FOUNDATION INVESTIGATION AND DESIGN REPORT
SOUTH TROUT CREEK BRIDGE EBL
HIGHWAY 11/17 RED ROCK TO NIPIGON
FROM 4.8 KM WEST OF HWY 628 TO 1.5KM WEST OF HWY 585
DISTRICT OF THUNDER BAY

G.W.P. 647-89-00, SITE NO. 48C-10B

Geocres Number: 52A-166

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the proposed location of a bridge planned to carry the new Highway 11/17 eastbound lanes (EBL) over the South Trout Creek in the Township of Red Rock, Ontario. The proposed bridge is part of the Highway 11/17 four-laning project, involving construction of a divided highway from 4.8 km west of Highway 628 to 1.5 km west of Highway 585 in the District of Thunder Bay.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, a stratigraphic profile, cross sections, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to Hatch Mott MacDonald (HMM), under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0006.

A previous foundation investigation report was prepared for replacement of the bridge on the current Highway 11/17 alignment with a temporary structure (Foundation Investigation and Design Report, South Trout Creek Bridge Replacement, Highway 11/17, 14 km west of the Town of Nipigon, January 22, 2010, by TBT Engineering; Geocres 52A-140). The existing bridge is located approximately 8 to 12 m southeast of the new location. Selected boreholes from the previous foundation investigation report have been used in the preparation of this report.

2 SITE DESCRIPTION

The site is located approximately 12 km (by highway) southwest of Nipigon, Ontario and about 1.3 km southwest of the intersection of Highway 11/17 and Highway 628. At the bridge location, the new eastbound lanes of Highway 11/17 will be approximately 12 to 19 m northwest of the existing highway.

South Trout Creek at the proposed crossing generally flows southerly and then easterly towards Lake Superior at Red Rock. The creek bed is situated at an approximate elevation of 212 m. The creek channel is approximately 6 m wide and 1.5 m deep. The ground elevation surrounding the site drops from approximately 218.5 m on the west side to approximately 213.5 m on the east side. The surrounding lands are typically heavily treed with occasional vacant areas of grass and shrubs.

The site is located between local roads Red Rock Road No. 7 and Red Rock Road No. 6, which are approximately 60 m southwest and 200 m northeast of South Trout Creek respectively. Overhead hydro cables run parallel to the northwest side of the highway, in close proximity to the centreline of the new eastbound lanes of Highway 11/17. The existing bridge crossing South Trout Creek was replaced in the fall of 2012 with a temporary double-lane modular steel structure.

Photographs in Appendix C show the general nature of the site and the surrounding lands.

The site lies within the physiographic region known as the Quetico Subprovince of the Superior Province of the Canadian Shield. The bedrock consists of sedimentary rock of the Sibley Group, which is overlain by deposits of lacustrine clay and silt and glacial till.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out during the period of April 24 to May 8, 2013 and consisted of drilling and sampling four boreholes (numbered STE-01 to STE-04) in the area of the proposed foundation units and approach embankments. A foundation investigation which consisted of six boreholes for the proposed westbound bridge over South Trout Creek was conducted concurrently with this investigation. Two boreholes from the westbound investigation (numbered STW-03 and STW-05) are incorporated into this report.

Based on the limited access conditions at the site, including a steep slope in close proximity to the creek as well as overhead hydro wires near the alignment of the eastbound lanes, it was not practical to advance two boreholes at each foundation element of the eastbound bridge. Therefore, it was agreed during discussions with MTO Foundations Office that abutment boreholes would be drilled where access was practical and boreholes drilled for the westbound bridge would be used to supplement this data. Similarly, one borehole (numbered STC08-1) from the previous investigation for the existing temporary bridge was used to supplement the data.

A summary of the locations, designations, termination depths and termination elevations of all boreholes used in this report is provided in Table 3.1. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix G.

Table 3.1 – Borehole Designations

Foundation Unit	Borehole Number	Borehole Termination Depth (m)	Borehole Termination Elevation (m)
West approach	STE-01	9.8	208.7
West abutment	STE-02, STC08-1 and STW-03	10.8 to 16.9	206.2 to 201.9
East abutment	STE-03 and STW-05	10.7 to 12.3	203.0 to 201.7
East approach	STE-04	9.5	204.6

The borehole locations were marked in the field and utility clearances were obtained prior to drilling.

Drilling was carried out using a track-mounted CME 55 drill rig and the boreholes were advanced with hollow-stem augers. In general, samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the native soils.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. The boreholes were backfilled with bentonite holeplug in general accordance with O.Reg. 903 upon completion. Standpipe piezometers consisting of 19 mm PVC pipe with slotted screen enclosed in filter sand were installed in Boreholes STE-02, STE-03, and STW-05 to permit longer term groundwater level monitoring. The piezometers will be subsequently decommissioned in general accordance with MOE Regulation 903 following additional water level monitoring. The installation and completion details of the piezometer and boreholes are shown in Table 3.2.

Table 3.2 – Borehole Completion Details

Borehole	Piezometer Tip Depth/ Elevation (m)	Completion Details
STE-01	None installed	Borehole backfilled with bentonite to surface.
STE-02	10.7/204.1	Sand from 10.9 m to 6.3 m, bentonite from 6.3 m to surface.
STE-03	10.7/203.0	Sand from 10.7 m to 6.7 m, bentonite to surface.
STE-04	None installed	Borehole backfilled with bentonite to surface.
STW-03	None installed	Borehole backfilled with bentonite to surface.
STW-05	11.9/202.1	Sand from 12.3 m to 5.9 m, bentonite to surface.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and hydrometer) and Atterberg Limits testing where appropriate. The results of this testing program are summarized on the Record of Borehole sheets included in Appendix A and on the figures presented in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil and rock stratigraphy are presented in these sheets and on the "Borehole Locations and Soil Strata" drawing included in Appendix G. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

The subsurface stratigraphy at this site varies between the west and east portions of the site. At the west portion, the stratigraphy typically consists of a topsoil layer over a relatively thick deposit of silty clay, underlain by deposits of clayey silt, sandy silt, and silt and sand glacial till. At the east portion, topsoil/alluvium is underlain by deposits of clayey silt, sandy silt, and silt and sand glacial till, with no thick silty clay deposit encountered. Refusal was generally encountered within the silt and sand till deposit. The boreholes for this investigation did not reach bedrock. More detailed descriptions of the individual strata are presented below.

5.1 Sand Fill

A layer of sand fill with trace gravel was encountered surficially in Borehole STE-02. The borehole was located beside the existing Highway 11/17, and the fill comprises the edge of the existing approach embankment for the bridge over South Trout Creek. The fill layer was 1.7 m thick. The base of the fill layer was at Elev. 213.1 m.

An SPT N-value recorded in the sand fill layer was 10 blows per 0.3 m of penetration, indicating a compact relative density.

The moisture content of one sample of the sand fill was 14%.

5.2 Topsoil/Alluvium

Topsoil and/or alluvial stream deposits were identified at the ground surface in all of the boreholes except Borehole STE-02. The topsoil layer ranged from a thin veneer of topsoil 175 mm thick to a 1.3 m thick layer of silty sand alluvium containing trace gravel, wood and roots and rootlets. The topsoil/alluvium thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities.

An SPT N-value of 12 blows per 0.3 m penetration was recorded in the alluvial layer in Borehole STE-03. The moisture content of the sample was 75%.

5.3 Sandy Clayey Silt

A layer of sandy, clayey silt was encountered underlying the alluvial deposits in Boreholes STE-03, STE-04, and STW-05, and below the sand fill in Borehole STE-02. The sandy clayey silt contained organic material including topsoil, roots and wood fragments. The thickness of the clayey silt layer was 0.9 m to 1.7 m. The depth to the base of the clayey silt layer was 1.7 m to 2.9 m (Elev. 211.5 m to 212.4 m)

SPT N-values in the clayey silt ranged from 0 to 13 blows per 0.3 m penetration, indicating a very soft to stiff relative density. The moisture content of the clayey silt samples ranged from 28% to 39%.

Grain size distribution curves for two samples of the clayey silt are presented on Figure B1 of Appendix B. The results are summarized on the Record of Borehole sheets and are as follows:

Gravel %	0
Sand %	24 to 36
Silt %	41 to 52
Clay %	23 to 24

5.4 Silty Clay

A thick deposit of native brown to grey silty clay with trace sand and occasional silt seams and sand pockets was encountered below the topsoil in Boreholes STE-01 and STW-03 drilled above the west valley slope, and below a layer of clayey silt in Borehole STE-02.

At Boreholes STE-01 and STW-03, which were drilled from a higher elevation, the clay deposit was encountered at Elev. 218.0 m and ranged in thickness from 8.3 m to 8.8 m. At Borehole STE-02, the clay was encountered at Elev. 211.9 m and was 1.5 m thick. The lower boundary of the silty clay layer ranged from Elev. 209.1 to 210.4.

Standard Penetration tests performed in the silty clay deposit gave SPT N-values ranging from 0 to 7 blows per 0.3 m of penetration, indicating a very soft to firm consistency. The values higher than 3 were obtained in the upper 2.0 to 2.5 m of the clay in Boreholes STE-01 and STW-03 drilled above the west slope, indicating the presence of an upper firm to soft crust.

In-situ vane shear tests carried out on the cohesive deposits measured undrained shear strengths of 30 kPa to 70 kPa. It is likely however that the measured strengths, particularly the higher values, are affected by the silt seams in the clay. The Sensitivity ranged from 2 to 6.

The moisture contents of samples of the silty clay varied from 26% to 59%.

Selected samples of the silty clay underwent laboratory grain size analysis testing and Atterberg Limits tests. The grain size distribution curves for tested samples of silty clay are presented in Appendix B, Figure B2. The results of the Atterberg Limits tests are presented in Figure B6, Appendix B. The results are summarized on the Record of Borehole sheets included in Appendix A, and in the following tables:

Gravel %	0
Sand %	0
Silt %	29 to 49
Clay %	51 to 71

Liquid Limit	41 to 61
Plastic Limit	19 to 23

The above results indicate that the silty clay varies from intermediate to high plasticity with group symbols of CI and CH.

5.5 Silt and Sand

In Boreholes STE-02, STW-03, and STW-05, a layer of grey silt and sand containing trace gravel was contacted below the silty clay and clayey silt at depths from 1.9 m to 9.6 m (Elev. 209.1 m to 212.1 m). The layer was 1.7 m to 2.6 m thick and the base of the silt and sand was encountered at 3.8 m to 12.2 m depth (Elev. 206.6 m to 210.2 m).

SPT N-values recorded in the silt and sand ranged from 4 to 10 blows per 0.3 m of penetration, indicating a loose to compact relative density. The moisture content of the silt and sand samples ranged from 13% to 18%.

5.6 Sandy Silt to Silt and Sand Till

A deposit of grey glacial till ranging in composition from silt and sand to sandy silt was encountered below the silty clay, clayey silt, or silt and sand layers in all of the boreholes at depths ranging from 1.7 m to 12.2 m (Elev 206.6 m to 212.4 m). The till contained trace to some gravel, trace clay, and occasional cobbles. All of the boreholes were terminated within the till deposit at depths ranging from 9.5 m to 16.9 m (Elev. 201.7 m to 208.7 m). All boreholes except Borehole STE-01 were terminated in the till deposit after advancing at least 3 m into refusal soil as defined by SPT N-values of greater than 100 blows per 0.3 m penetration.

SPT N-values recorded in the till deposit ranged from 19 blows per 0.3 m of penetration to 100 blows per 0.1 m of penetration, indicating a compact to very dense relative density.

The moisture content of samples of the till ranged from 10% to 18%, with one higher value of 28% recorded.

Selected samples of the till underwent laboratory grain size analysis testing. The grain size distribution curves for tested samples are presented in Appendix B, Figures B3 and B4. The results are summarized on the Record of Borehole sheets included in Appendix A, and in the following table:

Gravel %	0 to 10
Sand %	21 to 41
Silt %	44 to 71
Clay %	4 to 9

Till deposits inherently contain cobbles and boulders, and these should be anticipated during construction.

5.7 Sand / Gravelly Sand

Boreholes STE-02 and STW-05 encountered deposits of sand to gravelly sand within the glacial till described above. The sand was grey to dark grey in colour, and contained some silt. The boreholes encountered the sand at depths of 9.1 m and 9.6 m (Elev. 205.7 m and 204.4 m). In Borehole STE-02, the sand layer was 0.7 m thick, and in Borehole STW-05, the sand deposit was 2.6 m thick. The base of the sand was contacted at depths of 9.8 m and 12.2 m (Elev. 205.0 m and 201.8 m).

SPT N-values of 100 blows per 0.1 to 0.2 m of penetration were recorded within the sand, indicating a very dense relative density. Moisture contents of 15% and 16% were measured.

The results of a grain size distribution analysis conducted on a sample of the sand are presented on the Record of Borehole sheet and on Figure B5 of Appendix B. The results are summarized as follows:

Gravel %	6
Sand %	82
Silt & Clay%	12

The sand and gravel deposits may contain cobbles and boulders, and these should be anticipated during construction.

5.8 Water Levels

Water levels were observed in the boreholes during and upon completion of drilling. Standpipe piezometers were installed in Boreholes STE-02, STE-03, and STW-05 to monitor water levels after completion of drilling. The water levels measured upon drilling completion and in the piezometers are summarized in Table 5.1.

