVIATIONS AND DEFINITIONS

This Index sheet accompanies Cone Penetration Test Data. Please refer to the Boring Log Descriptive Terminology Sheet for information relevant to conventional boring logs.

This Cone Penetration Test (CPT) Sounding follows ASTM D 5778 and was made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since this sounding was not taken to gather information relating to the construction of the project, the data noted in the field and recorded may not necessarily be the same as that which a contractor would desire. While the Department believes that the information as to the conditions and materials reported is accurate, it does not warrant that the information is necessarily complete. This information has been edited or abridged and may not reveal all the information which might be useful or of interest to the contractor. Consequently, the Department will make available at its offices, the field logs relating to this sounding.

Since subsurface conditions outside each CPT Sounding are unknown, and soil, rock and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this sounding will necessarily be the same as or similar to those shown on this log. Furthermore, the Department will not be responsible for any interpretations, assumptions, projections or interpolations made by contractors, or other users of this log.

Water pressure measurements and subsequent interpreted water levels shown on this log should be used with discretion since they represent dynamic conditions. Dynamic Pore water pressure measurements may deviate substantially from hydrostatic conditions, especially in cohesive soils. In cohesive soils, water pressures often take extended periods of time to reach equilibrium and thus reflect their true field level. Water levels can be expected to vary both seasonally and yearly. The absence of notations on this log regarding water does not necessarily mean that this boring was dry or that the contractor will not encounter subsurface water during the course of construction.

CPT Terminology

CPT............. Cone Penetration Test
CPTU........... Cone Penetration Test with Pore Pressure measurements
SCPTU......... Cone Penetration Test with Pore Pressure and Seismic measurements
Piezocone...Common name for CPTU test

(Note: This test is not related to the Dynamic Cone Penetrometer DCP)

q_T TIP RESISTANCE

The resistance at the cone corrected for water pressure. Data is from cone with 60 degree apex angle and a 10 cm² end area.

f_s SLEEVE FRICTION RESISTANCE

The resistance along the sleeve of the penetrometer.

FR Friction Ratio

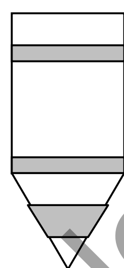
Ratio of sleeve friction over corrected tip resistance.
FR = fs/qt

V_s Shear Wave Velocity

A measure of the speed at which a siesmic wave travels through soil/rock.

PORE WATER MEASUREMENTS

Pore water measurements reported on CPT Log are representative of water pressures measured at the U2 location, just behind the cone tip, prior to the sleeve, as shown in the figure below. These measurements are considered to be dynamic water pressures due to the local disturbance caused by the cone tip. Dynamic water pressure decay and Static water pressure measurements are reported on a Pore Water Pressure Dissipation Graph.



SBT SOIL BEHAVIOR TYPE

Soil Classification methods for the Cone Penetration Test are based on correlation charts developed from observations of CPT data and conventional borings. Please note that these classification charts are meant to provide a guide to Soil Behavior Type and should not be used to infer a soil classification based on grain size distribution.

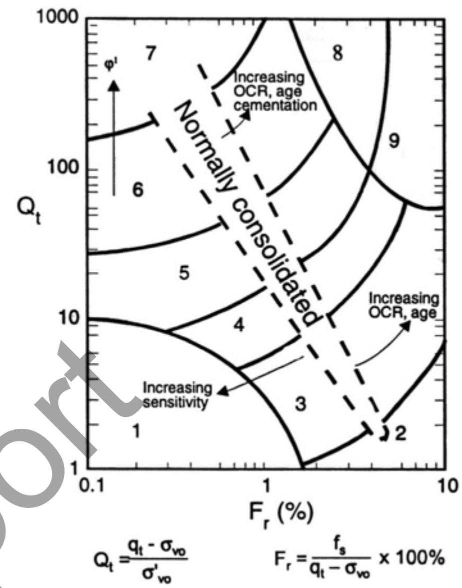
The numbers corresponding to different regions on the charts represent the following soil behavior types:

