

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
SOUTH TROUT CREEK BRIDGE WBL  
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-10A**

**Geocres Number: 52A-177**

**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 westbound lanes (WBL) 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 40 m southeast of the new WBL Bridge.

## 2 SITE DESCRIPTION

The site is located approximately 12 km 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 westbound lanes of Highway 11/17 will be approximately 40 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 is situated at an approximate elevation of 212 m. The creek channel is approximately 9 m wide. The ground elevation surrounding the site drops from approximately 219.0 at the west approach to approximately 214.0 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 2, 2013 and consisted of drilling and sampling six boreholes (numbered STW-01 to STW-06) in the area of the proposed foundation units and approach embankments.

A summary of the borehole locations, designations, termination depths and termination elevations 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 Location, Termination Depth and Elevation**

Foundation Unit	Borehole Number	Borehole Termination Depth (m)	Borehole Termination Elevation (m)
West Approach	STW-01	12.8	206.3
West Abutment	STW-02, STW-03	16.9 to 22.9	201.9 to 196.0
East Abutment	STW-04, STW-05	12.3 to 13.9	201.7 to 199.8
East Approach	STW-06	9.4	205.1

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. It was necessary to relocate Boreholes STW-02 and STW-03 to the top of the valley slope due to the severity of slope at the west abutment location.

Drilling was carried out using a track-mounted CME55 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 STW-02 and STW-05 to permit longer term groundwater level monitoring. The piezometers were subsequently decommissioned in general accordance with MOE Regulation 903 following additional water level monitoring. The installation and completion details of the piezometers and boreholes are shown in Table 3.2.

**Table 3.2 – Borehole Completion Details**

<b>Borehole</b>	<b>Piezometer Tip Depth/ Elevation (m)</b>	<b>Completion Details</b>
STW-01	None installed	Borehole backfilled with bentonite to surface.
STW-02	22.9/196.0	Sand from 22.9 m to 18.9 m, bentonite from 18.9 m to surface.
STW-03	None installed	Borehole backfilled with bentonite to surface.
STW-04	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.
STW-06	None installed	Borehole backfilled with 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” drawings 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 proposed west abutment and east abutment. At the west abutment, the stratigraphy typically consists of a topsoil layer over a thick deposit of typically firm to very soft silty clay, underlain by a loose to compact silt and sand layer, overlying typically very dense sandy silt to silt and sand till. At the east abutment, a topsoil/alluvium layer is underlain by layers of soft to firm sandy clayey silt and loose silt and sand, underlain by very dense sandy silt to silt and sand till. Very dense sand was encountered below the till in two boreholes. The boreholes for this investigation did not reach bedrock.

More detailed descriptions of the individual strata are presented below.

### 5.1 Topsoil / Alluvium

Topsoil and/or alluvial deposits were identified at the ground surface in all boreholes. The surficial layer ranged in thickness from 175 mm to 1.1 m and contained roots and rootlets, as well as wood fibres. The layer thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities.

### 5.2 Sandy Clayey Silt

A layer of sandy clayey silt was encountered underlying the topsoil/alluvium in Boreholes STW-04 and STW-05 at the east abutment. The sandy clayey silt contained organic material including rootlets and wood fibres. The thickness of this layer was 1.1 and 1.7 m. The depth to the base of the layer was 1.9 m (Elev. 211.7 to 212.1 m) in both boreholes.

SPT N-values in the sandy clayey silt ranged from 2 to 8 blows per 0.3 m penetration, indicating a soft to firm consistency. The moisture content of the clayey silt samples ranged from 21% to 33%.

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 %	20 to 24
Silt %	52 to 60
Clay %	20 to 24

### 5.3 Silty Clay

A thick deposit of native brown to grey silty clay with occasional silt seams and sand pockets was encountered below the topsoil in Boreholes STW-01, STW-02, and STW-03 drilled at the west approach and west abutment.

The silty clay deposit ranged in thickness from 8.8 to 10.4 m. The lower boundary of the silty clay layer was contacted at depths of 9.6 to 10.9 m (Elev. 208.1 to 209.1 m).

Standard Penetration Tests obtained in the silty clay deposit typically ranged from 0 to 2 blows per 0.3 m of penetration, indicating a very soft consistency. However, N-values ranging from 3 to 16 blows per 0.3 m of penetration were recorded within the upper 1.5 to 2.5 m of this layer, indicating the presence of a very stiff to firm crust.

In-situ vane shear tests carried out in the clay below the crust measured undrained shear strengths of 27 to 70 kPa, indicating a firm to stiff consistency. It is possible however that the measured strengths are affected by silt seams in the clay. The calculated sensitivity, a ratio of undisturbed strength to remoulded strength, ranged from 2 to 7, indicative of low to medium sensitivity.

The natural moisture content of the silty clay samples varied from 30 to 61%.

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, Figures B2 and B3. The results of the Atterberg Limits tests are presented in Appendix B, Figures B8 and B9. The results are summarized on the Record of Borehole sheets included in Appendix A, and in the following tables:

Gravel %	0
Sand %	0
Silt %	30 to 49
Clay %	51 to 70

Liquid Limit	40 to 61
Plastic Limit	19 to 22

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

### 5.4 Silt and Sand

A layer of grey silt and sand was encountered below the silty clay at depths of 10.7 and 9.6 m (Elev. 208.1 and 209.1) in Boreholes STW-02 and STW-03 drilled on the west side of the creek, and below the topsoil/alluvium and sandy clayey silt at depths of 1.1 to 1.9 m (Elev.



211.7 to 213.3) in Boreholes STW-04 to STW-06 located on the east side. The thickness of this layer ranged from 1.1 to 2.1 m. The lower boundary was encountered at depths of 12.2 and 11.7 m (Elev. 206.7 and 207.1) on the west side of the creek, and at depths of 2.3 to 4.0 m (Elev. 210.0 to 212.2) on the east side.

SPT N-values recorded in the deposit ranged from 2 to 10 blows per 0.3 m of penetration, indicating a typically loose condition. The moisture content of the silt and sand samples ranged from 12 to 18%.

The grain size distribution curve for a sample of the silt and sand is presented on Figure B4 of Appendix B. The results are summarized on the Record of Borehole sheet and are as follows:

Gravel %	1
Sand %	38
Silt %	59
Clay %	2

## 5.5 Sandy Silt to Silt and Sand Till

Grey glacial till ranging in composition from silt and sand to sandy silt was encountered in all boreholes at depths ranging from 10.9 to 12.2 m (Elev. 208.3 to 206.7) on the west side of the creek and from 2.3 to 4.0 m (Elev. 212.2 to 210.0) on the east side. The till contained trace to some gravel, trace clay, and occasional cobbles.

Boreholes STW-01, STW-03, STW-04 and STW-06 were terminated within the till deposit at depths ranging from 9.4 to 16.9 m (Elev. 199.8 to 206.3). In Boreholes STW-02 and STW-05, the layer was 2.7 and 5.6 m thick with a lower boundary at depths of 14.9 and 9.6 m (Elev. 203.9 and 204.4).

SPT N-values recorded in the till deposit typically ranged from 30 blows per 0.3 m of penetration to 100 blows for no penetration, indicating a dense to very dense relative density. N-values of 9 to 29 blows per 0.3 m of penetration were obtained near the upper boundary of this unit in Boreholes STW-01 to STW-03, indicating a locally loose to compact condition.

The moisture content of the till samples ranged from 5 to 22%.

Selected samples of the till underwent laboratory grain size analysis. The grain size distribution curves for tested samples are presented in Appendix B, Figures B5 and B6. The results are summarized on the Record of Borehole sheets included in Appendix A, and in the following table:

Gravel %	0 to 16
Sand %	20 to 42
Silt %	44 to 69
Clay %	3 to 10

Glacial till inherently contains cobbles and boulders and these should be anticipated during construction.

## 5.6 Sand

A sand deposit was encountered below the till in Boreholes STW-02 and STW-05. The sand was grey to dark grey in colour, and contained trace to some silt, trace gravel, and occasional cobbles and boulders. The upper boundary of the sand was encountered at depths of 14.9 and 9.6 m (Elev. 203.9 and 204.4 m). The boreholes were terminated within the sand at depths of 22.9 and 12.3 m (Elev. 196.0 and 201.7).

SPT N-values ranging from 85 blows per 0.3 m to 100 blows with no penetration were recorded in the sand, indicating a very dense relative density. The moisture content of samples ranged from 11 to 17%.

The results of grain size distribution analyses conducted on two samples of the sand are presented on the Record of Borehole sheets and on Figure B7 of Appendix B. The results are summarized as follows:

Gravel %	6 to 8
Sand %	78 to 82
Silt & Clay%	12 to 14

## 5.7 Water Levels

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

**Table 5.1 – Water Level Measurements**

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
STW-02	May 9, 2013	4.2	214.7	In piezometer
	June 23, 2013	5.8	213.1	
STW-03	May 2, 2013	6.2	212.6	Upon completion
STW-04	April 25, 2013	0.7	213.0	Upon completion
STW-05	May 9, 2013	0.6	213.4	In piezometer
	June 23, 2013	0.7	213.3	
STW-06	April 24, 2013	0.9	213.6	Upon completion

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 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.

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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 westbound lanes (WBL) over South Trout Creek in the Township of Red Rock, Ontario.

The new WBL structure will be located approximately 40 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 14.4 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 217.9 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 between the proposed west abutment and east abutment. At the west abutment, the stratigraphy typically consists of a topsoil layer over a thick deposit of typically firm to very soft silty clay, underlain by a loose to compact silt and sand layer, overlying typically very dense sandy silt to silt and sand till. At the east abutment, a topsoil/alluvium layer is underlain by layers of soft to firm sandy clayey silt and loose silt and sand, underlain by very dense sandy silt to silt and sand till. Very dense sand was encountered below the till in two boreholes. The boreholes for this investigation did not reach bedrock.

Groundwater levels measured in the piezometers typically ranged from 0.7 to 5.8 m below the ground surface, at Elevation 213.1 to 213.4 m. The creek water level was reported to be at Elev. 212.9 m, and the high water level is indicated to be at Elev. 213.6 m.