Table 5.1 – Water Level Measurements

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
STE-02	May 9, 2013 June 23, 2013	0.3 2.6	214.5 212.2	In piezometer In piezometer
STE-03	April 30, 2013 May 9, 2013 June 23, 2013	0.0 0.2 0.8	213.7 213.5 212.9	Upon completion In piezometer In piezometer
STE-04	April 24, 2013	7.9	206.2	Upon completion
STW-03	May 2, 2013	6.2	212.6	Upon completion
STW-05	May 9, 2013 June 23, 2013	0.6 0.7	213.4 213.3	In piezometer In piezometer

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

The groundwater level is also expected to be influenced by the water level in South Trout Creek, which is shown on the preliminary GA drawing provided by HMM to be at Elev. 212.9 m (date not noted). The high water level is indicated at Elev. 213.6.

6 MISCELLANEOUS

Borehole locations were selected by Thurber Engineering Ltd. The borehole locations were staked in the field by TBT Engineering Limited surveyors. The co-ordinates and ground surface elevations at the boreholes were provided by the surveyors.

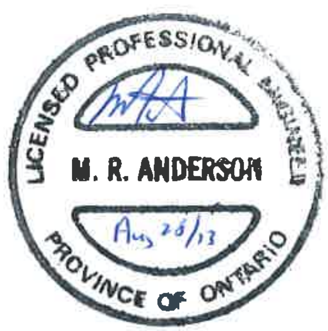
TBT Engineering Limited from Thunder Bay, Ontario supplied a track mounted CME 55 drill rig and conducted the drilling, sampling and in-situ testing operations.

Full time supervision of the field activities was carried out by Ms. Eckie Siu of Thurber. Overall supervision of the field program was conducted by Mr. Mark Farrant, P. Eng.

Interpretation of the data and preparation of the report were carried out by Mr. Mark Farrant, P.Eng. and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Murray R. Anderson, P.Eng.
Senior Foundations Engineer



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for selection and design of a suitable foundation system for the new bridge planned to carry the Highway 11/17 eastbound lanes (EBL) over South Trout Creek in the Township of Red Rock, Ontario.

The new EBL structure will be located approximately 12 to 19 m northwest of the existing Highway 11/17 bridge. Based on the preliminary General Arrangement (GA) drawing provided by Hatch Mott MacDonald, the current design concept calls for a single-span structure consisting of precast concrete box girders supported on integral abutments. The span will be 27 m between abutment bearings. The structure will be approximately 14.9 m wide.

The abutment will consist of a precast concrete ballast wall on top of a precast concrete header beam. Precast concrete wingwalls will be structurally connected to and supported by the header beam and ballast wall.

The proposed finished grade on the structure will be at about Elevation 217.0 m.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the investigation. The plans and profiles used for preparation of this report were provided by Hatch Mott MacDonald.

8 STRUCTURE FOUNDATIONS

The subsurface stratigraphy at this site varies significantly between the west and east sides of South Trout Creek. Above the creek valley slope at the west abutment, the stratigraphy consists of a topsoil layer over a relatively thick deposit of firm to very soft silty clay underlain by compact to very dense silt and sand till. Adjacent to the creek, the stratigraphy consists of surficial fill over relatively shallow clayey silt to silty clay underlain by silt and sand till. At the east abutment, the stratigraphy is characterized by a relatively thick topsoil/alluvium layer over a thin layer of firm to stiff clayey silt underlain by deep deposit of compact to very dense silt and sand till.

Groundwater levels measured in three piezometers ranged from 0.2 to 2.6 m below the ground surface, at Elevation 212.2 to 214.5 m. The creek water level was reported to be at Elev. 212.9, and the high water level is indicated to be at Elev. 213.6.

Based on the existing site conditions, consideration was given to the following foundation types:

- Spread footings on native soils
- Driven H-piles
- Augered caissons (drilled shafts)
- Pipe piles

A comparison of the technical advantages and disadvantages of alternative foundation schemes is presented in Appendix D. These foundation alternatives are discussed in the following sections. A foundation scheme preferred from a foundations perspective is also recommended.

8.1 Spread Footings on Native Soils

The firm to very soft silty clay deposit on the west side of the creek is considered unsuitable for support of spread footings due to the low bearing resistance available and the potential for excessive consolidation settlements under bridge and embankment fill loads. Further, extending footings below the silty clay and loose silt and sand to the underlying very dense silt and sand till at a depth of approximately 6 m (Borehole STE-02) is not practical in the presence of a high ground water table. Further, excavation may impact on the creek. Therefore, spread footings are not recommended for the west abutment.

At the east abutment, footing construction would require excavation to depths of about 2.5 to 3.8 m to penetrate the topsoil/alluvium, sandy clayey silt layer and loose silt and sand to found on very dense silt and sand till. Excavation to these depths will require dewatering to lower the groundwater level prior to construction. In view of the depth of excavation, the dewatering requirements and the potential for impact on the creek as a consequence, supporting the east abutment on spread footings is not recommended.

8.2 Driven Steel H-Piles

The subsurface conditions at both the west and east abutments are considered suitable for the use of steel H-piles driven to refusal in the very dense sand and silt till. The anticipated pile tip elevation, estimated pile lengths (based on an approximate pile cut-off elevation of 215.5 as per the preliminary GA), and recommended axial geotechnical resistances of HP310x110 driven to refusal in the till are summarized in Table 8.1.

Table 8.1 – Pile Tip Elevations and Recommended Resistance Values

Abutment	Anticipated Pile Tip Elevation	Estimated Pile Length (m)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Resistance at SLS (kN)
West	205 m	10.5	1400	1200
East	205 m	10.5	1400	1200

The actual pile tip elevations will be controlled as described in Section 8.2.2 Pile Installation.

Oversize materials (e.g. greater than 75 mm nominal diameter) must not be used in any fills through which the piles will be driven.

8.2.1 Pile Tips

The tips of all H-piles must be fitted with pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent. Pile tip protection is recommended to prevent pile damage if cobbles or boulders are encountered in the very dense till prior to achieving the required resistance.

8.2.2 Pile Installation

Pile installation should be in accordance with OPSS 903.

Pile driving must be controlled by the Hiley Formula as per Standard SS103-11. The appropriate pile driving note is “Piles to be driven in accordance with Standard SS103-11 using an ultimate geotechnical resistance of “R” kN per pile”. “R” must have a minimum value of twice the design load at ULS but must not exceed 2800 kN for HP 310x110 piles.

If a pile has not developed the specified resistance after being driven 2 m beyond the design pile tip elevation, the contractor shall stop pile driving and check the Hiley calculation and all input values. If calculation still shows that the pile has not reached the specified resistance, the following procedure should be implemented:

1) Stop driving in that pile group for 48 hours (minimum);

2) After 48 hours, warm up the hammer on another pile then re-tap the subject pile and measure the resistance;

3) If the pile still does not reach the specified resistance, the Quality Verification Engineer (QVE) must immediately advise the Contract Administrator (CA) who, in turn, should refer the issue to the design team.

8.2.3 Integral Abutment Considerations

The use of H-piles at the abutments allows for the design of an integral abutment structure. The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. At this site, the near surface materials consist of surficial fill and firm clayey silt to silty clay at the west abutment, and topsoil/alluvium (to be removed and replaced by granular fill) and stiff clayey silt at the east abutment. The lateral resistance of a pile in these materials may not provide sufficient flexibility. Accordingly, to provide the required flexibility in the piles, the upper 3 m of the piles should be surrounded by a 600 mm diameter CSP as specified by the integral abutment design procedures.

After the pile is installed, the space between the pile and the CSP should be filled with sand. An NSSP should be included in the contract drawings specifying the gradation of the sand according to Table 8.2.

Table 8.2 – Integral Abutment Sand Backfill Grading

MTO Sieve Designation		Percentage Passing
2 mm	#10	100%
600 µm	#30	80%-100%
425 µm	#40	40%-80%
250 µm	#60	5%-25%
150 µm	#100	0%-6%

8.2.4 Lateral Resistance

The lateral resistance of a steel H-pile may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) in the cohesionless soils as follows:

$$k_s = n_h * z / D \quad (kN/m^3)$$

$$p_{ult} = 3 * \gamma * z * K_p \quad (kPa)$$

where
z = depth of embedment of pile in metres
D = pile width in metres
n_h = value in Table 8.3
γ = unit weight of soils (Table 8.3)
K_p = passive earth pressure coefficient (Table 8.3)

In cohesive soils, the lateral resistance may be calculated as follows:

k_s = $67 * S_u / D$ (kN/m^3)
p_{ult} = $9 * S_u$ (kPa) at and below a depth of 3D and reduced to zero at the ground surface

where D = pile width in metres
s_u = undrained shear strength (kPa)

Table 8.3 – Parameters for Lateral Resistance

Abutment	Top Elev.	Bottom Elev.	n_h (kN/m^3)	K_p	S_u (kPa)	Unit Weight (kN/m^3)	Soil Conditions
West	214.8	213.1	2,500	3.0	-	10*	Sand fill
	213.1	210.4	-	-	50	8*	Clayey silt to silty clay
	210.4	208.7	2,500	3.0	-	10*	Silt and sand
	208.7	-	6,500	3.5	-	12*	Sandy silt till
East	213.7	212.4	3,000	3.2	-	11*	Granular Fill (to replace topsoil)
	212.4	211.5	-	-	60	9*	Clayey silt
	211.5	-	6,500	3.5	-	12*	Sandy silt till

* Buoyant unit weight below groundwater table.

The above equations and recommended parameters may be used to analyse the interaction between a single foundation element and the surrounding soils. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

The spring constant, K, for analysis may be obtained by the expression, $K = k_s*L*D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3), D is the foundation width or diameter (m) and L is the length (m) of the foundation segment or element used in the analysis. The ultimate lateral resistance on any one segment of foundation, P_{ult}, may be obtained from the expression, $P_{ult} = p_{ult}*L*D$. This represents the ultimate load at which the foundation fails and will not support any additional load at greater displacements. It is recommended however that the total lateral resistance by one pile be limited to 120 kN at factored ULS and 35 kN at SLS.

The modulus of subgrade reaction may have to be reduced, based on the pile spacing. Where a pile group is oriented ***perpendicular*** to the direction of loading, group action may be considered by reducing values for k_s by a reduction factor R as follows:

Pile Spacing Perpendicular to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
4 D*	1.00
1 D*	0.50

* D is the width of the pile, and spacing is measured centre to centre

Where a pile group is oriented ***parallel*** to the direction of loading, group action may be considered by reducing values for k_s by a reduction factor R as follows:

Pile Spacing Parallel to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
8 D	1.00
6 D	0.70
4 D	0.40
3 D	0.25

Intermediate values may be obtained by interpolation.

8.3 Augered Caissons (Drilled Shafts)

Caissons supporting the abutments would need to be founded in the very dense silt and sand till below the level of all fill, topsoil/alluvium, soft silty clay/clayey silt and loose silt and sand deposits. The required caisson length would be in the order of 8 to 10 m. The loose silt and sand layer and very dense silt and sand till are essentially cohesionless materials. The groundwater level at the site is near the ground surface.

For these conditions, caisson installation will require the use of steel liners, drilling mud or other measures to support the sidewalls during augering and prevent heave and disturbance of the caisson base. In addition, cobbles and boulders may be encountered in the till deposits during augering. Considering the potential for installation difficulties and disturbance of the founding surfaces, the use of augered caissons is not recommended at this site and this option has not been developed further.

8.4 Pipe Piles

The use of driven steel pipe piles is not recommended at this site due to the potential for damage to the pile tip when driving into very dense till with possible cobbles and boulders. Drilled-in pipe piles socketed into rock is not considered to be a practical alternative as bedrock was not encountered within the refusal depths explored.

8.5 Downdrag

Downdrag is not considered to be an issue at the east abutment. At the west abutment, downdrag forces will develop along the length of pile embedded in the soft silty clay layer and overlying fill and clayey silt due to consolidation of the clay under the approach embankment loads.

For design purposes, an unfactored downdrag load of 90 kN is recommended to evaluate the impact of downdrag on the west abutment piles. For an integral abutment, the upper 3 m of the pile will be surrounded by loose sand, and the unfactored downdrag load for assessment may be reduced to 60 kN.

This downdrag load should be multiplied by a load factor of 1.25 as per CHBDC Commentary Clause C8.6.4 to obtain a factored downdrag load. In accordance with Section 6.8.4 of the CHBDC and Clause C6.8.4 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag. Live load effects should not be considered.

The location of the neutral plane for a pile or group of piles should be determined by using unfactored loads and unfactored geotechnical parameters.

Factored dead and downdrag load should not exceed the factored structural resistance of a pile.

8.6 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, steel H-piles driven to refusal in the very dense till are the recommended foundation option for supporting both abutments.

8.7 Depth of Frost Penetration

The design depth of frost penetration at this site is 2.3 m. The base of all buried pile caps, if employed, must be provided with a minimum of 2.3 m of earth cover as protection against frost action.

9 BACKFILL TO ABUTMENTS

The current design concept calls for installation of a precast concrete ballast wall on top of a precast concrete header beam to act as a low abutment wall. Precast concrete wingwalls will be structurally connected to and supported by the header beam and ballast wall. Fill will be placed in front of the header beam to form a front slope inclined at 2H:1V.

Backfill to the abutments and wingwalls should consist of Granular A, Granular B Type II or Granular B Type III material meeting the requirements of Special Provision 110S13 "Amendment to OPSS 1010, April 2004". The backfill must be in accordance with OPSS 902, and placed to the extents shown in OPSD 3101.150.

All new embankment fill should be placed in uniform lifts and be compacted in accordance with OPSS 501. Also, compaction equipment to be used adjacent to retaining structures must be restricted in accordance with OPSS 501 and SP 105S21.

The design of the abutment must incorporate a subdrain as shown in OPSD 3101.150 or OPSD 3101.200, as applicable.

10 LATERAL EARTH PRESSURES

Lateral earth pressures acting on the structure may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$p_h = K(\gamma h + q)$

Where:

p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 10.1)

γ = unit weight of retained soil (see Table 10.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 10.1.