1. Sensitive, Fine Grained
2. Organic Soils - Peats
3. Clays - Clay to Silty Clay
4. Silt Mixtures - Clayey Silt to Silty Clay
5. Sand Mixtures - Silty Sand to Sandy Silt
6. Sands - Clean Sand to Silty Sand
7. Gravelly Sand to Sand
8. Very Stiff Sand to Clayey Sand
9. Very Stiff, Fine Grained

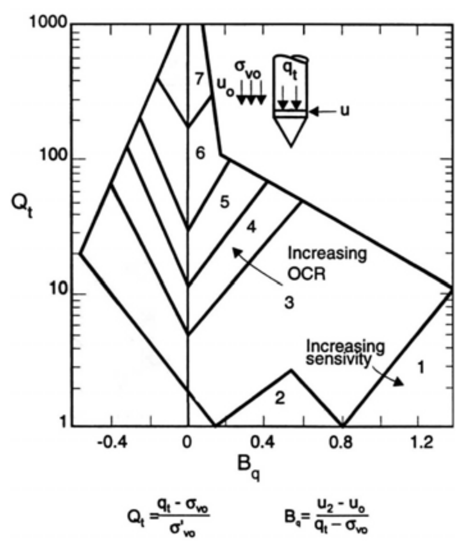
Note that engineering judgment, and comparison with conventional borings is especially important in the proper interpretation of CPT data in certain geo-materials.

The following charts are used to provide a Soil Behavior Type for the CPT Data.

Robertson CPT 1990
Soil Behavior type based on friction ratio



Robertson CPTU 1990
Soil Behavior type based on pore pressure



where ...
Q_T.......................... normalized cone resistance
B_q.......................... pore pressure ratio
F_r.......................... Normalized friction ratio
σ_{vo}........................ overburden pressure
σ'_{vo}....................... effective over burden pressure
u_2.......................... measured pore pressure
u_0.......................... equilibrium pore pressure

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

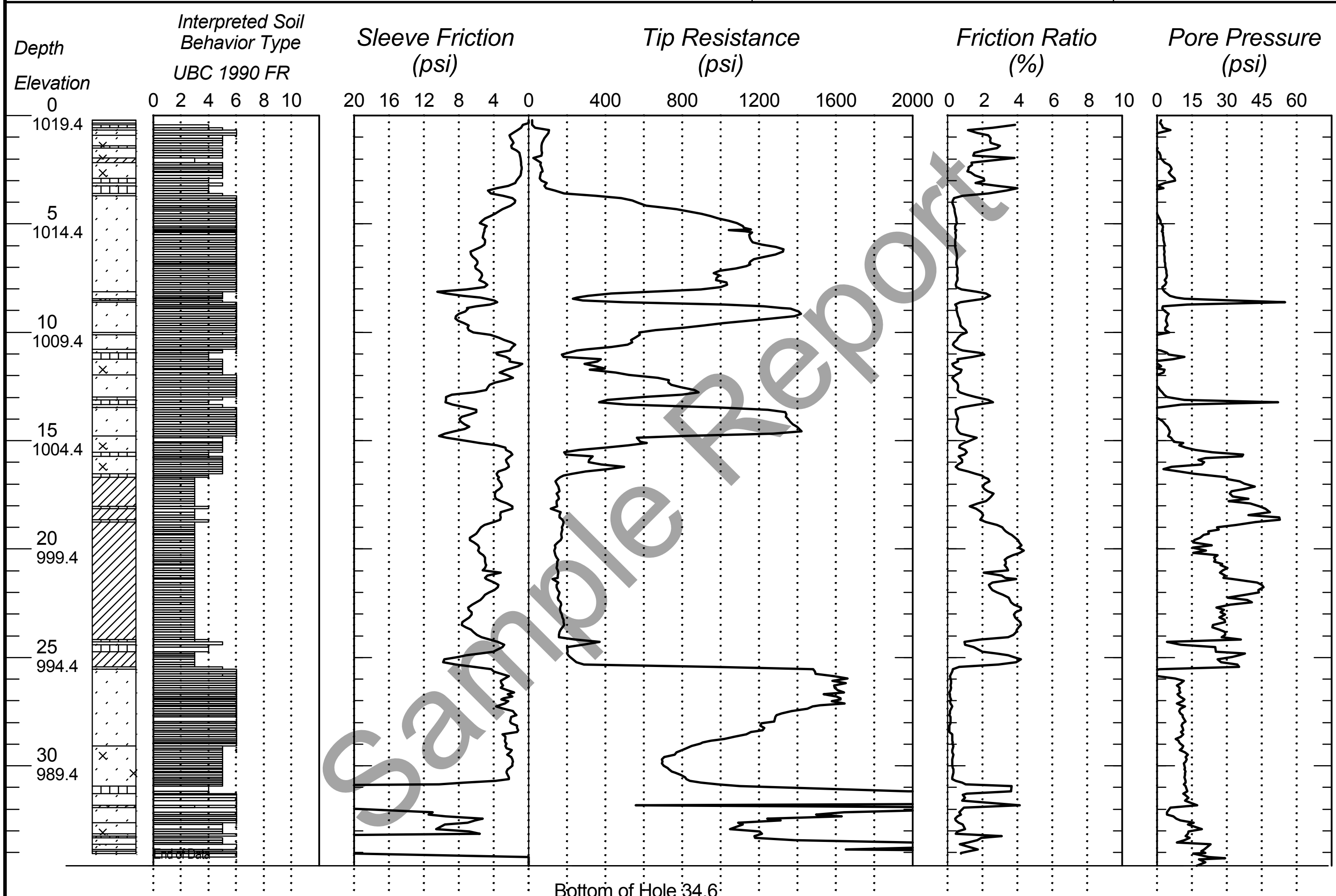
CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 73137