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 14 m (Borehole STW-03) is not practical in the presence of a high ground water table. Further, excavation may impact 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 3.0 to 4.0 m to penetrate the topsoil/alluvium, sandy clayey silt layer and loose silt and sand to be founded 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 consequent impact on the creek, 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 216 as per the preliminary GA), and recommended axial geotechnical resistances of HP310x110 piles 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 below assumed cut-off Elev. 216 (m)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Resistance at SLS (kN)
West	202 m	14	1400	1200
East	203 m	13	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 a minimum of 48 hours;

- 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 typically requires that the piles possess horizontal flexibility in the upper 3 m of the pile length. At this site, the near surface materials consist of very stiff to very soft silty clay at the west abutment, and topsoil/alluvium (to be removed and replaced by granular fill), soft to firm clayey silt and loose silt and sand at the east abutment. The lateral resistance of a pile in the near-surface soils 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:

$$k_s = n_h z / D \quad (\text{kN/m}^3)$$

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

where

$z$  = depth of embedment of pile in metres

$D$  = pile width in metres

$n_h$  = value in Table 8.3

$$\begin{aligned}\gamma &= \text{unit weight of soils (Table 8.3)} \\ K_p &= \text{passive earth pressure coefficient (Table 8.3)}\end{aligned}$$

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

$$\begin{aligned}k_s &= 67 S_u / D \quad (\text{kN/m}^3) \\ p_{ult} &= 9 S_u \text{ (kPa) at and below a depth of } 3D \text{ and} \\ &\quad \text{decrease to zero at the ground surface} \\ \text{where } D &= \text{pile width in metres} \\ S_u &= \text{undrained shear strength (kPa)}\end{aligned}$$

**Table 8.3 – Parameters for Lateral Resistance**

Abutment	Top Elev.	Bottom Elev.	$n_h$ ( $\text{kN/m}^3$ )	$K_p$	$S_u$ (kPa)	Unit Weight ( $\text{kN/m}^3$ )	Soil Conditions
West	216.0	213.0	-	-	40	18	Silty clay
	213.0	209.0	-	-	40	8*	Silty clay
	209.0	207.0	2,500	3.0	-	10*	Silt and Sand
	207.0	202.0	6,500	3.3	-	12*	Silt and Sand Till
East	214.0	213.0	3,000	3.0	-	21	Granular Fill (to replace topsoil/alluvium)
	213.0	212.0	-	-	40	9*	Clayey silt
	212.0	210.0	2,500	3.0	-	10*	Silt and Sand
	210.0	203.0	6,500	3.3	-	12*	Silt and Sand 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 ( $\text{kN/m}^3$ ),  $D$  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 of  $k_s$  by a reduction factor  $R$  in the following table.  $D$  is the width of the pile in the loading direction, and pile spacing is measured centre to centre.



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

Where a pile group is oriented *parallel* to the direction of loading, group action may be considered by reducing values of  $k_s$  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 topsoil/alluvium, soft silty clay and loose silt and sand deposits. The required caisson length would be in the order of 10 to 15 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 due to consolidation of the clay under the approach embankment loads.

For design purposes, an unfactored downdrag load of 230 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 150 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 in the assessment.

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 OPSS.PROV 1010. 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)

$\gamma$  = 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 $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	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 $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
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 firm to very soft silty clay and very dense till, and the east side is underlain by thin clayey silt and silt and sand 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 to 4.0 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 3 m west of the west abutment. Between this point and the west abutment, a maximum 1.2 m thickness of fill will be placed over the existing slope to form the approach embankment. The forward slope under the bridge will remain at the current inclination.
- On the east approach, up to 3.5 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 STW-01 to STW-03)

The embankment foundation soils under the west approach include a relatively thick deposit of firm to very soft silty clay. 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 of the west valley slope was conducted to assess the stability of the existing slope geometry. The existing inclination of approximately 2.75H:1V will remain essentially unchanged by construction. 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 and geotechnical parameters evaluated from the borehole and laboratory data. Drained strength parameters for the silty clay were determined through correlation with the results of direct shear tests carried out in other sections of the Highway 11/17 four-laning project.

The geotechnical model and results of the analyses are shown on Figures 1 and 2 in Appendix F. Factors of safety of 2.7 and 1.9 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**

A small wedge of fill with a maximum thickness of 1.2 m will be placed immediately behind the west abutment. The fill will induce time dependent (consolidation) settlement in the underlying silty clay. Based on analyses using one-dimensional consolidation theory and geotechnical parameters assessed from the borehole and laboratory data, as well as oedometer testing completed for other aspects of the Highway 11/17 assignment, the total consolidation settlement due to this wedge of fill is estimated to be in the order of 10 to 15 mm. This settlement is expected to occur over a period of about 6 months.

## **12.2 East Approach (Boreholes STW-04 to STW-06)**

Up to 1.1 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 soft to firm sandy clayey silt and loose silt and sand over very dense silt and sand till.

### **12.2.1 Slope Stability**

Analysis of the global stability of the proposed forward slope at the east abutment was conducted to assess the stability of the proposed slope geometry. The fill embankment and forward slope will be constructed using granular material with finished inclinations of 2H:1V. Existing topsoil/alluvium will be removed prior to fill placement.

The stability analyses were carried out using the commercially available slope stability program GEO-SLOPE, applying the Morgenstern-Price method and geotechnical parameters evaluated from the borehole and laboratory data. Short-term and long-term analyses were conducted.

The geotechnical model and results of the analyses are shown on Figures 3 and 4 in Appendix F. Factors of safety of 2.2 and 1.8 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.

### **12.2.2 Settlement**

Placement of approximately 3.5 m of granular fill to construct the east approach embankment will induce time dependent (consolidation) settlement in the relatively thin deposit of sandy

clayey silt and elastic (immediate) settlement in the underlying layer of loose silt and sand. The surficial topsoil/alluvium will be removed prior to fill placement.

Based on elastic theory, immediate settlement of the foundation soils due to the embankment load is expected to be in the order of 15 mm and occur essentially as the fill is placed. Based on analyses using one-dimensional consolidation theory and geotechnical parameters assessed from the borehole and laboratory data, the consolidation settlement under a maximum 3.5 m of new fill is estimated to be in the order of 10 to 15 mm and occur over a period of about 3 months.

### **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, all 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.

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 construct the proposed abutment and wingwall structures and to remove topsoil/alluvium at the east abutment. At the west abutment, the excavation will be carried out primarily within firm to very soft silty clay.

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the 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 typically ranged from Elev. 213.1 to 213.4 m. The reported water level in the creek was Elev. 212.9 m. Based on the groundwater levels and reported creek level, removal of the topsoil/alluvium at the east abutment may require excavations extending in the order of 0.5 m 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 actual

depth of excavation below the water level at the time of construction, excavation in wet conditions and backfilling with coarse clear stone to above the water level may be feasible for shallow excavations, or alternatively pumping from within a temporary sandbag or sheet pile cofferdam may be required to dewater the excavation and enable proper compaction of backfill.

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 may require excavation of soft/organic materials below the creek and groundwater levels. Measures to deal with the groundwater during excavation may be required to enable placement and compaction of embankment material. Alternatively, excavation in wet conditions and backfilling with coarse clear stone to above the water level may be required.



## 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



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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 <sup>(1)</sup> '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

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


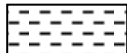



 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (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.

# UNIFIED SOILS CLASSIFICATION

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

## EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
<b>Fresh (FR)</b>	No visible signs of weathering.		
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.		CLAYSTONE
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
<b>Completely Weathered (CW)</b>	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	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



<u>TERMS</u>	
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.

# RECORD OF BOREHOLE No STW-01

1 OF 2

METRIC

WP# 647-89-00 LOCATION N 5 424 487.4 E 205 859.9 ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2013.04.29 - 2013.04.30 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)			
								20 40 60 80 100						PLASTIC LIMIT w <sub>P</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE							
219.1	0.0						219									
218.6																
0.5																
			1	SS	16											
			2	SS	4								0 0 38 62			
			3	SS	2											
			4	SS	0											

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity




20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No STW-01

2 OF 2

METRIC

WP# 647-89-00 LOCATION N 5 424 487.4 E 205 859.9 ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2013.04.29 - 2013.04.30 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE							
	Continued From Previous Page						20	40	60	80	100	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
							20	40	60	80	100	WATER CONTENT (%)			
208.3	Silty <b>CLAY</b> Firm to Very Soft Grey						209		3.0						
10.9	Sandy <b>SILT</b> , some gravel, trace clay Compact Grey Wet to Moist (TILL)		9	SS	17		208						○		16 30 50 4
206.3			10	SS	29		207						○		
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.														

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No STW-02

1 OF 3

METRIC

WP# 647-89-00 LOCATION N 5 424 500.7 E 205 868.6 ORIGINATED BY ES  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2013.05.01 - 2013.05.01 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+	FIELD VANE								
								● QUICK TRIAXIAL	×	LAB VANE								
218.9								20	40	60	80	100						
0.0	TOPSOIL, some clay, occasional wood fibres																	
218.6	Dark Brown																	
0.3	Silty <b>CLAY</b> , trace sand																	
	Stiff Brown (Cl)		1	SS	10		218								0	0	35	65
	Firm to Very Soft		2	SS	4		217											
			3	SS	3		216											
			4	SS	2		215											
	Grey						214											
			5	SS	0		213											
							212											
			6	SS	0		211											
							210											
			7	SS	2		209											
			8	SS	0													

Continued Next Page

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



# RECORD OF BOREHOLE No STW-02

2 OF 3

METRIC

WP# 647-89-00 LOCATION N 5 424 500.7 E 205 868.6 ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2013.05.01 - 2013.05.01 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
	Continued From Previous Page																
208.1	Silty <b>CLAY</b> , trace sand Firm to Very Soft Grey																
10.7	<b>SILT</b> and <b>SAND</b> , trace gravel, trace clay Loose to Compact Grey Wet		9	SS	2												
206.7																	
12.2	Sandy <b>SILT</b> , trace clay, trace to some gravel Loose to Dense Grey Wet (TILL)		10	SS	9											16 35 44 5	
			11	SS	30											4 29 58 9	
203.9																	
14.9	<b>SAND</b> , trace to some silt, trace gravel, occasional cobbles Very Dense Grey to Dark Grey Moist to Wet		12	SS	100/ 0.125												
			13	SS	100/ 0.075												
			14	SS	85											8 79 13 (SI+CL)	
			15	SS	100/ 0.075												