Table 10.1 – Earth Pressure Coefficient (K)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8\ kN/m^3$		OPSS Granular B Type I or Type III $\phi = 32°, \gamma = 21.2\ kN/m^3$	
	Horizontal Surface	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the wall.

The factors in Table 10.1 are "ultimate" values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.16 in the Commentary to the Canadian Highway Bridge Design Code (CHBDC).

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or Type III or 1.7 m for Granular A or Granular B Type II.

11 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0
- Peak Horizontal Acceleration 0.011g

The soil profile type at this site has been classified as Type II. Therefore, according to Clause 4.4.6 of the CHBDC, Site Coefficients "S" (ground motion amplification factor) of 1.2 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 11.1 may be used:

Table 11.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8$ **kN/m^3**	**OPSS Granular B Type I or Type III** $\phi = 32°, \gamma = 21.2$ **kN/m^3**
Active (K_{AE})*	0.28	0.32
Passive (K_{PE})	3.7	3.2
At Rest (K_{OE})**	0.45	0.50

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.
** After Woods

The west side of the site is underlain by stiff to firm silty clay and very dense till, and the east side is underlain by thin clayey silt deposits over very dense till. In view of these conditions and the velocity related seismic zone of zero, liquefaction is not considered to be a concern at this site.

12 APPROACH EMBANKMENTS

The finished road grade over the bridge will be approximately 3.5 m above the original grade adjacent to the creek channel. Construction of the approach embankments to the bridge will entail the following:

- At the west approach, the existing ground surface rises towards the west such that the roadway will enter into a cut section approximately 10 m west of the west abutment.

Between this point and the west abutment, a maximum 2.0 m thickness of fill will be placed over the existing slope to form the approach embankment. The forward slope under the abutment will be inclined at 2H:1V.

- On the east approach, up to 3.0 m of fill will be placed to construct the east embankment. The forward and side slopes of the fill embankment will be inclined at 2H:1V.

Recommendations for construction of the approach embankments at the west and east abutments are presented below.

12.1 West Approach (Boreholes STE-01 and STE-02)

The embankment foundation soils under the west approach include a relatively thick deposit of firm to very soft silty clay and clayey silt. Design and construction of the embankment must address the stability of the embankment slopes and the potential for long term settlements due to consolidation of the clay under the embankment loading.

12.1.1 Slope Stability

Analysis of the global stability at the west abutment was conducted to assess the stability of the proposed 3.5 m high slope inclined at 2H:1V. Short-term and long-term analyses were conducted. The stability analyses were carried out using the commercially available slope stability program GEO-SLOPE, applying the Morgenstern-Price method.

The geotechnical model and results of the analyses are shown on Figures 1 and 2 in Appendix F. Factors of safety of 2.2 and 1.6 were computed for short-term and long-term conditions respectively.

The computed factors of safety for the proposed slopes exceed the minimum values of 1.3 and 1.5 normally accepted for this type of analysis under short and long term conditions, respectively. Stability of the approach embankment is therefore not considered to be an issue.

12.1.2 Settlement

Placement of fill the west abutment will induce time dependent (consolidation) settlement in the underlying silty clay. Based on analyses using one-dimensional consolidation theory, the total consolidation settlement under a maximum 2.0 m of new fill is estimated to be in the order of 40 mm. This settlement is expected to occur over a period of 1 to 2 years.

To reduce the post-construction settlement, it is recommended that lightweight fill (EPS or cellular concrete) be incorporated into the west approach embankment. Assuming the approach is constructed with a 1.5 m thickness of EPS overlain by an approximate 1.0 m pavement/soil cover, the estimated post-construction settlement is in the order of 10 mm.

For 1.5 m of cellular concrete, the post-construction settlement is estimated to be approximately 20 mm.

The lightweight fill (cellular concrete or EPS) must be placed above the high water level in the creek.

12.2 East Approach (Boreholes STE-03 and STE-04)

Up to 1.3 m of topsoil/alluvium was encountered in the boreholes drilled within the east approach area. Sub-excavation and replacement of the topsoil/alluvium with compacted granular material is recommended as part of embankment construction. The underlying foundation soils will consist of a 0.9 m layer of firm to stiff sandy clayey silt over compact to very dense silt and sand till.

Analysis of the global stability of the embankment slopes was conducted to assess the stability of the proposed 3.5 m high embankment inclined at 2H:1V. Short-term and long-term analyses were conducted. The stability analyses were carried out using the commercially available slope stability program GEO-SLOPE, applying the Morgenstern-Price method.

The geotechnical model and results of the analyses are shown on Figure 3 in Appendix F (short term and long term results are the same. A factor of safety of 1.4 was computed for both short-term and long-term conditions. The computed factor of safety exceeds the minimum value of 1.3 normally accepted for this type of analysis, and therefore stability of the approach embankment is not considered to be an issue.

Settlement of the foundation soils due to the embankment loads is expected to be in the order of 15 mm and occur essentially as the fill is placed.

13 SHEET PILE WALLS

As an alternative to the proposed ballast wall and wingwalls, installation of steel sheet pile walls adjacent to the abutment foundations could be considered. The sheet piles will provide containment and resistance to lateral earth pressures from the approach fill.

Very dense till with possible cobbles and boulders is present at shallow depth at the east abutment and may limit the depth of penetration achieved by sheet piles. If employed, sheet piles advanced into the till should be provided with tip protection to minimize any tip damage. Any visible boulders on the ground surface should be removed prior to driving of the sheet piles.

At the west abutment, the sheet piles should be driven through the clay and into the underlying till.

Design of permanent sheet pile walls must consider environmental conditions such as road salts or fluctuating water levels that may cause corrosion and reduce the service life of the structure.

14 EXCAVATION AND GROUNDWATER CONTROL

Excavation will be required to provide a competent foundation subgrade for the approach embankments. At the west abutment, the excavation for subgrade preparation will be carried out within existing embankment fill. At the east embankment, excavation of the topsoil/alluvium is required.

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the fill and native soils above the water table may be classed as Type 3 soils. The topsoil/alluvium below the water table on the east side of the creek is classed as a Type 4 soil.

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902.

Groundwater levels measured in the piezometers ranged from Elev. 212.2 to 214.5. The reported water level in the creek was Elev. 212.9. Based on the groundwater levels and reported creek level, it is anticipated that removal of the topsoil/alluvium at the east abutment will require excavations extending below the water level.

Where the excavation extends below the water level, measures may be required to maintain a stable excavation and enable placement and compaction of embankment fill. Depending upon the water levels prevailing at the time of construction, measures to be considered may include pumping from sumps and/or installation of a temporary sheet pile cofferdam.

Selection and design of the excavation and dewatering system required for construction is the responsibility of the Contractor. The Contract Documents should contain a NSSP alerting the Contractor to the conditions associated with excavation of the soils below the groundwater level.

15 SCOUR AND EROSION PROTECTION

Erosion protection should be provided along any soil surfaces that may be in contact with the creek flow. In particular, erosion protection must be provided to prevent undermining of the abutment header walls and wingwalls.

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

16 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Pile tips should be properly protected to avoid sustaining damages when encountering obstructions in the very dense till.
- The sandy silt till at this site contains cobbles and boulders. The possibility exists that piles may encounter refusal in cobbles and boulders above the anticipated founding

elevation, and that piles within a group may achieve refusal at different elevations. It is important that the founding elevations of the piles be monitored closely and any significant deviation from the design elevation must be reported to the designer for assessment. "Significant" in this instance can be taken as 2 to 3 m.

- Preparation of the embankment subgrade will require excavation of soft/organic materials below the creek and groundwater levels. Measures to deal with the groundwater may be required to enable placement and compaction of embankment material.

17 CLOSURE

Engineering analysis and preparation of the report were carried out by Mr. Keli Shi, P.Eng. and Mr. Murray Anderson, P.Eng.

The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Keli Shi, P.Eng.
Geotechnical Engineer

Murray R. Anderson, P.Eng.
Senior Foundations Engineer

Report reviewed by:
P.K. Chatterji, P.Eng.
Review Principal

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT[(1)] 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS Split Spoon Sample WS Wash Sample AS Auger (Grab) Sample
TW Thin Wall Shelby Tube Sample TP Thin Wall Piston Sample
PH Sampler Advanced by Hydraulic Pressure PM Sampler Advanced by Manual Pressure
WH Sampler Advanced by Self Static Weight RC Rock Core SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

<u>UNIFIED SOILS CLASSIFICATION</u>

<table>
<tr><th colspan="2">MAJOR DIVISIONS</th><th>GROUP SYMBOL</th><th>TYPICAL DESCRIPTION</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOILS</td><td rowspan="4">GRAVEL AND GRAVELLY SOILS</td><td>GW</td><td>Well-graded gravels or gravel-sand mixtures, little or no fines.</td></tr>
<tr><td>GP</td><td>Poorly-graded gravels or gravel-sand mixtures, little or no fines.</td></tr>
<tr><td>GM</td><td>Silty gravels, gravel-sand-silt mixtures.</td></tr>
<tr><td>GC</td><td>Clayey gravels, gravel-sand-clay mixtures.</td></tr>
<tr><td rowspan="4">SAND AND SANDY SOILS</td><td>SW</td><td>Well-graded sands or gravelly sands, little or no fines.</td></tr>
<tr><td>SP</td><td>Poorly-graded sands or gravelly sands, little or no fines.</td></tr>
<tr><td>SM</td><td>Silty sands, sand-silt mixtures.</td></tr>
<tr><td>SC</td><td>Clayey sands, sand-clay mixtures.</td></tr>
<tr><td rowspan="7">FINE GRAINED SOILS</td><td rowspan="4">SILTS AND CLAYS $W_L < 50\%$</td><td>ML</td><td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.</td></tr>
<tr><td>CL</td><td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).</td></tr>
<tr><td>CI</td><td>Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).</td></tr>
<tr><td>OL</td><td>Organic silts and organic silty-clays of low plasticity.</td></tr>
<tr><td rowspan="3">SILTS AND CLAYS $W_L > 50\%$</td><td>MH</td><td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.</td></tr>
<tr><td>CH</td><td>Inorganic clays of high plasticity, fat clays.</td></tr>
<tr><td>OH</td><td>Organic clays of medium to high plasticity, organic silts.</td></tr>
<tr><td colspan="2">HIGHLY ORGANIC SOILS</td><td>Pt</td><td>Peat and other highly organic soils.</td></tr>
<tr><td colspan="3">CLAY SHALE</td><td rowspan="5"></td></tr>
<tr><td colspan="3">SANDSTONE</td></tr>
<tr><td colspan="3">SILTSTONE</td></tr>
<tr><td colspan="3">CLAYSTONE</td></tr>
<tr><td colspan="3">COAL</td></tr>
</table>

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

DISCONTINUITY SPACING

Bedding	**Bedding Plane Spacing**
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

STRENGTH CLASSIFICATION

Rock Strength	**Approximate Uniaxial Compressive Strength (MPa)**	**(psi)**	**Field Estimation of Hardness***
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

THURBER

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No STE-01

METRIC

GWP# 647-89-00 | LOCATION N 5 424 485.5 E 205 884.3 | ORIGINATED BY ES

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.05.04 - 2013.05.04 | CHECKED BY MEF

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	FIELD VANE (Sensitivity)	WATER CONTENT (%) / LIMITS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
218.5								
0.0	**TOPSOIL**, some roots and rootlets, occasional wood fibres, Dark Brown, Moist							
218.0 / 0.5	Silty **CLAY**, trace sand, trace rootlets, Firm, Brown (CI)				218			
		1	SS	6				
					217			
		2	SS	4				0 0 47 53
	Occasional silt seams	3	SS	5	216			
		4	SS	2				
	Soft to Very Soft, Becoming grey (CH)				215	4		
		5	SS	0	214			
					213	5		
		6	SS	1	212			0 0 29 71
						5		
		7	SS	1	211			
					210	4		
209.7 / 8.8	**SILT** and **SAND**, trace clay, trace gravel, Compact, Grey, Wet (TILL)	8	SS	19	209			
208.7 / 9.8	END OF BOREHOLE AT 9.8m.							

Column headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3; GROUND WATER CONDITIONS; STRAT PLOT.

Continued Next Page

+ 3, × 3 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No STE-01

METRIC

GWP# 647-89-00
LOCATION N 5 424 485.5 E 205 884.3
ORIGINATED BY ES
HWY 11/17
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2013.05.04 - 2013.05.04
CHECKED BY MEF

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.										

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No STE-02

METRIC

GWP#	647-89-00	LOCATION	N 5 424 487.5 E 205 907.3	ORIGINATED BY	ES
HWY	11/17	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.05.08 - 2013.05.08	CHECKED BY	MEF

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
214.8 / 0.0	**SAND**, fine grained, trace gravel, occasional cobbles Compact Brown Moist (FILL)	1	SS	10		
213.1 / 1.7	Clayey **SILT**, sandy, trace gravel, trace roots and rootlets Soft Brown Moist	2	SS	0		
	Becoming grey with wood fibres	3	SS	2		
211.9 / 2.9	Silty **CLAY**, trace sand Soft Grey (CI)	4	SS	1		0 0 47 53
210.4 / 4.4	**SILT** and **SAND**, trace gravel Loose Grey Wet	5	SS	7		
208.7 / 6.1	Sandy **SILT** to **SILT** and **SAND**, trace clay, trace gravel Very Dense Grey Moist (TILL)	6	SS	104/ 0.200		8 32 56 4
	Occasional cobbles	7	SS	100/ 0.075		
205.7 / 9.1	Gravelly **SAND** Very Dense Grey Wet	8	SS	100/ 0.200		
205.0 / 9.8	Sandy **SILT**, trace clay, trace gravel					

Elevation scale: 214, 213, 212, 211, 210, 209, 208, 207, 206, 205

Dynamic cone penetration resistance plot: 20 40 60 80 100

Shear strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100 (field vane reading at approx. elev. 210.8: +3)

Plastic limit w_P — Natural moisture content w — Liquid limit w_L; Water content (%) 20 40 60

Unit weight γ kN/m³

Ground water level ▼ at approx. elev. 212.3

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No STE-02

METRIC

GWP# 647-89-00 | LOCATION N 5 424 487.5 E 205 907.3 | ORIGINATED BY ES

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.05.08 - 2013.05.08 | CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Continued From Previous Page													
203.9	Sandy **SILT**, trace clay, trace gravel Very Dense Grey Moist (TILL)		9	SS	100/ 0.225		204		o		0	21	71	8
10.9	END OF BOREHOLE AT 10.9m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.													