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
0503-75		**23**	**c01b**	**1019.4** *(DTM)*

Location **Benton Co. Coordinate: X=504874 Y=117457** (ft.)	*CPT Machine* **99649 CPT Track**	*SHEET 1 of 1*
Latitude (North)=45°36'25.33" Longitude (West)=94°01'51.45"	*CPT Operator* **Hasselquist**	*Date Completed*
No Station-Offset Information Available	*Hole Type* **CPT-STD**	**11/4/09**



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Minnesota Department of Transportation
Geotechnical Section
Flat Plate Dilatometer Test (DMT) Index Sheet

USER NOTES, ABBREVIATIONS AND DEFINITIONS

This Index sheet accompanies Flat Plate Dilatometer (DMT) data.

This DMT Sounding follows ASTM Standard Test Method D6635-01 and was made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since this DMT sounding was not taken to gather information relating to the construction of the project, the data noted in the field and recorded may not necessarily be the same as that which a contractor would desire. While the Department believes that the information as to the conditions and materials reported is accurate, it does not warrant that the information is necessarily complete. This information has been edited or abridged and may not reveal all the information which might be useful or of interest to the contractor. Consequently, the Department will make available at its offices, the field logs relating to this sounding.

Since subsurface conditions outside each DMT Push are unknown, and soil, rock and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this DMT push will necessarily be the same as or similar to those shown on this log. Furthermore, the Department will not be responsible for any interpretations, assumptions, projections or interpolations made by contractors, or other users of this log.

Water pressure measurements and subsequent interpreted water levels shown on this log should be used with discretion since they represent dynamic conditions. Dynamic Pore water pressure measurements may deviate substantially from hydrostatic conditions, especially in cohesive soils. In cohesive soils, water pressures often take extended periods of time to reach equilibrium and thus reflect their true field level. Water levels can be expected to vary both seasonally and yearly. The absence of notations on this log regarding water does not necessarily mean that this boring was dry or that the contractor will not encounter subsurface water during the course of construction.