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No STW-02

3 OF 3

METRIC

WP# 647-89-00 LOCATION N 5 424 500.7 E 205 868.6 ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2013.05.01 - 2013.05.01 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
	Continued From Previous Page				0.075												
	SAND, trace to some silt, trace gravel, occasional cobbles Very Dense Grey to Dark Grey Moist to Wet																
	Probable cobbles		16	SS	100/												
					0.025												
196.0																	
22.9	END OF BOREHOLE AT 22.9m. 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 4.2 214.7 Jun. 23/13 5.8 213.1		17	SS	100/												
					0.0												

# RECORD OF BOREHOLE No STW-03

1 OF 2

METRIC

WP# 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			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								20   40   60   80   100	○ UNCONFINED      + FIELD VANE	● QUICK TRIAXIAL      × LAB VANE	W <sub>P</sub> W      W <sub>L</sub>								
218.8	0.0	TOPSOIL, some roots and rootlets, occasional wood fibres Dark Brown Wet																	
218.0	0.8	Silty <b>CLAY</b> , trace sand Firm to Soft Brown (Cl to CH)					218												
			1	SS	7														
			2	SS	5		217											0   0   49   51	
		Varved, occasional silt seams	3	SS	3		216												
		Becoming Very Soft Occasional sand pockets Grey	4	SS	0													0   0   39   61	
			5	SS	0		215												
			6	SS	0		214												
			7	SS	0		213												
			8	SS	1		212												
							211											0   0   30   70	
							210												
209.1	9.6	SILT and <b>SAND</b> , trace gravel Compact					209												

Continued Next Page

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

RECORD OF BOREHOLE No STW-03

2 OF 2

METRIC

WP# 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			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
							WATER CONTENT (%)						
							20 40 60						
	Continued From Previous Page												
207.1	<b>SILT</b> and <b>SAND</b> , trace gravel Compact Grey Moist		9	SS	10		208						
11.7	Sandy <b>SILT</b> , trace clay, trace gravel Compact to Very Dense Grey Moist (TILL)  												

ONTMT4S 05117.GPJ 2012TEMPLATE(MTO).GDT 3/28/14

# RECORD OF BOREHOLE No STW-04

1 OF 2

METRIC

WP# 647-89-00 LOCATION N 5 424 525.3 E 205 900.1 ORIGINATED BY ES  
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2013.04.25 - 2013.04.25 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC      NATURAL      LIQUID LIMIT      MOISTURE      LIMIT CONTENT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				WATER CONTENT (%) w <sub>P</sub> w      w <sub>L</sub>						
213.7								20	40	60	80	100						
0.0	TOPSOIL/ALLUVIUM, some roots, wood fibres Dark Brown Moist						213										0   20   61   19	
212.9																		
0.8	Clayey SILT, sandy, trace rootlets Soft to Firm Brown		1	SS	2										○			
211.7			2	SS	8				212						○			
1.9	SILT and SAND, trace clay, trace gravel Loose to Very Dense Grey Moist								211						○			
			3	SS	6													
210.6																		
3.0	SAND and SILT to Sandy SILT, trace clay, trace gravel, occasional cobbles Very Dense to Dense Grey Moist (TILL)		4	SS	79/ 0.100		210						○			9   41   46   4		
			5	SS	101/ 0.175		209						○					
							208											
			6	SS	112/ 0.250		207						○					
																1   20   69   10		
							206						○					
			7	SS	44		205											
			8	SS	108/ 0.225		204						○					

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No STW-04

2 OF 2

METRIC

WP# 647-89-00 LOCATION N 5 424 525.3 E 205 900.1 ORIGINATED BY ES  
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2013.04.25 - 2013.04.25 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
	Continued From Previous Page																
	Sandy <b>SILT</b> , trace clay, trace gravel, occasional cobbles Very Dense Grey Moist (TILL)		9	SS	100/ 0.0		203										
							202										
			10	SS	106/ 0.150		201										
199.8			11	SS	100/ 0.050		200										
13.9	END OF BOREHOLE AT 13.9m UPON AUGER REFUSAL. WATER LEVEL AT 0.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No STW-05

1 OF 2

METRIC

WP# 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

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
214.0							214	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				
0.0	TOPSOIL: (175mm)							20 40 60 80 100				
0.2	Clayey SILT, sandy, trace rootlets, occasional wood fibres Soft to Firm Brown		1	SS	3		213					0 24 53 23
212.1			2	SS	5							
1.9	SILT and SAND, trace clay, trace gravel Loose Grey Wet		3	SS	4		212					
			4	SS	8		211					
210.0							210					
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		209					
			6	SS	51		208					4 33 54 9
							207					
	Occasional sand pockets		7	SS	37		206					
			8	SS	100/ 0.175		205					
204.4												
9.6	SAND, coarse grained, some silt, trace gravel											

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No STW-05

2 OF 2

METRIC

WP# 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

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page																
	SAND, coarse grained, some silt, trace gravel Very Dense Dark Grey Wet		9	SS	100/												
				0.125													
201.7			10	SS	100/												
12.3	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				0.100												



RECORD OF BOREHOLE No STW-06

1 OF 2

METRIC

WP# 647-89-00 LOCATION N 5 424 535.5 E 205 922.4 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					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
								20 40 60 80 100								
214.5																
0.0	TOPSOIL/ALLUVIUM, trace roots, with wood fibres Dark Brown Wet						214									
213.3			1	SS	3											
1.1	SILT and SAND, trace clay, trace gravel Loose Brown to Grey Wet						213									
			2	SS	8											
212.2	SILT and SAND, trace clay, trace gravel, occasional cobbles Very Dense Grey Moist (TILL)   Possible cobbles/boulders at 6.1m   Occasional sand seam		3	SS	79/ 0.275		212									
			4	SS	86			211								
			5	SS	99/ 0.225			210								
			6	SS	100/ 0.025		209									
							208									
							207									
			7	SS	110/ 0.250											
							206									
205.1			8	SS	109/ 0.250											
9.4	END OF BOREHOLE AT 9.4m. WATER LEVEL AT 0.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH				0.250											

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No STW-06

2 OF 2

METRIC

WP# 647-89-00 LOCATION N 5 424 535.5 E 205 922.4 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		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page BENTONITE HOLEPLUG TO SURFACE.													

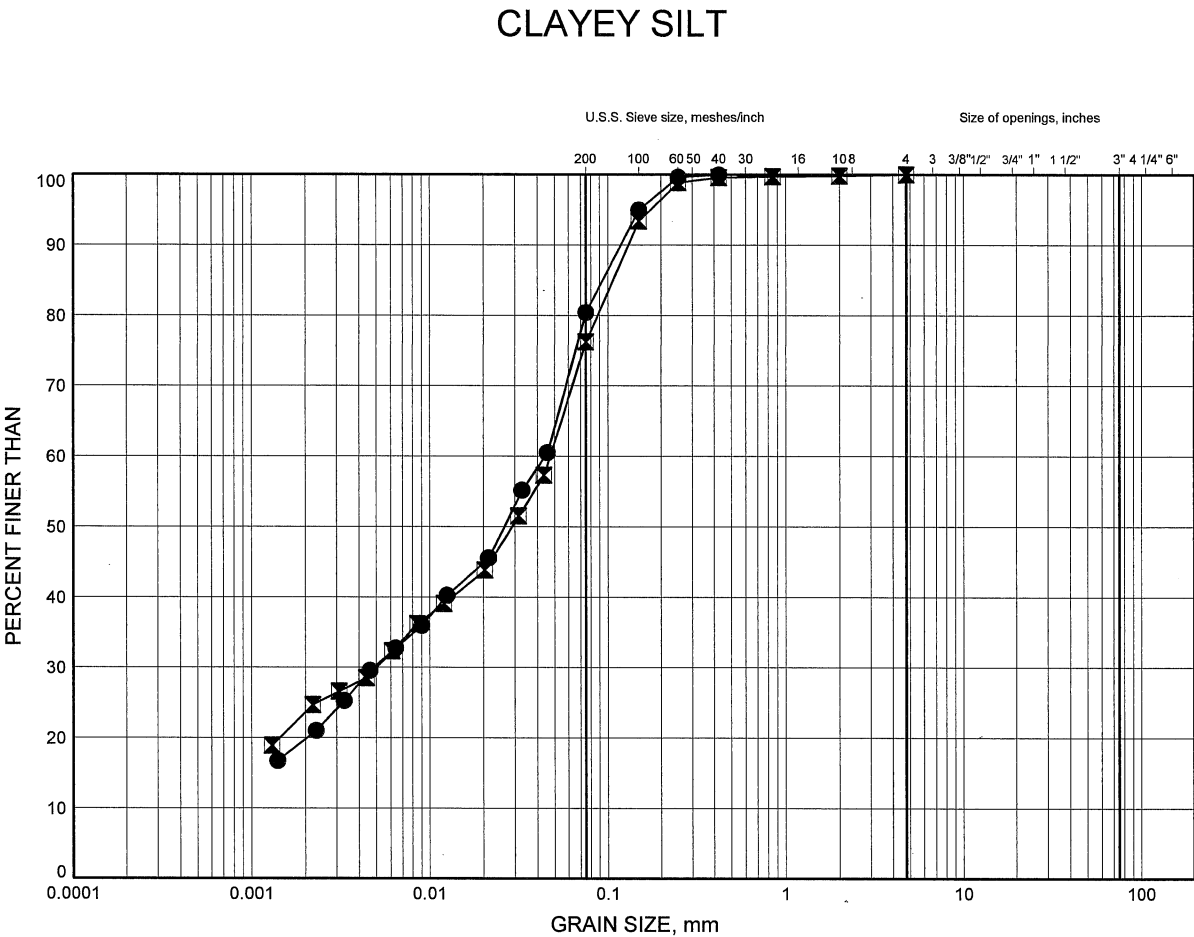
## **Appendix B**

### **Laboratory Test Results**

South Trout Creek - WBL

# GRAIN SIZE DISTRIBUTION

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-04	1.07	212.58
⊠	STW-05	1.07	212.92