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
May 09/13	0.3	214.5
Jun. 23/13	2.6	212.2

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. Plastic limit w_P, natural moisture content w, liquid limit w_L.

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No STE-03

METRIC

GWP#	647-89-00	LOCATION	N 5 424 509.5 E 205 929.3	ORIGINATED BY	ES
HWY	11/17	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.04.28 - 2013.04.30	CHECKED BY	MEF

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) | SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100) | PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
213.7								
0.0	**TOPSOIL/ALLUVIUM**, silty sand, trace gravel, trace roots and rootlets Loose to Compact Dark Brown Wet	1	SS	12				
212.4 1.3	Clayey **SILT**, sandy, trace gravel Stiff Grey	2	SS	13				
211.5 2.2	**SILT** and **SAND**, trace clay, trace gravel Very Dense Grey Moist (TILL)	3	SS	25	10	41	44	5
		4	SS	100/ 0.225				
	Occasional cobbles	5	SS	100/ 0.200	5	36	51	8
	Compact	6	SS	28				
		7	SS	100/ 0.150				
		8	SS	100/ 0.100				

Elevation scale: 213, 212, 211, 210, 209, 208, 207, 206, 205, 204 (water level ▼ at approx. 213)

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 / 15 ◈ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No STE-03

METRIC

GWP# 647-89-00
LOCATION N 5 424 509.5 E 205 929.3
ORIGINATED BY ES
HWY 11/17
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2013.04.28 - 2013.04.30
CHECKED BY MEF

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
203.0 10.7	**SILT** and **SAND**, trace clay, trace gravel Very Dense Grey Moist (TILL)		9	SS	100/ 0.075				○		

END OF BOREHOLE AT 10.7m.
WATER AT SURFACE UPON COMPLETION.
Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
May 09/13	0.2	213.5
Jun. 23/13	0.8	212.9

ONTMT4S 05117.GPJ 8/29/13

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No STE-04

METRIC

GWP# 647-89-00	LOCATION N 5 424 521.3 E 205 944.6	ORIGINATED BY ES
HWY 11/17	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE 2013.04.24 - 2013.04.24	CHECKED BY MEF

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
214.1						214	
0.0	**TOPSOIL/ALLUVIUM**, silty sand, trace roots and rootlets Dark Brown						
213.3 / 0.8	Clayey **SILT**, sandy, trace organics Firm Brown	1	SS	4		213	0 36 41 23
212.4 / 1.7	**SILT** and **SAND**, trace clay, trace gravel Compact to Very Dense Grey Brown to Grey (TILL)	2	SS	10		212	
		3	SS	38			
		4	SS	105/ 0.200		211	
						210	
		5	SS	120/ 0.175		209	0 40 55 5
		6	SS	100/ 0.050		208	
						207	
		7	SS	100/ 0.125	▽	206	
		8	SS	111/ 0.200		205	
204.6 / 9.5	END OF BOREHOLE AT 9.5m. WATER LEVEL AT 7.9m UPON COMPLETION.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No STE-04

METRIC

GWP# 647-89-00 | LOCATION N 5 424 521.3 E 205 944.6 | ORIGINATED BY ES
HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN
DATUM Geodetic | DATE 2013.04.24 - 2013.04.24 | CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.										

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 ◐ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No STW-03

METRIC

GWP# 647-89-00	LOCATION N 5 424 495.0 E 205 881.2	ORIGINATED BY ES
HWY 11/17	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE 2013.05.02 - 2013.05.02	CHECKED BY MEF

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
218.8	
0.0	**TOPSOIL/ALLUVIUM**, some roots and rootlets, occasional wood fibres Dark Brown Wet
218.0 / 0.8	Silty **CLAY**, trace sand, trace rootlets Stiff to Firm Brown (CI to CH) Varved, occasional silt seams Becoming Soft to Firm Occasional sand pockets Grey
209.1 / 9.6	**SILT** and **SAND**, trace gravel Compact

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	7				
2	SS	5	0	0	49	51
3	SS	3				
4	SS	0	0	0	39	61
5	SS	0				
6	SS	0				
7	SS	0	0	0	30	70
8	SS	1				

GROUND WATER CONDITIONS: water level symbol at approx. elevation 212.7

ELEVATION SCALE: 218, 217, 216, 215, 214, 213, 212, 211, 210, 209

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE — 20 40 60 80 100

Field vane results (sensitivity): 2 (at 215.0), 4 (at 213.2), 3 (at 211.7), 6 (at 210.1)

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+ 3, × 3 : Numbers refer to Sensitivity

20 / 15 ◐ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No STW-03

METRIC

GWP# 647-89-00 | LOCATION N 5 424 495.0 E 205 881.2 | ORIGINATED BY ES

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.05.02 - 2013.05.02 | CHECKED BY MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILT and **SAND**, trace gravel Compact Grey Moist				208					
		9	SS	10		~16				
207.1 / 11.7	Sandy **SILT**, trace clay, trace gravel Compact to Very Dense Grey Moist (TILL)				207					
		10	SS	27	206	~17	0	27	68	5
	Occasional cobbles	11	SS	100/ 0.175	205	~16				
		12	SS	100/ 0.125	204, 203	~15				
201.9 / 16.9	END OF BOREHOLE AT 16.9m. WATER LEVEL AT 6.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.	13	SS	100/ 0.150	202					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m3; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

+ 3, × 3: Numbers refer to Sensitivity   20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No STW-05

METRIC

GWP#	647-89-00	LOCATION	N 5 424 516.7 E 205 909.1	ORIGINATED BY	ES
HWY	11/17	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.04.25 - 2013.04.27	CHECKED BY	MEF

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
214.0						
0.0	**TOPSOIL:** (175mm)					
0.2	Clayey **SILT**, sandy, trace rootlets, occasional wood fibres Soft to Firm Brown	1	SS	3		0 24 52 24
		2	SS	5		
212.1 1.9	**SILT** and **SAND**, trace clay, trace gravel Loose Grey Wet	3	SS	4		
		4	SS	8		
210.0 4.0	Sandy **SILT** to **SILT** and **SAND**, trace clay, trace gravel, occasional coarse sand seams, occasional cobbles/boulders Very Dense to Dense Grey Moist (TILL) Sand layer at 4.6m	5	SS	100/ 0.125		
		6	SS	51		4 33 54 9
	Occasional sand pockets	7	SS	37		
		8	SS	100/ 0.175		
204.4 9.6	**SAND**, coarse grained, some silt, trace gravel					

Elevation scale: 214, 213, 212, 211, 210, 209, 208, 207, 206, 205

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100
Shear Strength kPa: ○ Unconfined + Field Vane ● Quick Triaxial × Lab Vane; 20 40 60 80 100
Plastic Limit w_P, Natural Moisture Content w, Liquid Limit w_L; Water Content (%) 20 40 60
Unit Weight γ kN/m3

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 05117.GPJ 8/29/13

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No STW-05

METRIC

GWP# 647-89-00 | LOCATION N 5 424 516.7 E 205 909.1 | ORIGINATED BY ES

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.04.25 - 2013.04.27 | CHECKED BY MEF

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	SAND, coarse grained, some silt, trace gravel Very Dense Dark Grey Wet (TILL)						204				
			9	SS	100/ 0.125				○		6 82 12 (SI+CL)
							203				
							202				
201.7 12.3			10	SS	100/ 0.100				○		
	END OF BOREHOLE AT 12.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.										

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
May 09/13	0.6	213.4
Jun. 23/13	0.7	213.3

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100. PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60.

+3, ×3: Numbers refer to Sensitivity   20 / 15 5 / 10 (%) STRAIN AT FAILURE

TBT Engineering Consulting Group

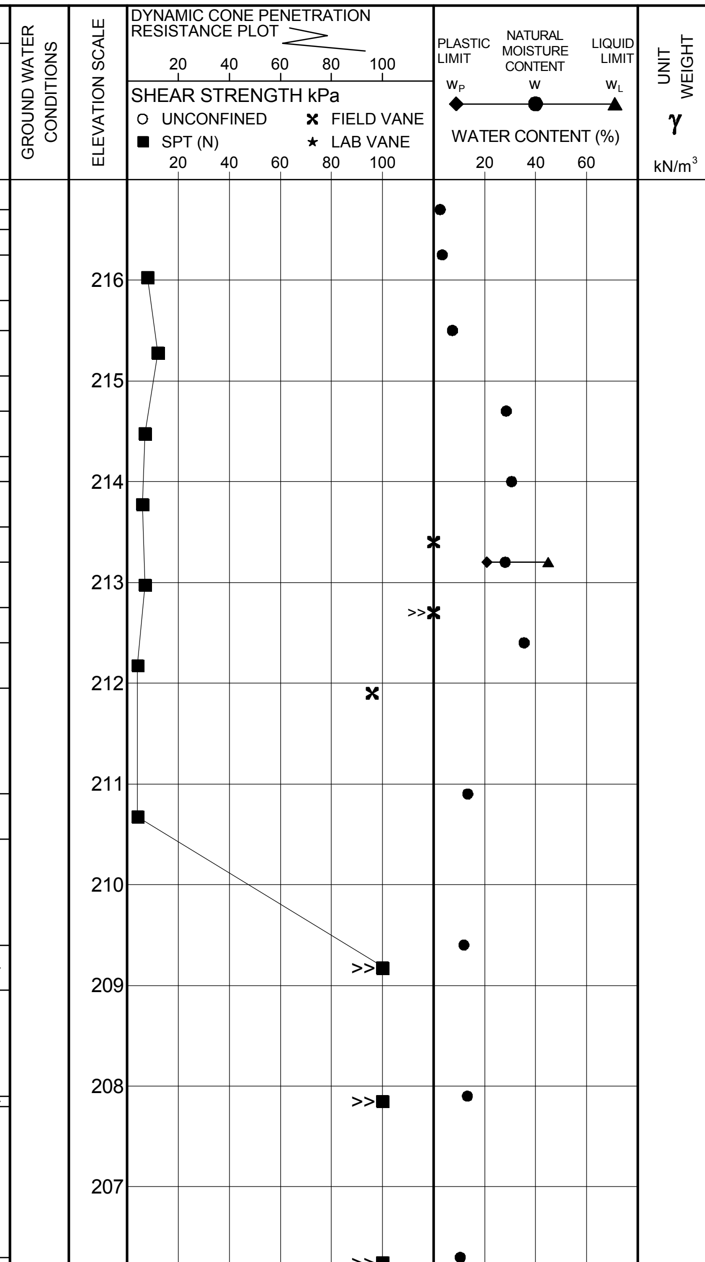
RECORD OF Borehole No STC08-1

METRIC

W.P.	496 00 00	PROJECT	South Trout Creek	SITE NO.	48-C-010
DIST	61 HWY 11/17	LOCATION	Sta. 13+569 o/s 6.0 Lt	TBTE JOB#	08-085
DATE	2008 July 15	BOREHOLE TYPE	Hollow Stem Auger	DATUM	Geodetic

ORIGINATED BY HF | COMPILED BY TB | CHECKED BY WH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
217.0					
216.9 / 0.1	ASPHALT - 120 mm				Water level @ 5.6 m on completion.
	FILL - SAND & GRAVEL - trace silt, brown, loose to compact	1	AS		39 55 (7)
		2	SS	8	
	- - - - - - some clay lumps, brown	3	SS	12	
214.8 / 2.2	CLAY - Silty, brown, stiff to very stiff	4	SS	7	
	- - - - - - trace organics, grey	5	SS	6	
		6	SS	7	
		7	SS	4	
211.1 / 5.9	GLACIAL TILL - SILT & SAND - trace gravel, occasional cobbles & boulders, grey, loose to very dense	8	SS	4	
		9	SS	100+	10 48 (42) 50 Blows for 0.1 m.
		10	SS	100+	Auger Refusal @ 8.3 m advanced with casing to 10.8 m. 50 Blows for 0.07 m.
206.2		11	SS	100+	50 Blows for 0.1 m.
10.8	End of Borehole @ 10.8 m.				