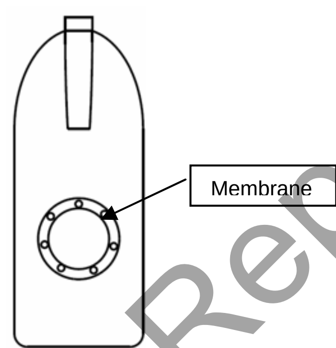
DMT Terminology

DMT…………………DilatoMeTer Test, original Italian name for Flate Plate Dilatometer Test
A-Pressure (po)……gas pressure against the inside of the membrane when center of membrane has lifted above its support and moved horizontally 0.05 (+0.02,-0.00) mm into the soil surrounding the vertical blade.
B-Pressure (p1)…….gas pressure against the inside of the membrane when the center of the membrane has lifted above its support and moved horizontally 1.10 ±0.03 mm into the soil surrounding the vertical blade.
C-Pressure (p2)………Gas pressure against the inside of the membrane obtained by slowly deflating the membrane (after A and B pressure readings) until contact is reestablished (membrane is flushed with the side of the blade).

Test Equipment

The flat dilatometer blade is made from stainless steel and includes an expandable steel membrane that is mounted flush on the face. Expansion of the membrane is measured with a three position electric switch.

The blade is approximately 235 mm long and 95 mm wide and has a thickness of 15 mm. The steel membrane is 60 mm in diameter.



Test Procedure

The test consists of pushing a flat blade attached to the end of push rods into the soil to a desired test depth. Once the test depth is reached, the operator uses gas pressure (nitrogen) to inflate a bladder within the blade that pushes out a steel membrane horizontally into the soil. The operator increases the gas pressure and records two readings (A-pressure and B-pressure). The operator then deflates the membrane and records a third pressure (C-Pressure). The blade is then pushed to the next test depth.

Material Index I_D

Soil Classification methods for the DMT are based on correlation charts developed from observations of DMT data and conventional borings. The soil type is presented as a Material Index (ID).

Please note that these classification charts are meant to provide a guide to Material Type and should not be used to infer a soil classification based on grain size distribution.

The following table shows the different Material Index for different soil types (from Marchetti 1980):

Soil Type	Material Index
Peat/Sensitive Clay	<0.10
Clay	0.10-0.35
Silty Clay	0.35-0.60
Clayey Silt	0.60-0.90
Clayey Silt	0.90-1.20
Silt	1.20-1.80
Silty Sand	1.80-3.30
Sand	>3.30

Note that engineering judgment, and comparison with conventional borings is especially important in the proper interpretation of DMT data in certain geo-materials.

Interpretation of Data

Many engineering soil parameters can be obtained from the DMT through various correlations. The reliability of these parameters is only as good as the size of the data base used to develop them and the correlations with local site geology.

The following are some of the more common parameters derived from the DMT.

Dilatometer stress index K_D
Dimensionless dilatometer horizontal stress index, $K_D=(p_o-u_o)/\sigma'_v$.

Coefficient of lateral earth pressure K_o
Ratio of the in-situ horizontal effective stress at the depth of the center of the blade membrane to the computed effective stress at the same point. This value is only approximate because it assumes an undisturbed condition, which is not possible with the insertion of the blade.

Drained Friction Angle, ϕ'
The penetration of the DMT blade in sands represents a drained bearing capacity failure approximating a plain strain condition.

Drained Constrained Modulus, M
Constrained modulus of soil compressibility. Also referred to as the tangent modulus, as found from the vertical effective stress versus vertical strain curve obtained in a 1-dimensional oedometer laboratory test.

Undrained Shear Strength, S_u
Undrained shear strength of cohesive soils, based on correlations versus unconfined compression and field vane tests.

Dilatometer Modulus, E_D
Modulus based on linear elastic theory

Preconsolidation Pressure, p'_c
The vertical effective stress in one-dimensional compression at which the soil structure changes relatively abruptly and becomes more compressible than at lower pressures.

Overconsolidation Ratio, OCR
Ratio of preconsolidation pressure versus existing effective vertical pressure.

MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

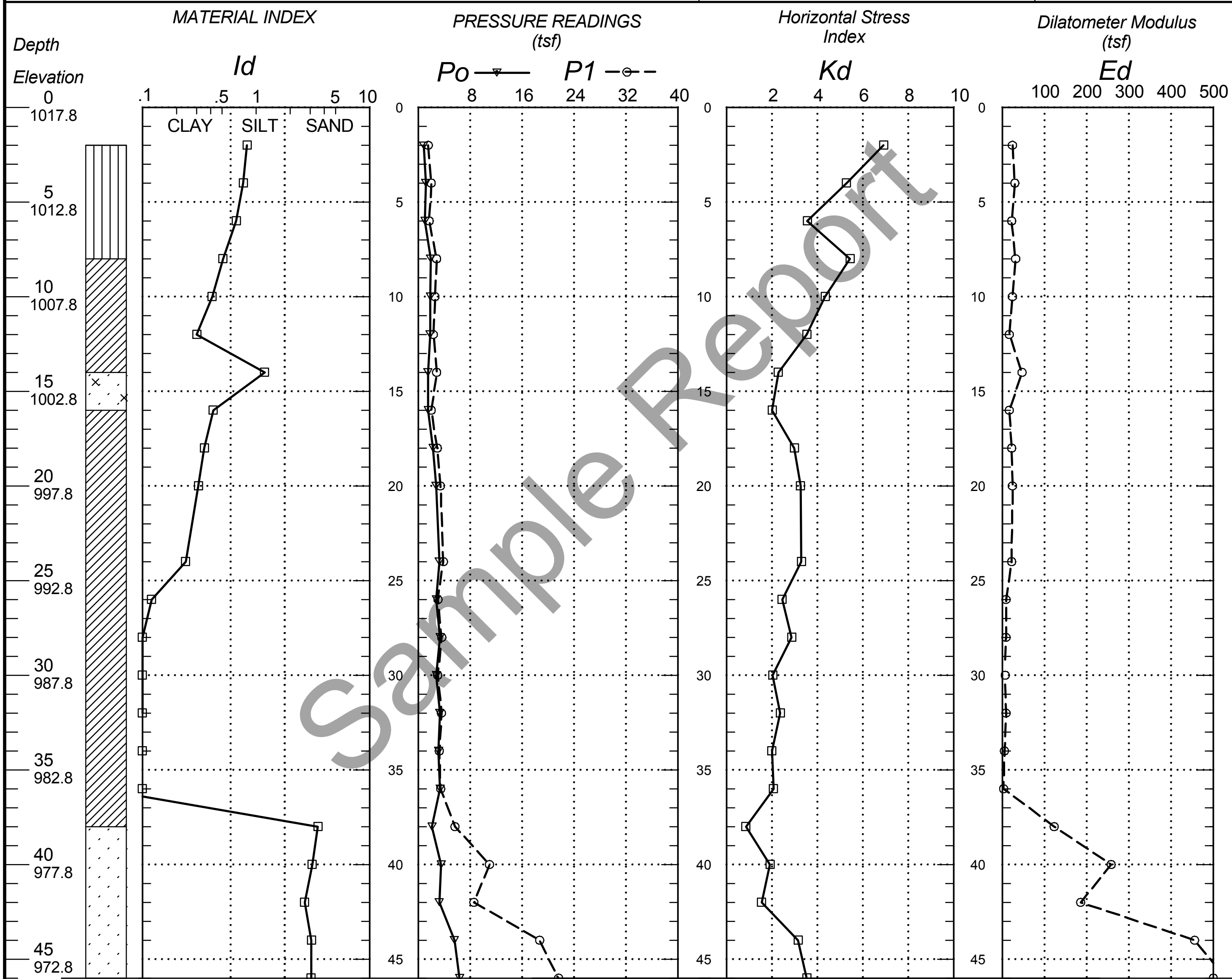
DILATOMETER (DMT) TEST RESULTS

UNIQUE NUMBER 73557

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	DMT Push No.	Ground Elevation
0503-75		**23**	**D01**	**1017.8** (from Plan)

Location	Benton Co. Coordinate: X=504510 Y=116864 (ft.)	CPT Machine **209332 GeoProbe**	SHEET 1 of 1
	Latitude (North)=45°36'19.47" Longitude (West)=94°01'56.57"	DMT Operator **Hasselquist**	Date Completed
	No Station-Offset Information Available	Hole Type **DMT**	**4/6/10**



Remarks

Index Sheet Code 3.0

Soil Class: Rock Class: Edit: Date: 6/4/10
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