GRAIN SIZE DISTRIBUTION - THURBER 05117.GPJ 9/20/13

Date September 2013  
GWP# 647-89-00

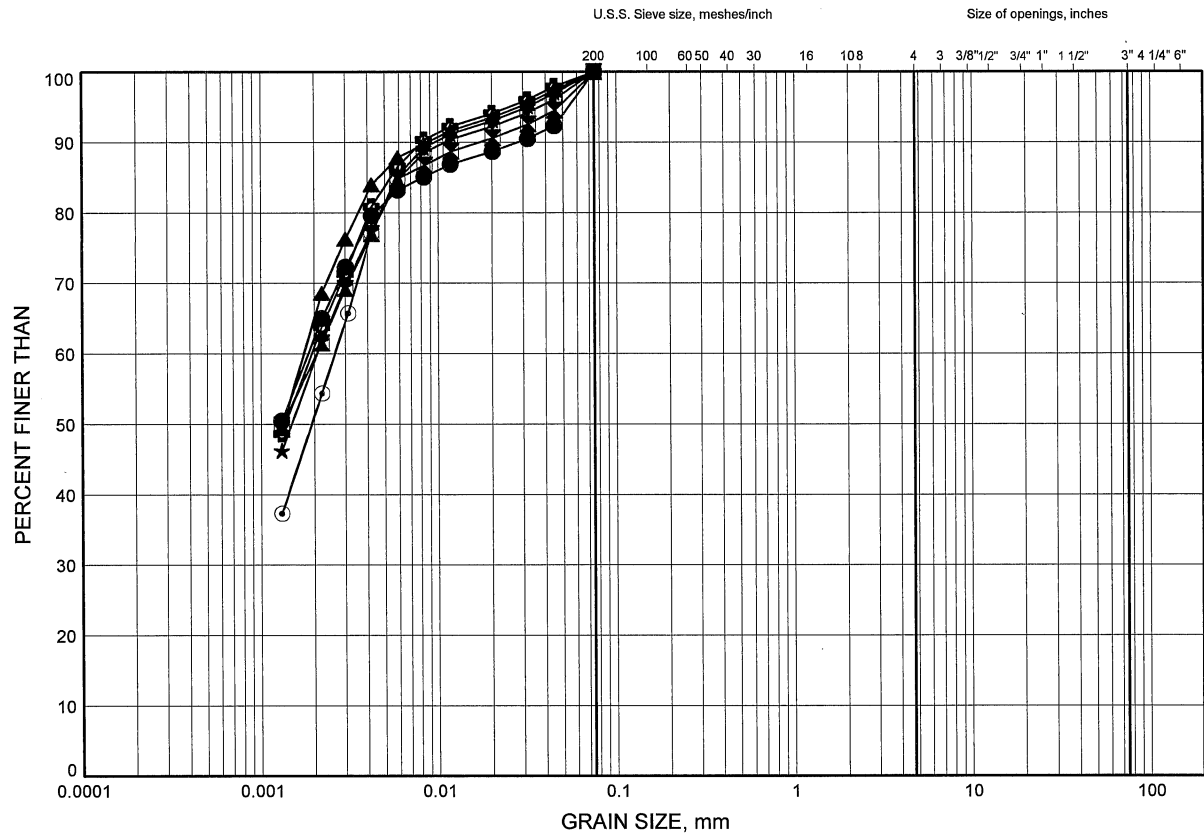


Prep'd AN  
Chkd. MRA

South Trout Creek - WBL  
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)
●	STW-01	1.83	217.31
⊠	STW-01	6.40	212.73
▲	STW-02	1.07	217.81
★	STW-02	4.88	214.00
⊙	STW-03	1.83	216.94
⊕	STW-03	3.35	215.42