$\times^3$, $\star^3$: Numbers refer to Sensitivity
NP Non Plastic
$O^{3\%}$ STRAIN AT FAILURE

Appendix B

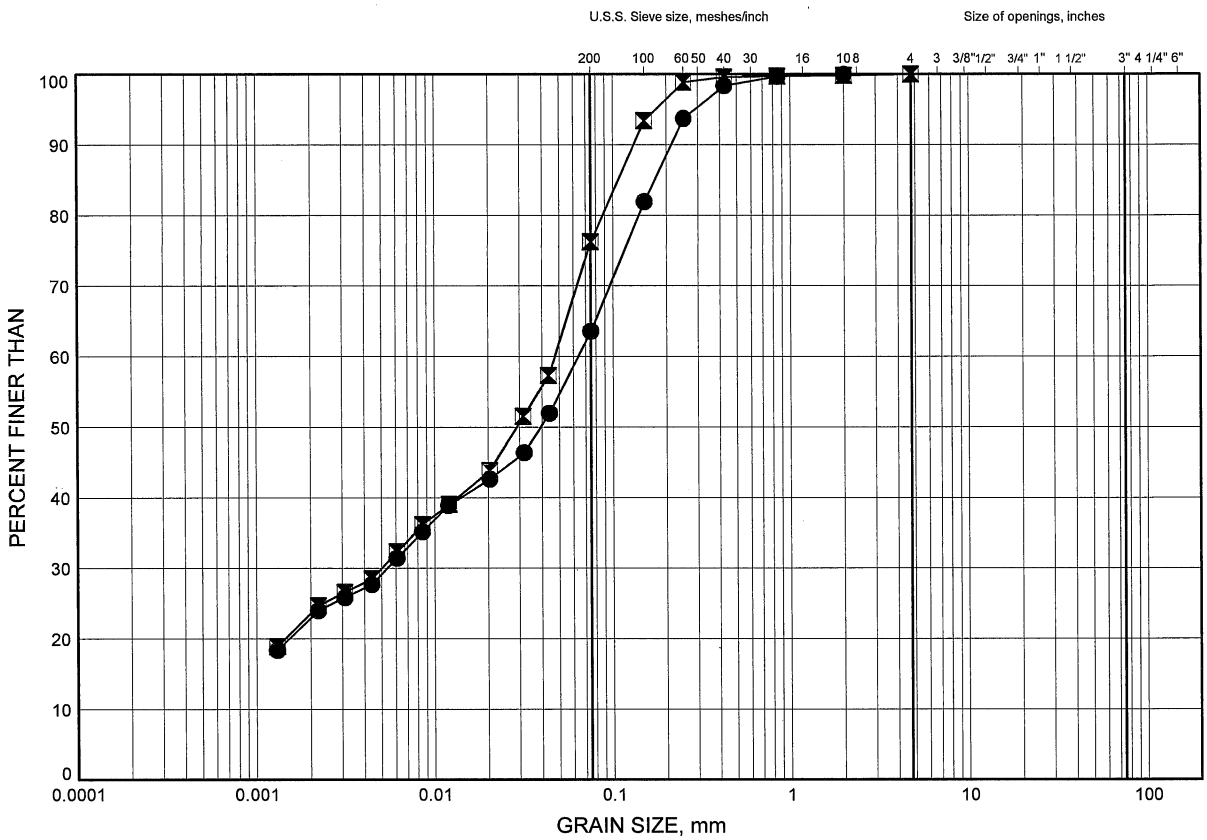
Laboratory Test Results

South Trout Creek - EBL

GRAIN SIZE DISTRIBUTION

FIGURE B1

SANDY, CLAYEY SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STE-04	1.07	213.00
⧗	STW-05	1.07	212.92

GRAIN SIZE DISTRIBUTION - THURBER 05117.GPJ 6/5/13

Date June 2013

GWP# 647-89-00

THURBER

Prep'd AN

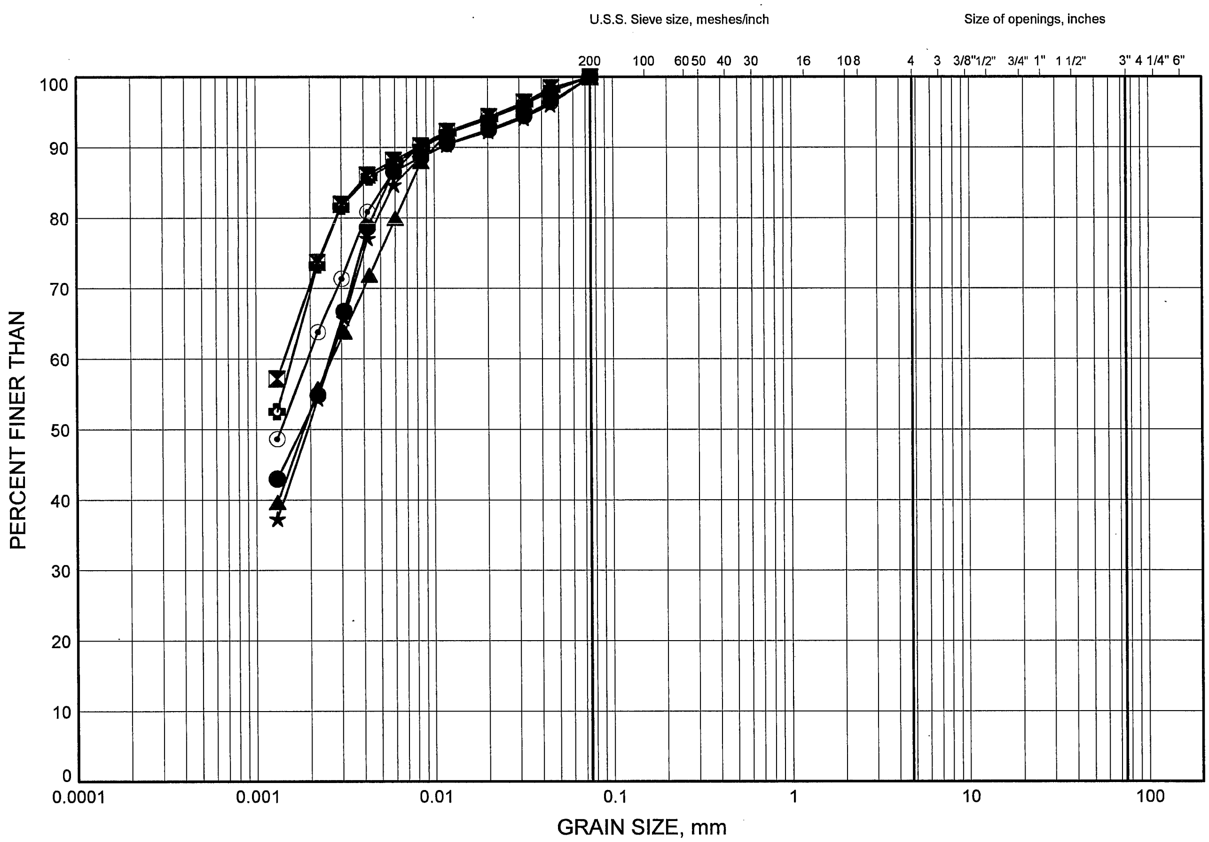
Chkd. KS

South Trout Creek - EBL

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STE-01	1.83	216.67
⧗	STE-01	6.40	212.10
▲	STE-02	3.35	211.45
★	STW-03	1.83	216.94
⊙	STW-03	3.35	215.42
✿	STW-03	7.92	210.84

Date June 2013

GWP# 647-89-00

THURBER

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Chkd. KS

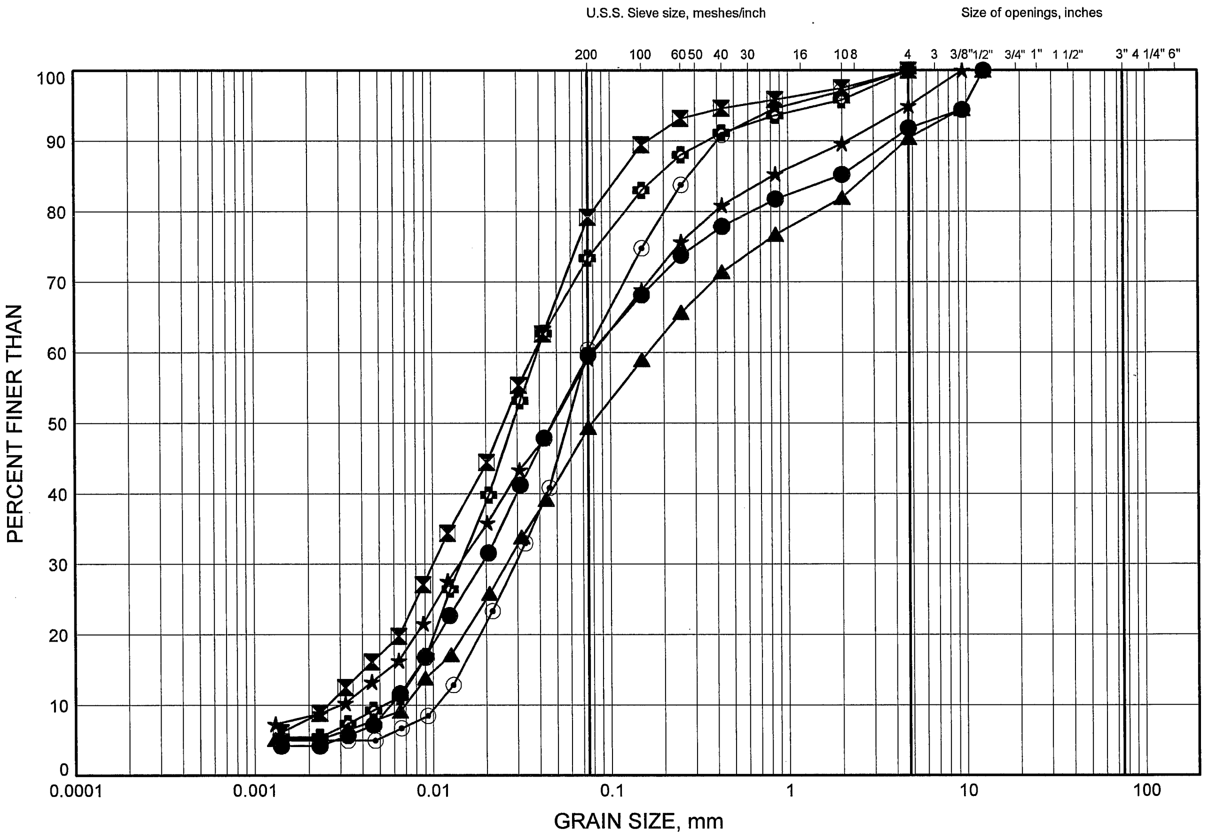
GRAIN SIZE DISTRIBUTION - THURBER 05117.GPJ 6/5/13

South Trout Creek - EBL

GRAIN SIZE DISTRIBUTION

FIGURE B3

SANDY SILT TO SILT & SAND TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STE-02	6.27	208.53
⧗	STE-02	10.78	204.02
▲	STE-03	2.59	211.11
★	STE-03	4.67	209.02
⊙	STE-04	4.74	209.33
✿	STW-03	12.50	206.27

Date June 2013

GWP# 647-89-00

THURBER

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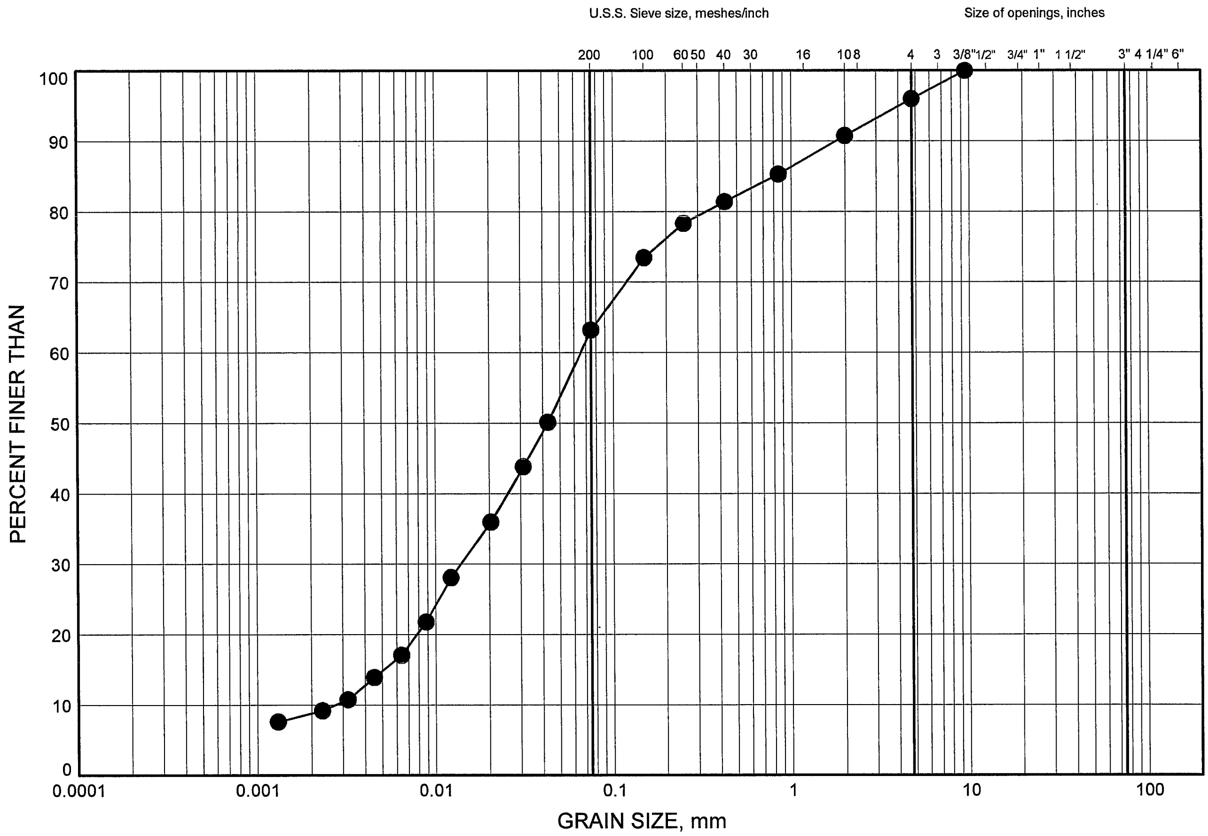
GRAIN SIZE DISTRIBUTION - THURBER 05117.GPJ 6/5/13