GRAIN SIZE DISTRIBUTION - THURBER 05117.GPJ 9/20/13

Date September 2013  
GWP# 647-89-00



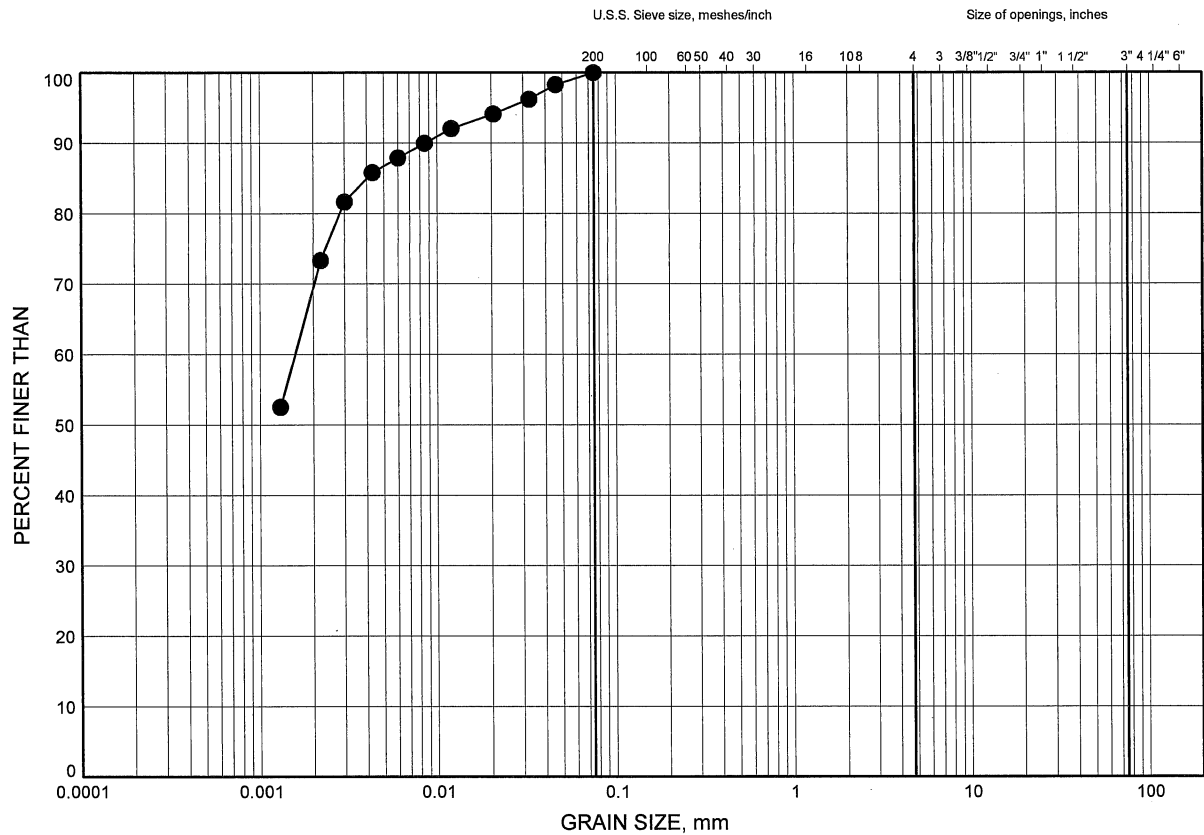
Prep'd AN  
Chkd. MRA

# South Trout Creek - WBL

## GRAIN SIZE DISTRIBUTION

FIGURE B3

### SILTY CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-03	7.92	210.84

Date September 2013  
 GWP# 647-89-00

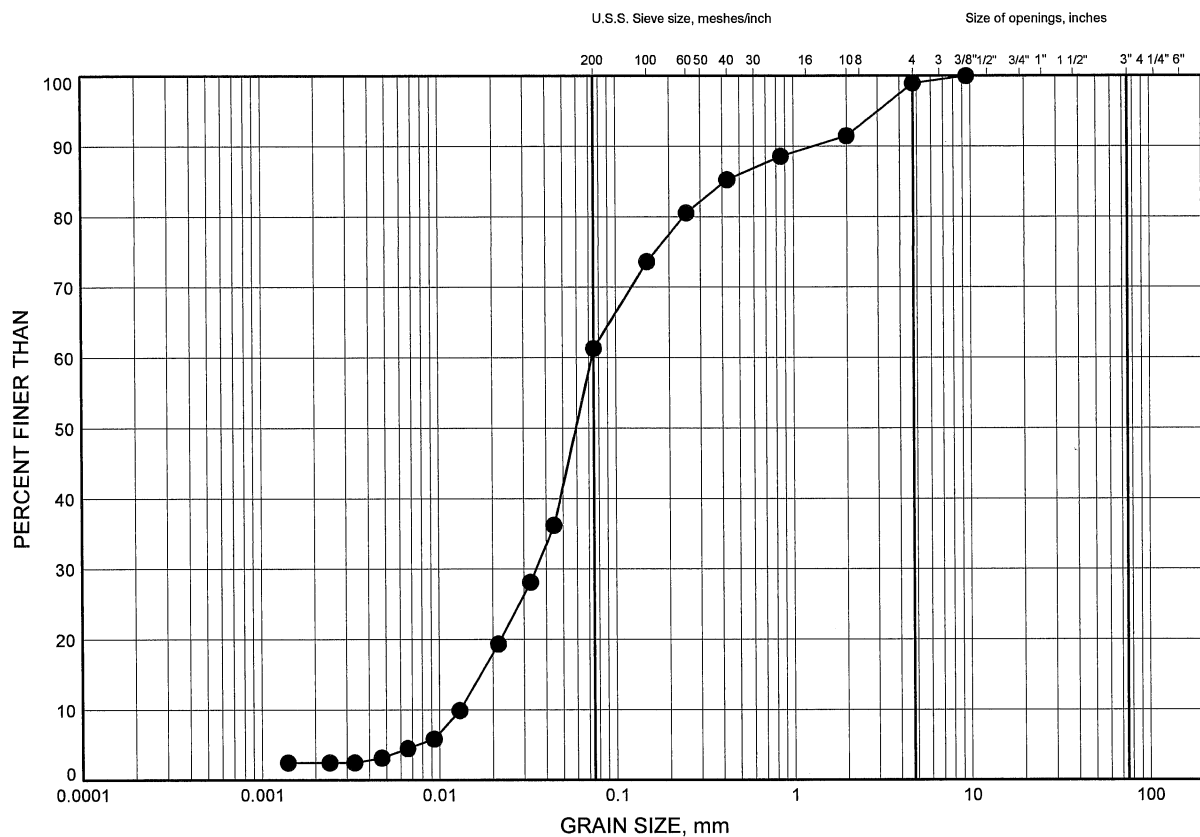


Prep'd AN  
 Chkd. MRA

# South Trout Creek - WBL GRAIN SIZE DISTRIBUTION

FIGURE B4

## SILT & SAND



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-06	1.83	212.64

Date September 2013

GWP# 647-89-00



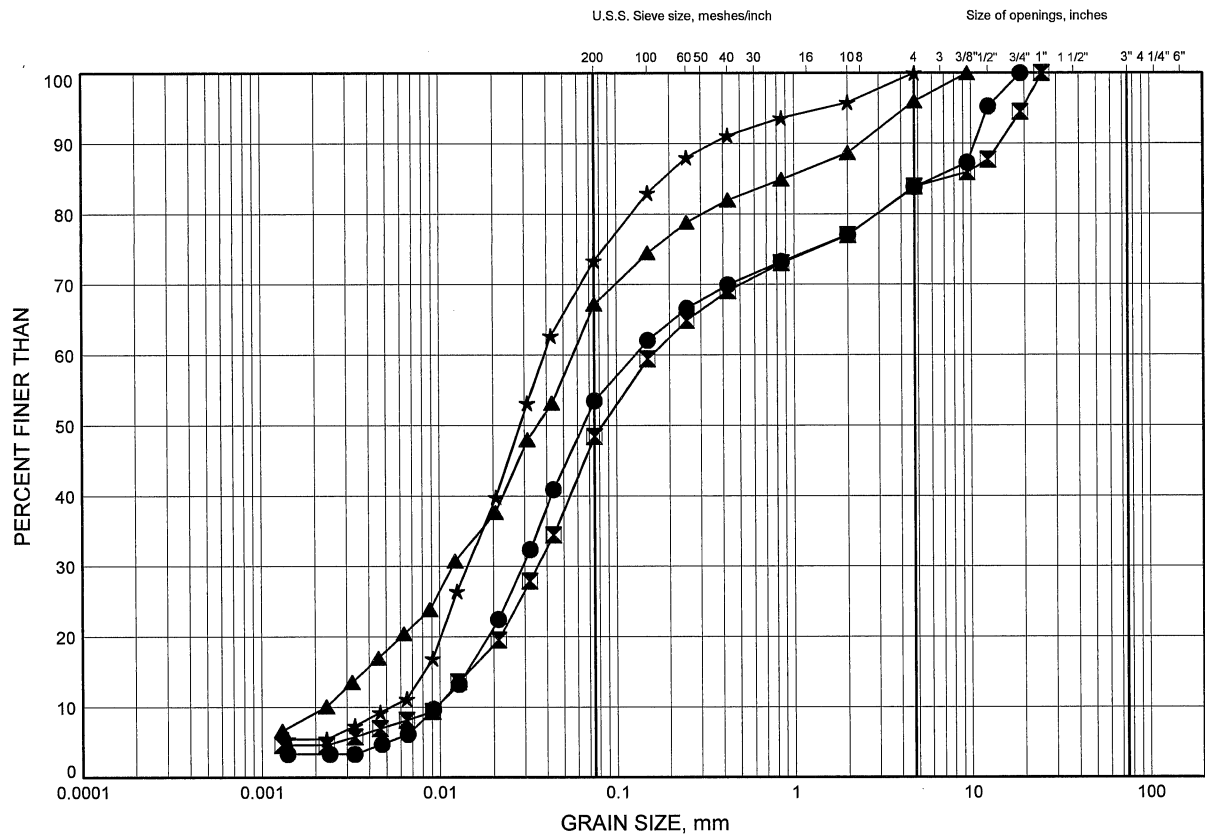
Prep'd AN

Chkd. MRA

# South Trout Creek - WBL GRAIN SIZE DISTRIBUTION

FIGURE B5

## 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-01	10.97	208.16
⊠	STW-02	12.50	206.38
▲	STW-02	14.02	204.86
★	STW-03	12.50	206.27

GRAIN SIZE DISTRIBUTION - THURBER 05117.GPJ 9/20/13

Date September 2013  
GWP# 647-89-00



Prep'd AN  
Chkd. MRA

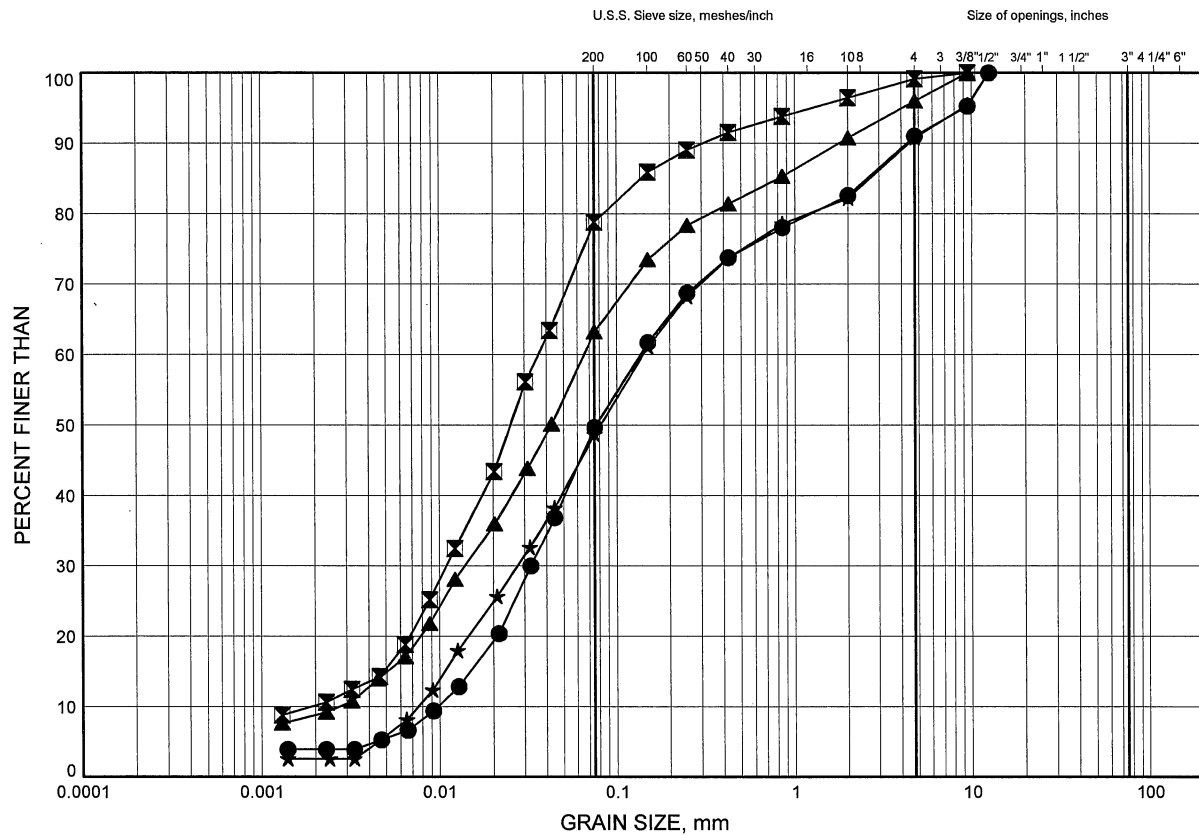


# South Trout Creek - WBL

## GRAIN SIZE DISTRIBUTION

FIGURE B6

### 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-04	3.24	210.41
⊠	STW-04	7.92	205.73
▲	STW-05	6.40	207.59
★	STW-06	7.75	206.72

Date September 2013

GWP# 647-89-00



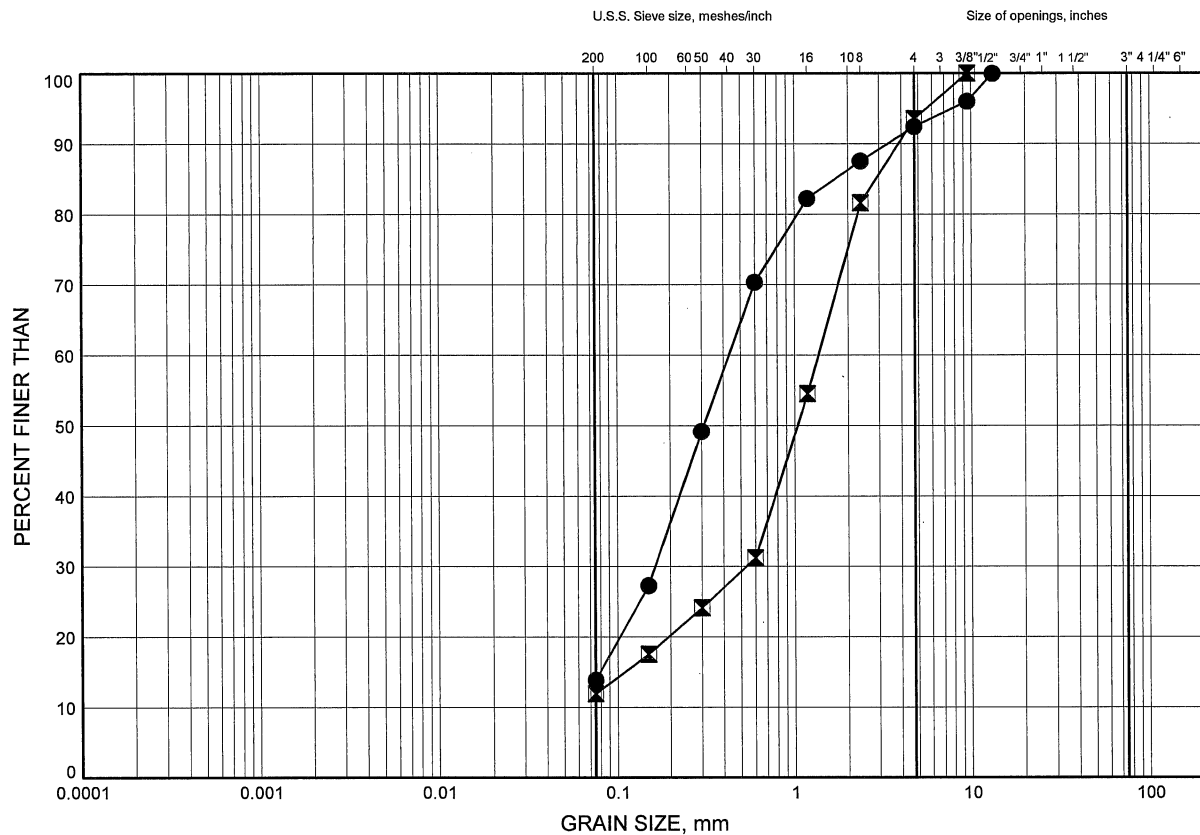
Prep'd AN

Chkd. MRA

# South Trout Creek - WBL GRAIN SIZE DISTRIBUTION

FIGURE B7

## SAND



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-02	18.59	200.29
⊠	STW-05	10.73	203.25