South Trout Creek - EBL

GRAIN SIZE DISTRIBUTION

FIGURE B4

SANDY SILT TO SILT & SAND TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-05	6.40	207.59

Date June 2013

GWP# 647-89-00

THURBER

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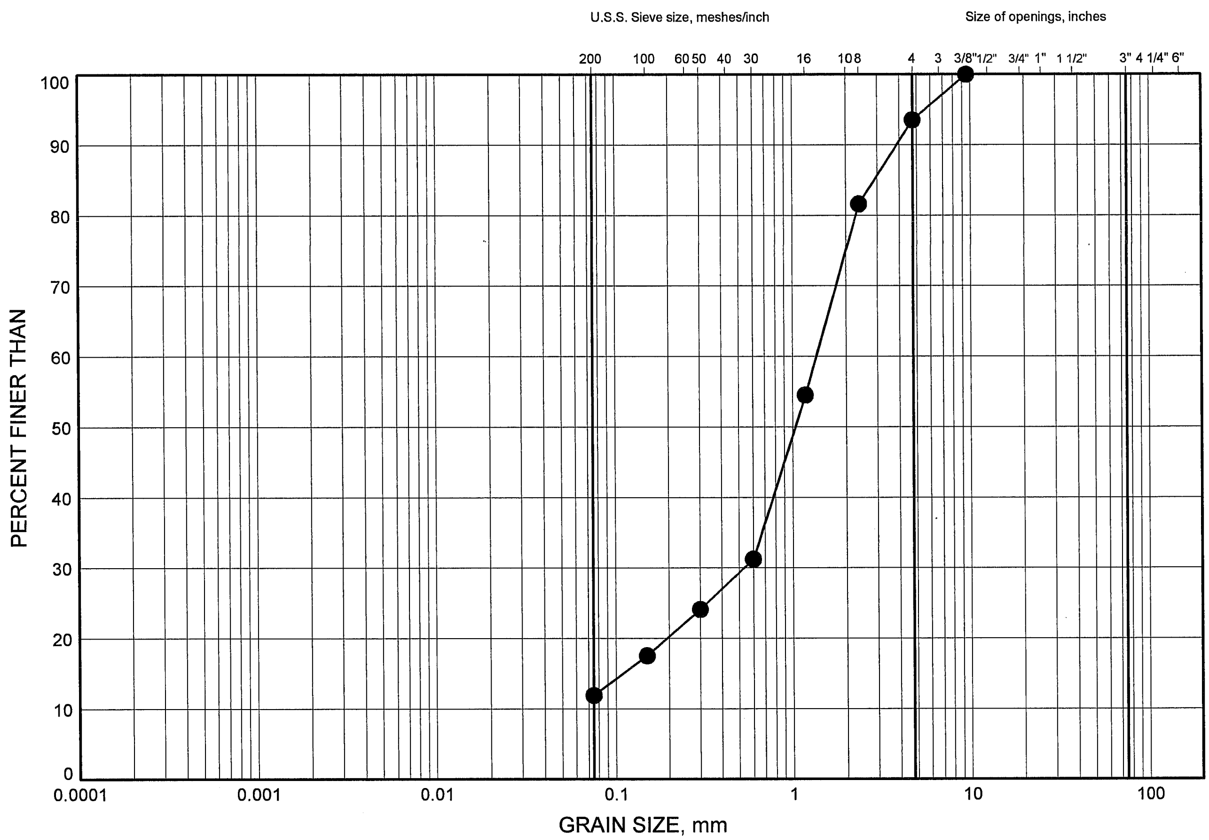
GRAIN SIZE DISTRIBUTION - THURBER 05117.GPJ 6/5/13

South Trout Creek - EBL

GRAIN SIZE DISTRIBUTION

FIGURE B5

SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-05	10.73	203.25

Date June 2013

GWP# 647-89-00

THURBER

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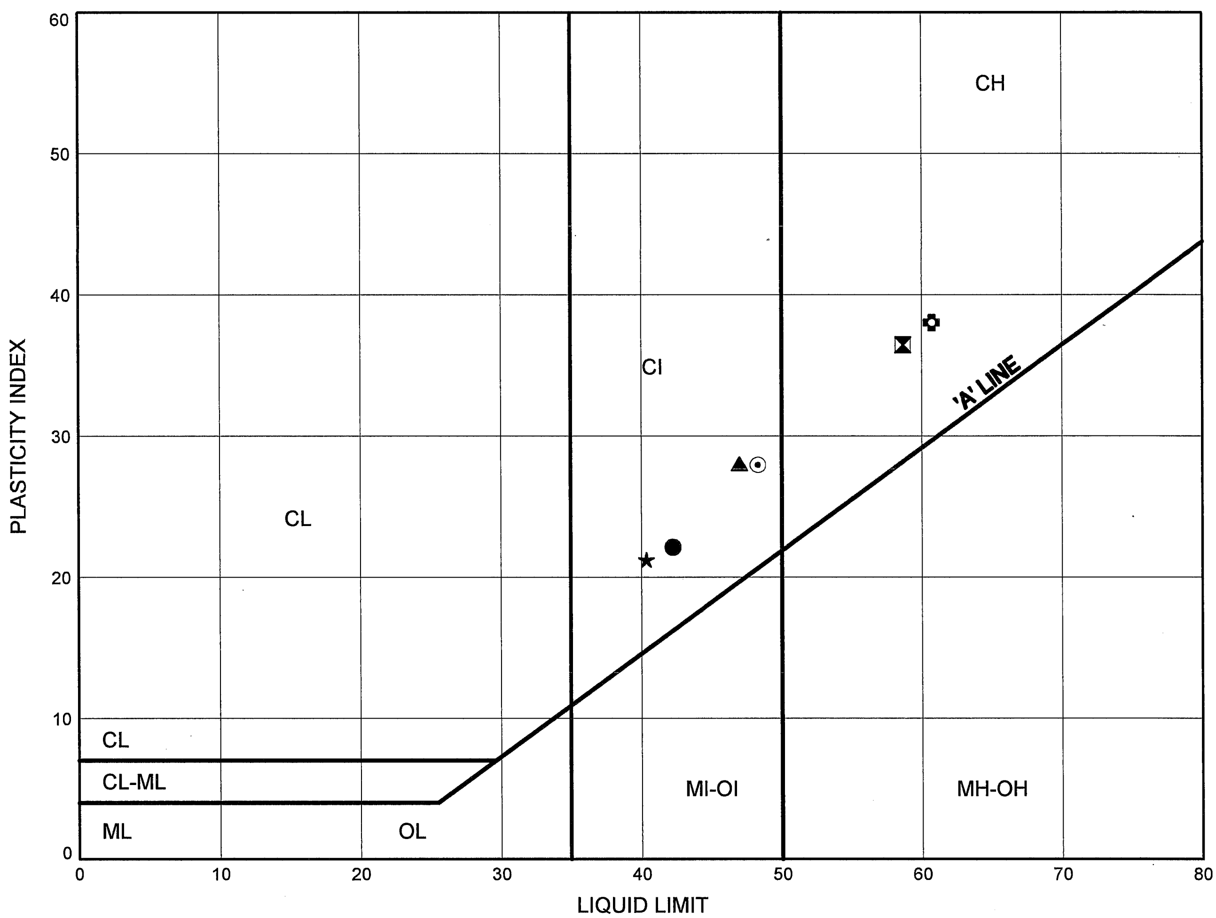
South Trout Creek - EBL

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STE-01	1.83	216.67
⧗	STE-01	6.40	212.10
▲	STE-02	3.35	211.45
★	STW-03	1.83	216.94
⊙	STW-03	3.35	215.42
✿	STW-03	7.92	210.84

THURBALT 05117.GPJ 6/5/13

Date June 2013

GWP# 647-89-00

THURBER

Prep'd AN

Chkd. KS

Appendix C

Site Photographs

Photograph 1 – Existing South Trout Creek bridge, looking west from east bank.

Photograph 2 – Existing conditions at South Trout Creek, looking east from west approach.

Photograph 3 – Existing conditions on east side of South Trout Creek

Photograph 4 – Existing conditions on west side of South Trout Creek

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Augered Caissons	Pipe Piles	Steel H-Piles
Advantages: i. Generally less costly construction than deep foundation elements.	***Advantages:*** i. High geotechnical resistance available for caissons. ii. Construction of caissons could continue in freezing weather. iii. Excavation and dewatering requirements are reduced.	***Advantages:*** i. High geotechnical resistance. ii. Liner is not required to support excavation sidewalls. iii. Excavation and dewatering requirements are minimized.	***Advantages:*** i. High geotechnical resistance. ii. Installation of piles could continue in freezing weather. iii. Excavation and dewatering requirements are minimized. iv. Suitable for integral abutment foundations.
Disadvantages: i. Low geotechnical resistance available on native soils at west abutment. ii. Potential consolidation settlement due to soft clay at west abutment. iii. Excavation depths to construct footings on very dense till are excessive on both banks. iv. Temporary dewatering is required to construct footings in the dry. v. Temporary excavation for footing construction may have environmental impact on the creek.	***Disadvantages:*** i. Higher unit costs than footings and other deep foundations. ii. Measures will be required to prevent squeezing in soft materials and base heave in cohesionless soils below groundwater. iii. Potential difficulty in cleaning and inspection of socket base.	***Disadvantages:*** i. Higher unit cost than footings on bedrock. ii. Potential for pile damage when driving into very dense till with possible cobbles and boulders. iii. Socketing into bedrock is not an option at this site. iv. Tremie concreting will be required for concreting the pipe due to infiltrating ground water.	***Disadvantages:*** i. Higher unit cost than footings on bedrock. ii. H-piles may encounter refusal at varying depths on cobbles and boulders in the till.
NOT RECOMMENDED	**NOT RECOMMENDED**	**NOT RECOMMENDED**	**RECOMMENDED**

Appendix E

List of SPs and OPSS, and Suggested Text for Selected NSSPs

1. List of Special Provisions and OPSS Documents Referenced in this Report:

- OPSS 501
- OPSS 804
- OPSS 902
- OPSS 903
- OPSS 1010
- OPSD 3101.150
- OPSD 3101.200
- SP 105S21
- SP 110S13

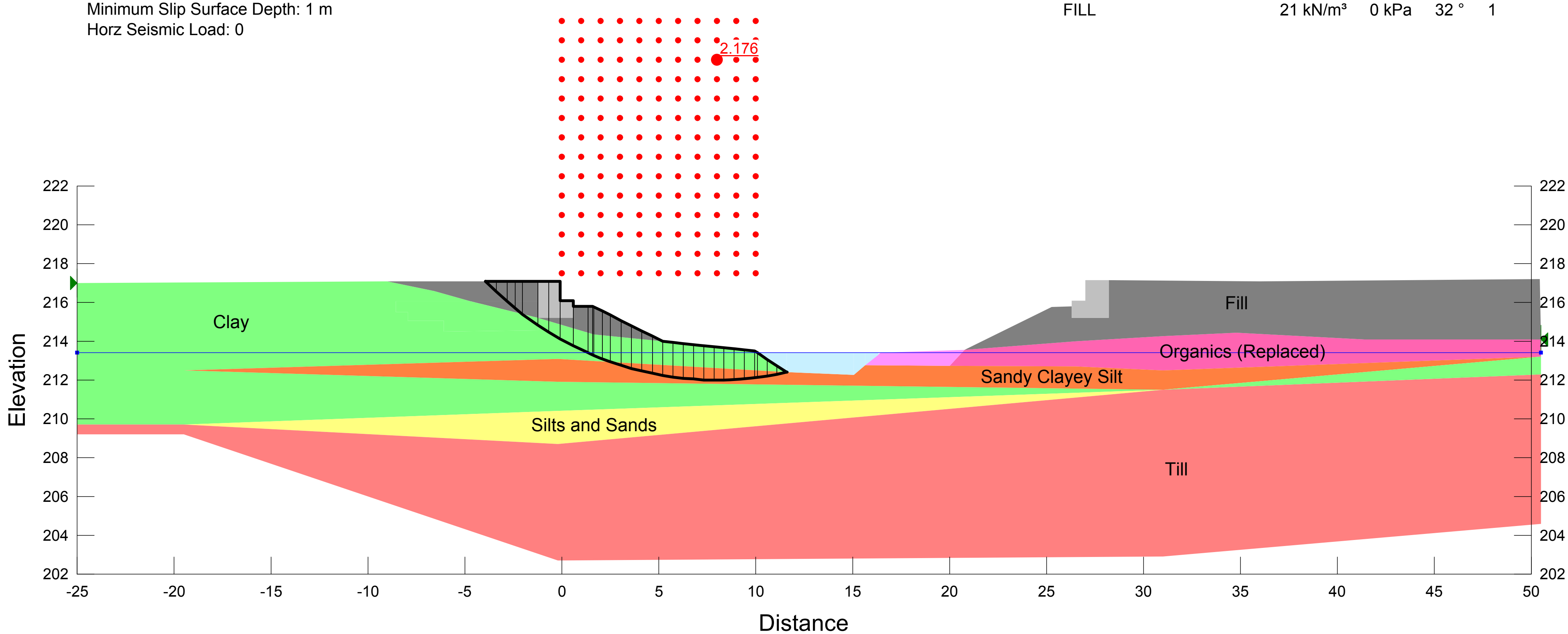
Appendix F

Slope Stability Output

Title: South Trout Creek (EBL)
Name: 2: WA (TSA)
Description: Wall & Light Weight Fill
Comments: Stability Analysis
Last Solved Date: 8/27/2013, 11:32:59 AM

Method: Morgenstern-Price
Interslice force function option: Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