Date September 2013  
GWP# 647-89-00

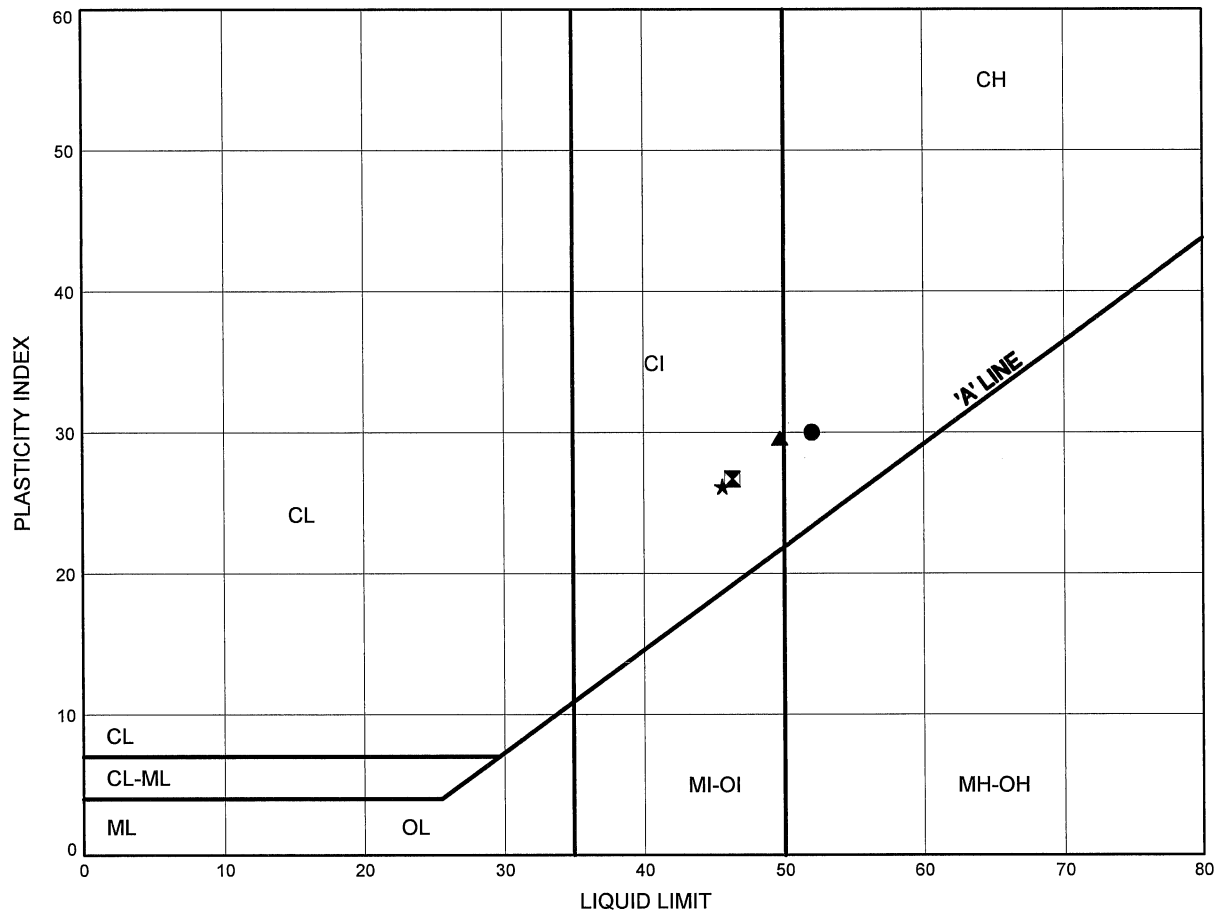


Prep'd AN  
Chkd. MRA

South Trout Creek - WBL  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B8

**SILTY CLAY**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-01	1.83	217.31
⊠	STW-01	6.40	212.73
▲	STW-02	1.07	217.81
★	STW-02	4.88	214.00

THURBALT 05117.GPJ 9/20/13

Date September 2013  
 GWP# 647-89-00



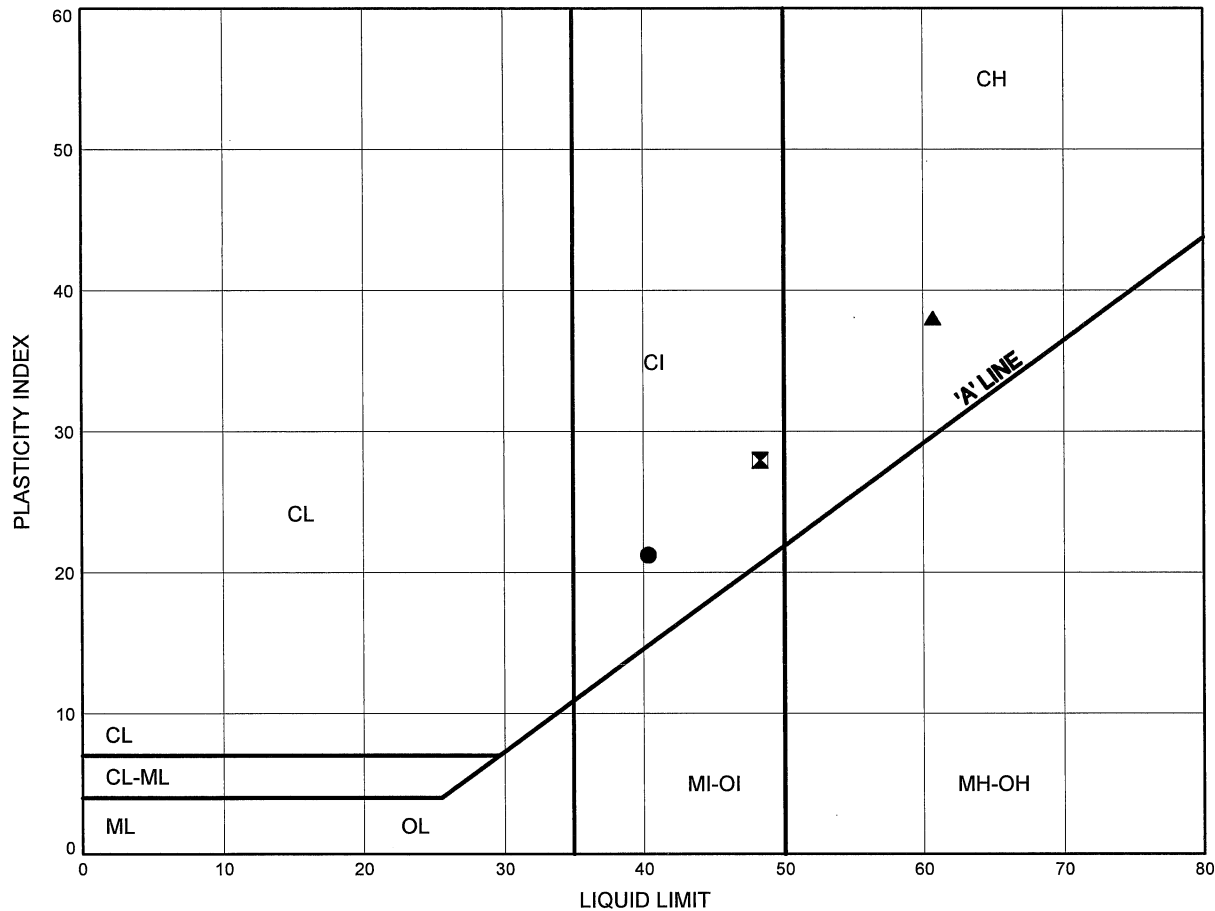
Prep'd AN  
 Chkd. MRA

South Trout Creek - WBL

# ATTERBERG LIMITS TEST RESULTS

FIGURE B9

## SILTY CLAY



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	STW-03	1.83	216.94
⊠	STW-03	3.35	215.42
▲	STW-03	7.92	210.84

Date September 2013  
GWP# 647-89-00



Prep'd AN  
Chkd. MRA

## **Appendix C**

### **Site Photographs**



**Photograph 1 – Existing conditions at South Trout Creek, looking northeast at southwest bank.**





**Photograph 2 – Existing conditions at South Trout Creek, looking north at northeast bank.**



**Photograph 3 – Existing conditions of the South Trout Creek**



## **Appendix D**

### **Foundation Comparison**

**COMPARISON OF FOUNDATION ALTERNATIVES**

<b>Footings on Native Soil</b>	<b>Augered Caissons</b>	<b>Pipe Piles</b>	<b>Steel H-Piles</b>
<p><b><i>Advantages:</i></b></p> <ul style="list-style-type: none"> <li>i. Generally less costly construction than deep foundation elements.</li> </ul>	<p><b><i>Advantages:</i></b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance available for caissons.</li> <li>ii. Construction of caissons could continue in freezing weather.</li> <li>iii. Excavation and dewatering requirements are reduced.</li> </ul>	<p><b><i>Advantages:</i></b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance.</li> <li>ii. Liner is not required to support excavation sidewalls.</li> <li>iii. Excavation and dewatering requirements are minimized.</li> </ul>	<p><b><i>Advantages:</i></b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance.</li> <li>ii. Installation of piles could continue in freezing weather.</li> <li>iii. Excavation and dewatering requirements are minimized.</li> <li>iv. Suitable for integral abutment foundations.</li> </ul>
<p><b><i>Disadvantages:</i></b></p> <ul style="list-style-type: none"> <li>i. Low geotechnical resistance available on native soils.</li> <li>ii. Potential consolidation settlement due to soft clay and clayey silt.</li> <li>iii. Excavation depths to construct footings on very dense till are excessive on both banks.</li> <li>iv. Temporary dewatering is required to construct footings in the dry.</li> <li>v. Temporary excavation for footing construction may have environmental impact on the creek.</li> </ul>	<p><b><i>Disadvantages:</i></b></p> <ul style="list-style-type: none"> <li>i. Higher unit costs than footings and other deep foundations.</li> <li>ii. Measures will be required to prevent squeezing in soft materials and base heave in cohesionless soils below groundwater.</li> <li>iii. Potential difficulty in cleaning and inspection of socket base.</li> </ul>	<p><b><i>Disadvantages:</i></b></p> <ul style="list-style-type: none"> <li>i. Higher unit cost than footings on bedrock.</li> <li>ii. Potential for pile damage when driving into very dense till with possible cobbles and boulders.</li> <li>iii. Piles socketed into bedrock is not an option at this site.</li> <li>iv. Tremie concreting will be required for concreting the pipe due to infiltrating ground water.</li> </ul>	<p><b><i>Disadvantages:</i></b></p> <ul style="list-style-type: none"> <li>i. Higher unit cost than footings on bedrock.</li> <li>ii. H-piles may encounter refusal at varying depths on cobbles and boulders in the till.</li> </ul>
<b>NOT RECOMMENDED</b>	<b>NOT RECOMMENDED</b>	<b>NOT RECOMMENDED</b>	<b>RECOMMENDED</b>

## **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.PROV 1010
- OPSD 3101.150
- OPSD 3101.200
- SP 105S21
- SP 110S13

## **Appendix F**

### **Slope Stability Output**

Title: South Trout Creek (WBL)  
Name: 1: WA (TSA)  
Comments: Stability Analysis  
Last Solved Date: 10/22/2013, 3:05:32 PM

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
Organics (REPLACEMENT)	21 kN/m³	0 kPa	32 °	1
SILT and SAND	20 kN/m³	0 kPa	31 °	1
TILL	20 kN/m³	0 kPa	38 °	1
WALL	0.001 kN/m³	200 kPa	34 °	1
FILL	21 kN/m³	0 kPa	32 °	1

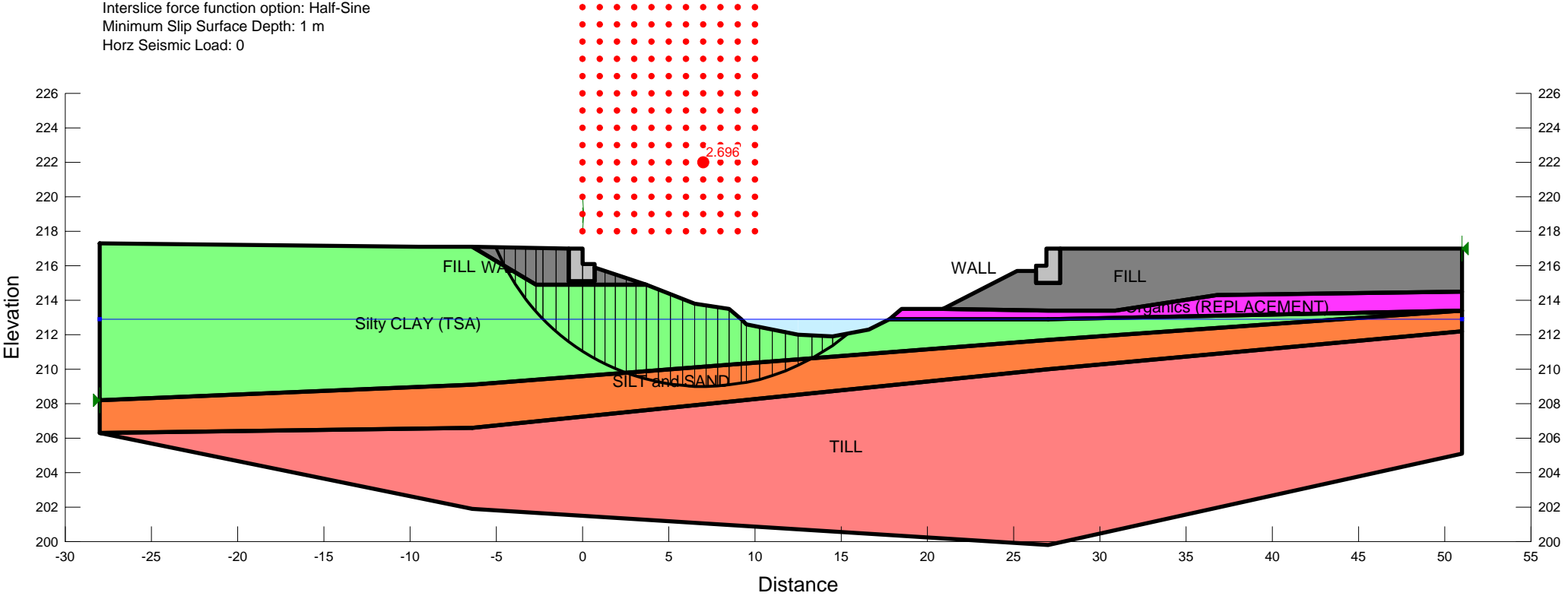
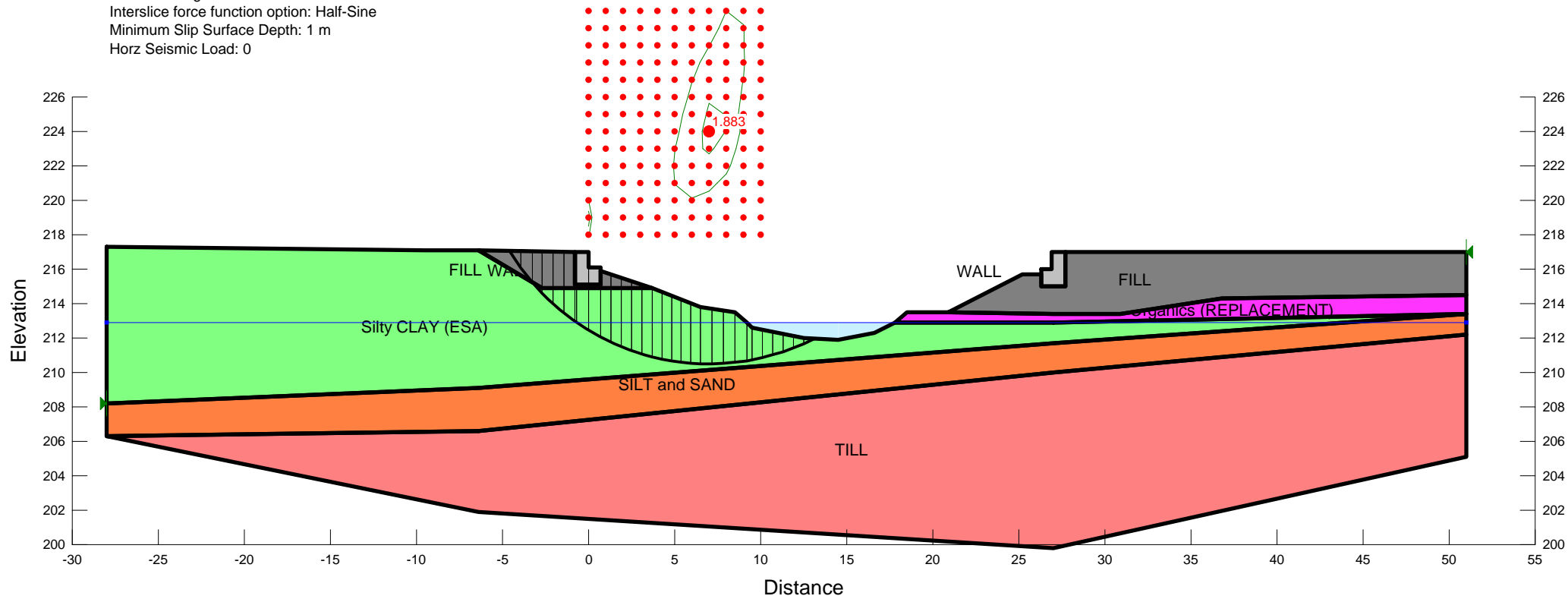


FIGURE 1

Title: South Trout Creek (WBL)  
 Name: 1: WA (ESA)  
 Comments: Stability Analysis  
 Last Solved Date: 10/22/2013, 3:05:25 PM

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

Silty CLAY (ESA)	18 kN/m <sup>3</sup>	7 kPa	23 °	1
Organics (REPLACEMENT)	21 kN/m <sup>3</sup>	0 kPa	32 °	1
SILT and SAND	20 kN/m <sup>3</sup>	0 kPa	31 °	1
TILL	20 kN/m <sup>3</sup>	0 kPa	38 °	1
WALL	0.001 kN/m <sup>3</sup>	200 kPa	34 °	1
FILL	21 kN/m <sup>3</sup>	0 kPa	32 °	1