Silty CLAY (TSA)	18 kN/m³	40 kPa	0 °	1
Clayey SILT Sandy (TSA)	18 kN/m³	0 kPa	28 °	1
Organics	14 kN/m³	0 kPa	10 °	1
Organics (REPLACEMENT)	21 kN/m³	0 kPa	32 °	1
Silts and Sands	20 kN/m³	0 kPa	29 °	1
TILL	20 kN/m³	0 kPa	32 °	1
WALL	24 kN/m³	200 kPa	34 °	1
FILL	21 kN/m³	0 kPa	32 °	1



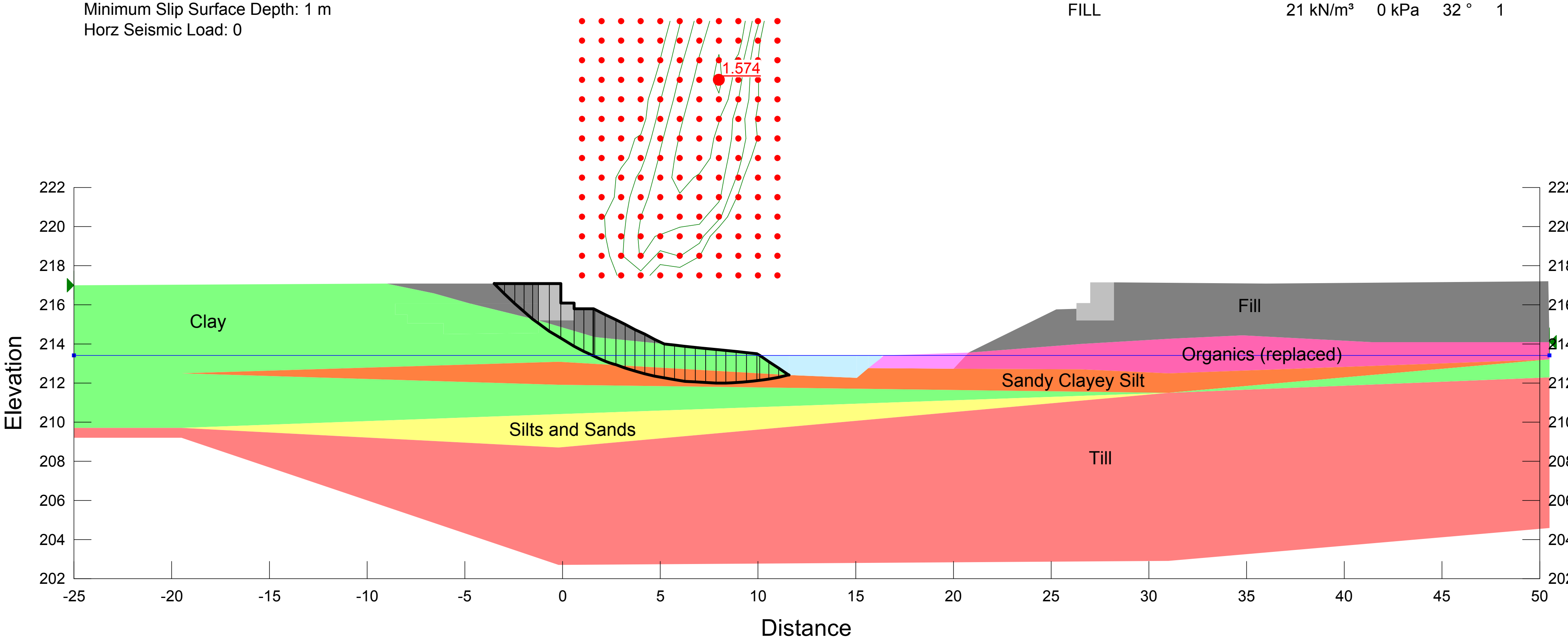
Directory: H:\19\1605\117 Hwy 11-17 Nipigon\Reports & Memos\South Trout EBL\Analysis\Stability [May29-13]\STC_003.gsz

FIGURE 1

Title: South Trout Creek (EBL)
Name: 2: WA (ESA)
Description: Wall & Light Weight Fill
Comments: Stability Analysis
Last Solved Date: 8/27/2013, 11:32:44 AM

Method: Morgenstern-Price
Interslice force function option: Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

Silty CLAY (ESA)	18 kN/m³	7 kPa	23 °	1
Clayey SILT Sandy (ESA)	18 kN/m³	0 kPa	28 °	1
Organics	14 kN/m³	0 kPa	10 °	1
Organics (REPLACEMENT)	21 kN/m³	0 kPa	32 °	1
Silts and Sands	20 kN/m³	0 kPa	29 °	1
TILL	20 kN/m³	0 kPa	32 °	1
WALL	24 kN/m³	200 kPa	34 °	1
FILL	21 kN/m³	0 kPa	32 °	1



Directory: H:\19\1605\117 Hwy 11-17 Nipigon\Reports & Memos\South Trout EBL\Analysis\Stability [May29-13]\STC_003.gsz

FIGURE 2

Title: South Trout Creek (EBL)
Name: 3: EA (ESA)
Description: WALL
Comments: Stability Analysis
Last Solved Date: 6/27/2013, 8:56:39 AM

Method: Morgenstern-Price
Interslice force function option: Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0

Silty CLAY (ESA)	18 kN/m³	7 kPa	23 °	1
Clayey SILT Sandy (ESA)	18 kN/m³	0 kPa	28 °	1
Organics	14 kN/m³	0 kPa	10 °	1
Organics (REPLACEMENT)	21 kN/m³	0 kPa	32 °	1
Silts and Sands	20 kN/m³	0 kPa	29 °	1
TILL	20 kN/m³	0 kPa	32 °	1
WALL	24 kN/m³	200 kPa	34 °	1
LWF	1.5 kN/m³	40 kPa	0 °	1
FILL	21 kN/m³	0 kPa	32 °	1

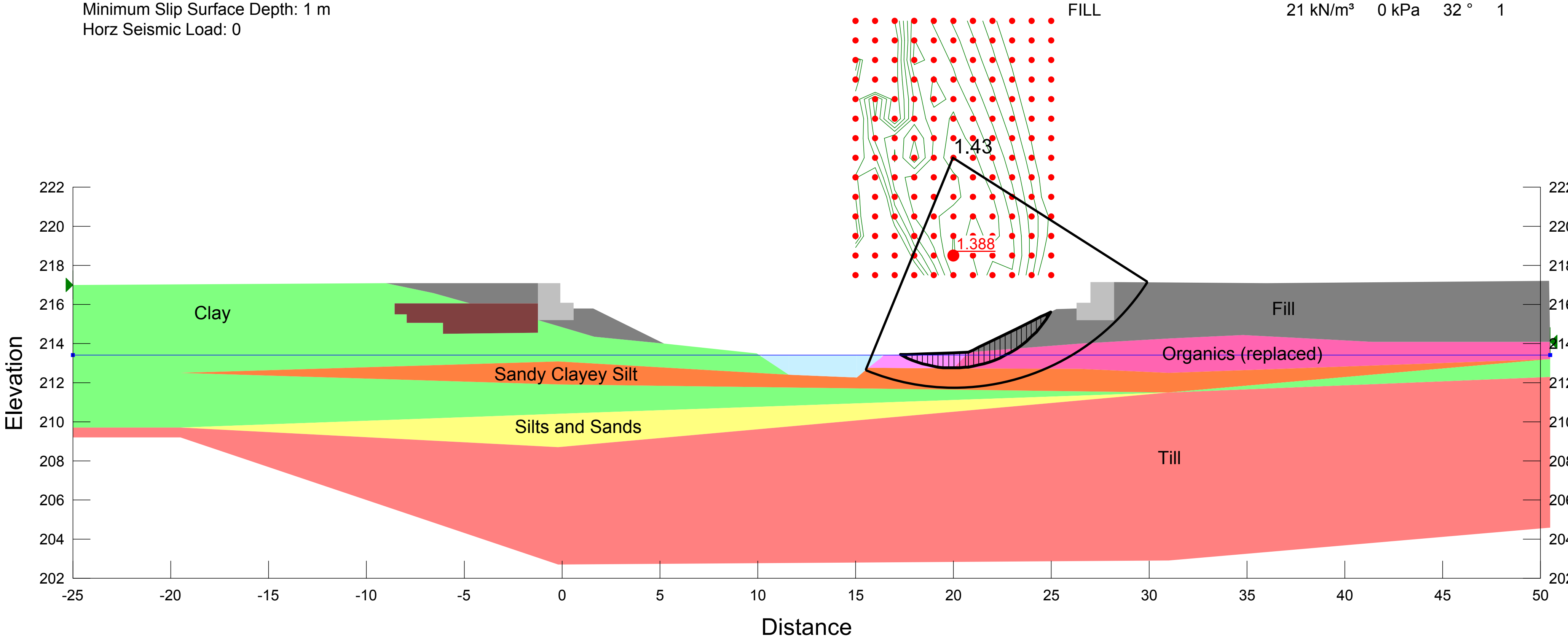


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FIGURE 3

Appendix G

Borehole Locations and Soil Strata Drawing

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2013-6016
WP No 6132-13-00

HIGHWAY 11/17 FOUR LANING
SOUTH TROUT CREEK
EASTBOUND LANE
BOREHOLE LOCATIONS AND SOIL STRATA

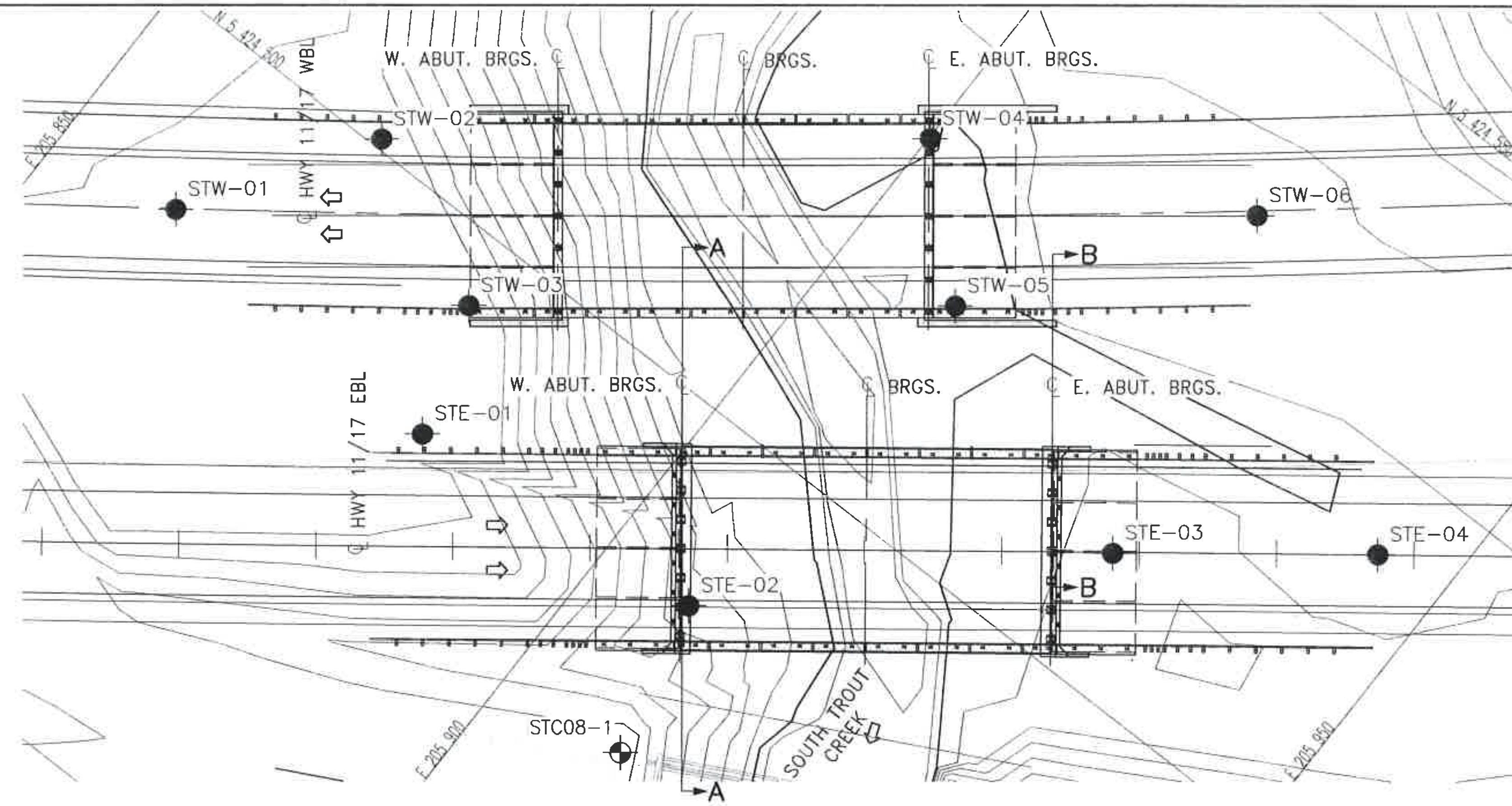
SHEET 26

Hatch Mott MacDonald

THURBER ENGINEERING LTD.

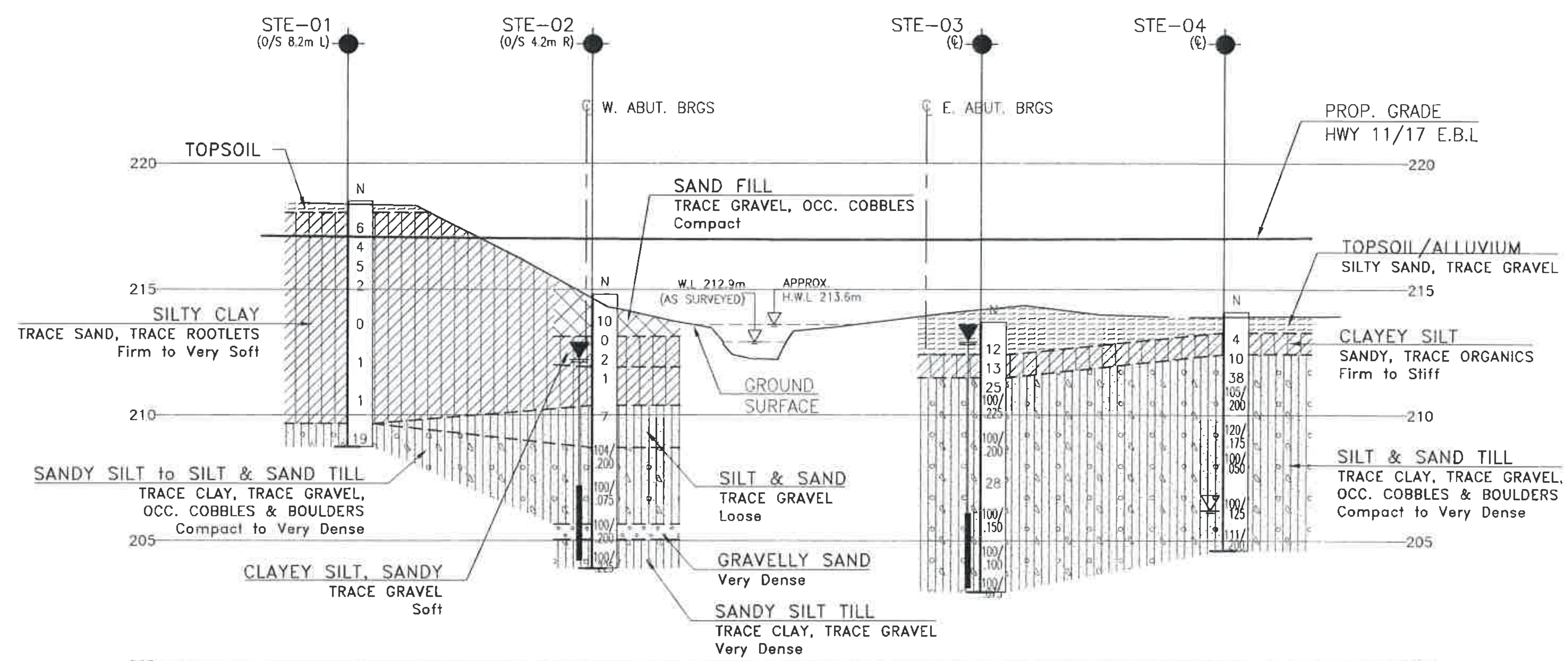
LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Aug 28/13
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Aug 28/13
PROVINCE OF ONTARIO



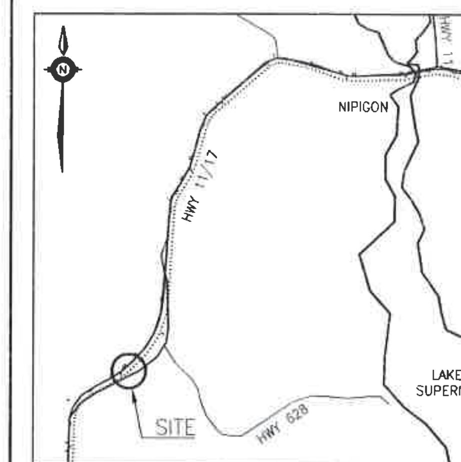
PLAN

SCALE 1:500



PROFILE ALONG ℄ HWY 11/17 EBL

H 1:500
V 1:250



KEYPLAN

LEGEND

Symbol	Description
⌖	Borehole (Current Investigation)
⌖	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level During Drilling
	Water Level In Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
STE-01	218.5	5 424 485.5	205 884.3
STE-02	214.8	5 424 487.5	205 907.3
STE-03	213.7	5 424 509.5	205 929.3
STE-04	214.1	5 424 521.3	205 944.6
STW-01	219.1	5 424 487.4	205 859.9
STW-02	218.9	5 424 500.7	205 868.6
STW-03	218.8	5 424 495.0	205 881.2
STW-04	213.7	5 424 525.3	205 900.1
STW-05	214.0	5 424 516.7	205 909.1
STW-06	214.5	5 424 535.5	205 922.4

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 52A-166

REVISIONS | DATE | BY | DESCRIPTION

DESIGN MEF | CHK MEF | CODE | LOAD | DATE JUN. 2013
DRAWN AN | CHK MRA | SITE 48C-108 | STRUCT | DWG 1

FILENAME: H:\Drafting\19\1605\117\ed5117-SouthTroutCreek(WBL&EBL)-Revise-June2013.dwg
PLOTDATE: 8/29/2013 9:22 AM

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2013-6016
WP No 6132-13-00

HIGHWAY 11/17 FOUR LANING
SOUTH TROUT CREEK
EASTBOUND LANE
BOREHOLE LOCATIONS AND SOIL STRATA

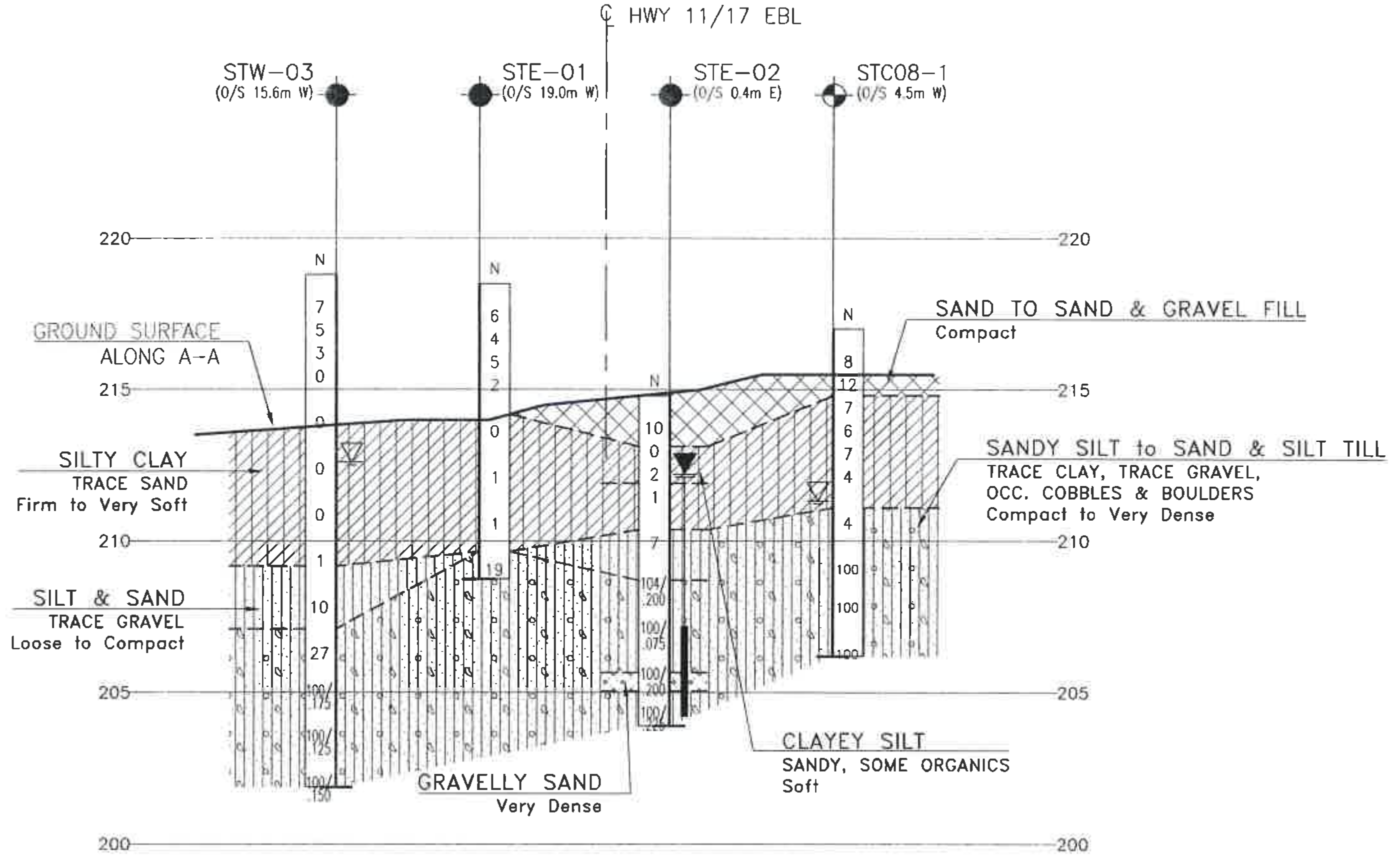
SHEET 27

Hatch Mott MacDonald

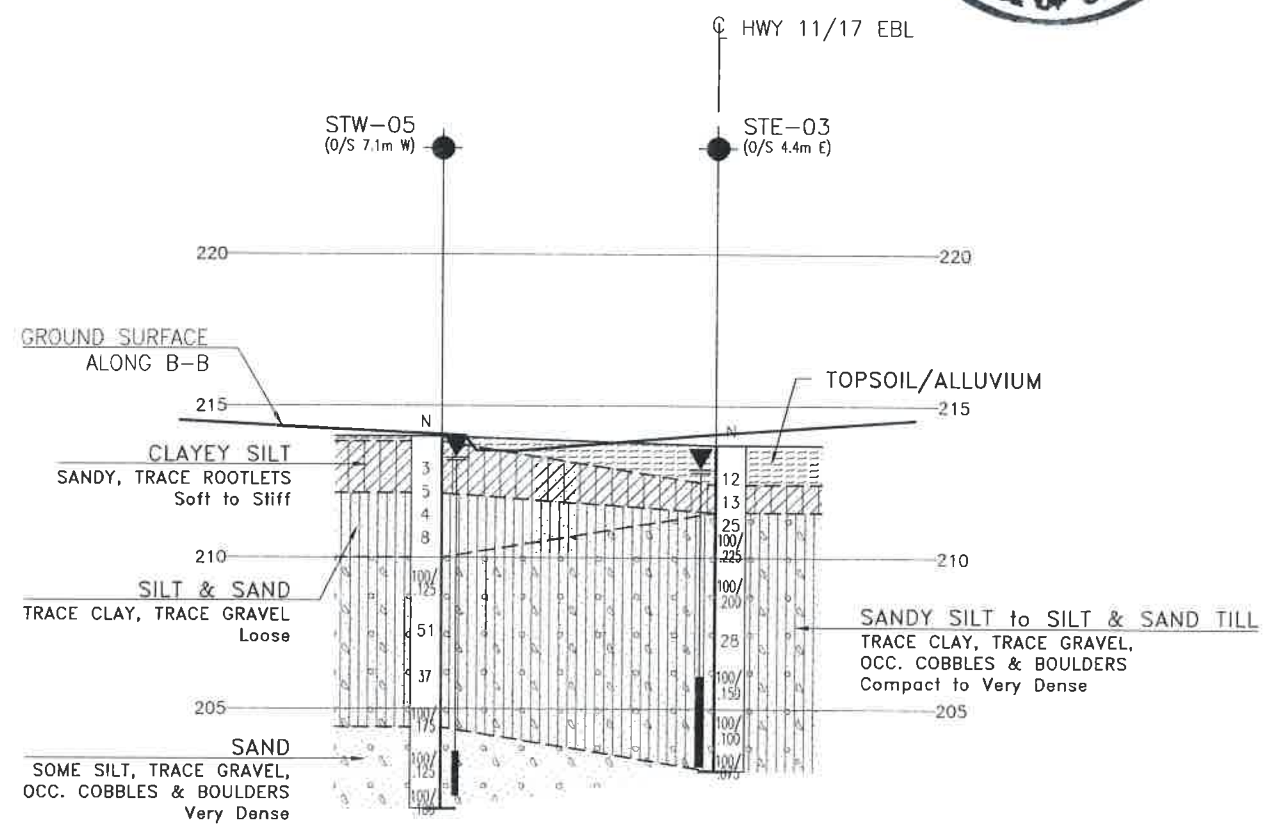
THURBER ENGINEERING LTD

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Aug 28/13
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Aug 28/13
PROVINCE OF ONTARIO



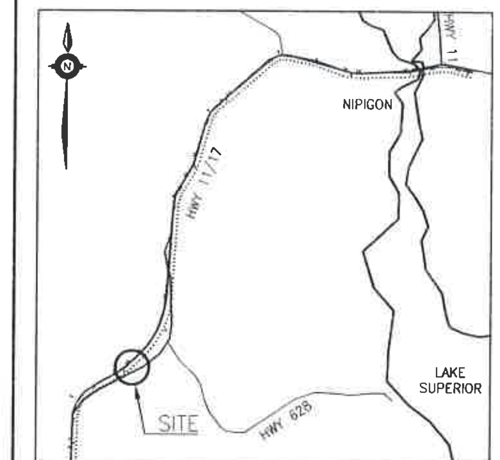
SECTION ALONG A-A



SECTION ALONG B-B

10 0 10 20m H 1:500

5 0 5 10 V 1:250



KEYPLAN

LEGEND

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⯁	Borehole (Previous Investigation)
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STW-01	219.1	5 424 487.4	205 859.9
STW-02	218.9	5 424 500.7	205 868.6
STW-03	218.8	5 424 495.0	205 881.2
STW-04	213.7	5 424 525.3	205 900.1
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GEOCRES No. 52A-166

REVISIONS	DATE	BY	DESCRIPTION

DESIGN MEF	CHK MEF	CODE		LOAD		DATE JUN. 2013	
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