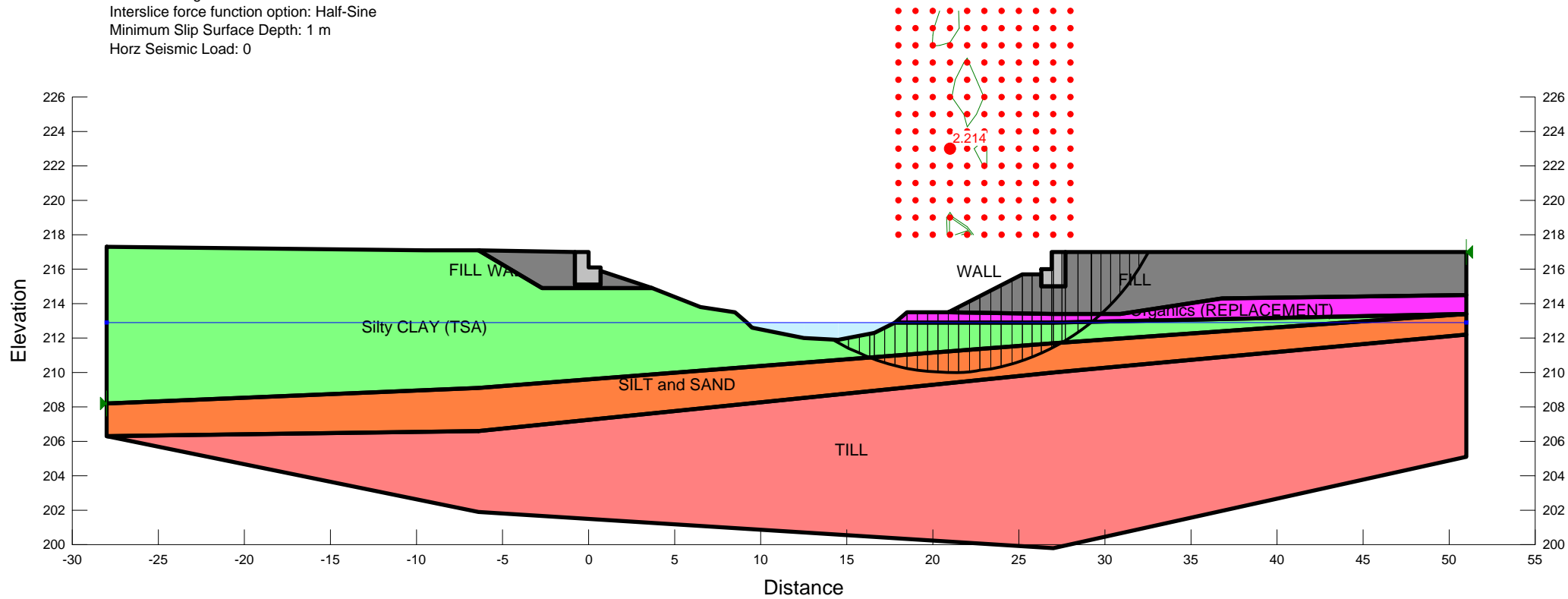
Directory: H:\19\1605\117 Hwy 11-17 Nipigon\Reports & Memos\South Trout WBL\Analysis\Stability [Oct04-13]\STC\_002.gsz

FIGURE 2

Title: South Trout Creek (WBL)  
 Name: 1: EA (TSA)  
 Comments: Stability Analysis  
 Last Solved Date: 10/22/2013, 3:05:20 PM

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

Silty CLAY (TSA)	18 kN/m <sup>3</sup>	40 kPa	0 °	1
Organics (REPLACEMENT)	21 kN/m <sup>3</sup>	0 kPa	32 °	1
SILT and SAND	20 kN/m <sup>3</sup>	0 kPa	31 °	1
TILL	20 kN/m <sup>3</sup>	0 kPa	38 °	1
WALL	0.001 kN/m <sup>3</sup>	200 kPa	34 °	1
FILL	21 kN/m <sup>3</sup>	0 kPa	32 °	1



Directory: H:\19\1605\117 Hwy 11-17 Nipigon\Reports & Memos\South Trout WBL\Analysis\Stability [Oct04-13]\STC\_002.gsz

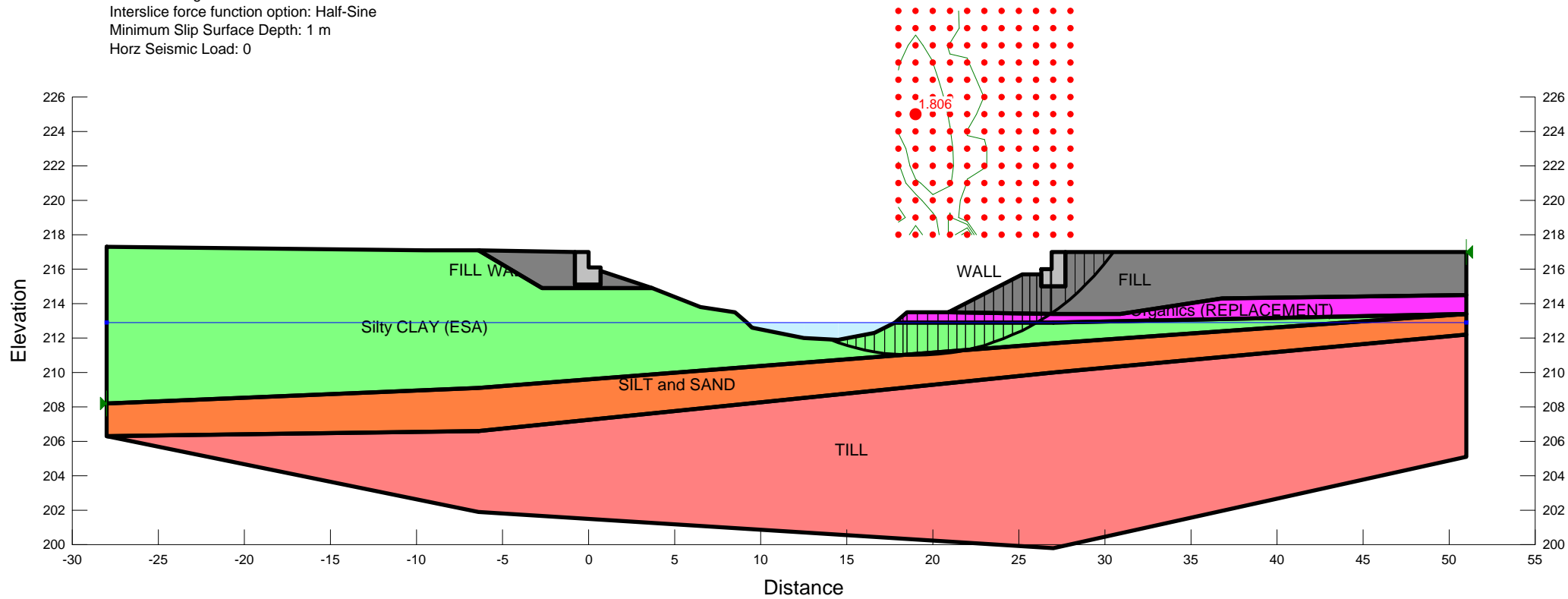
FIGURE 3



Title: South Trout Creek (WBL)  
 Name: 1: EA (ESA)  
 Comments: Stability Analysis  
 Last Solved Date: 10/22/2013, 3:05:14 PM

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

Silty CLAY (ESA)	18 kN/m <sup>3</sup>	7 kPa	23 °	1
Organics (REPLACEMENT)	21 kN/m <sup>3</sup>	0 kPa	32 °	1
SILT and SAND	20 kN/m <sup>3</sup>	0 kPa	31 °	1
TILL	20 kN/m <sup>3</sup>	0 kPa	38 °	1
WALL	0.001 kN/m <sup>3</sup>	200 kPa	34 °	1
FILL	21 kN/m <sup>3</sup>	0 kPa	32 °	1

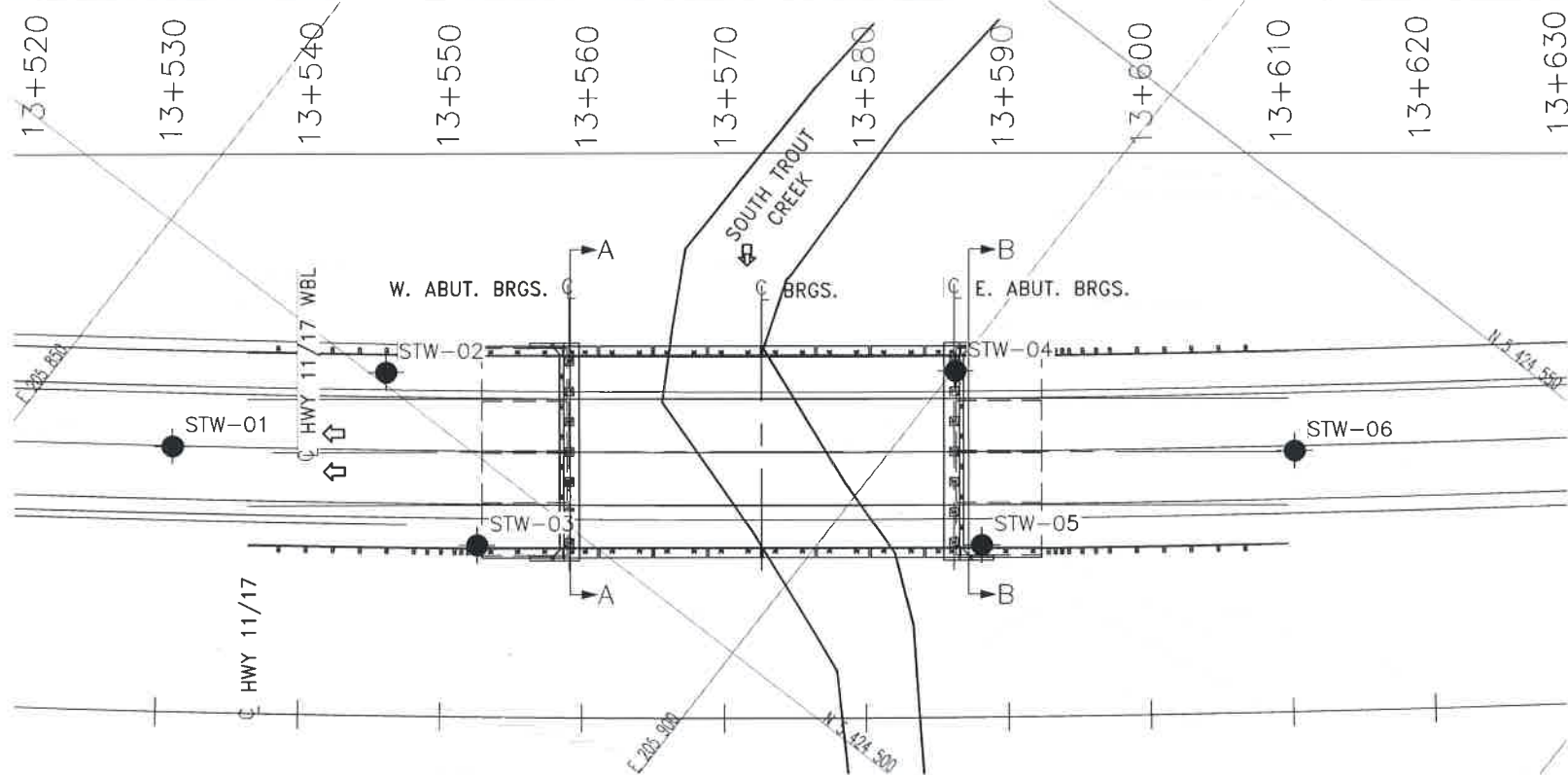


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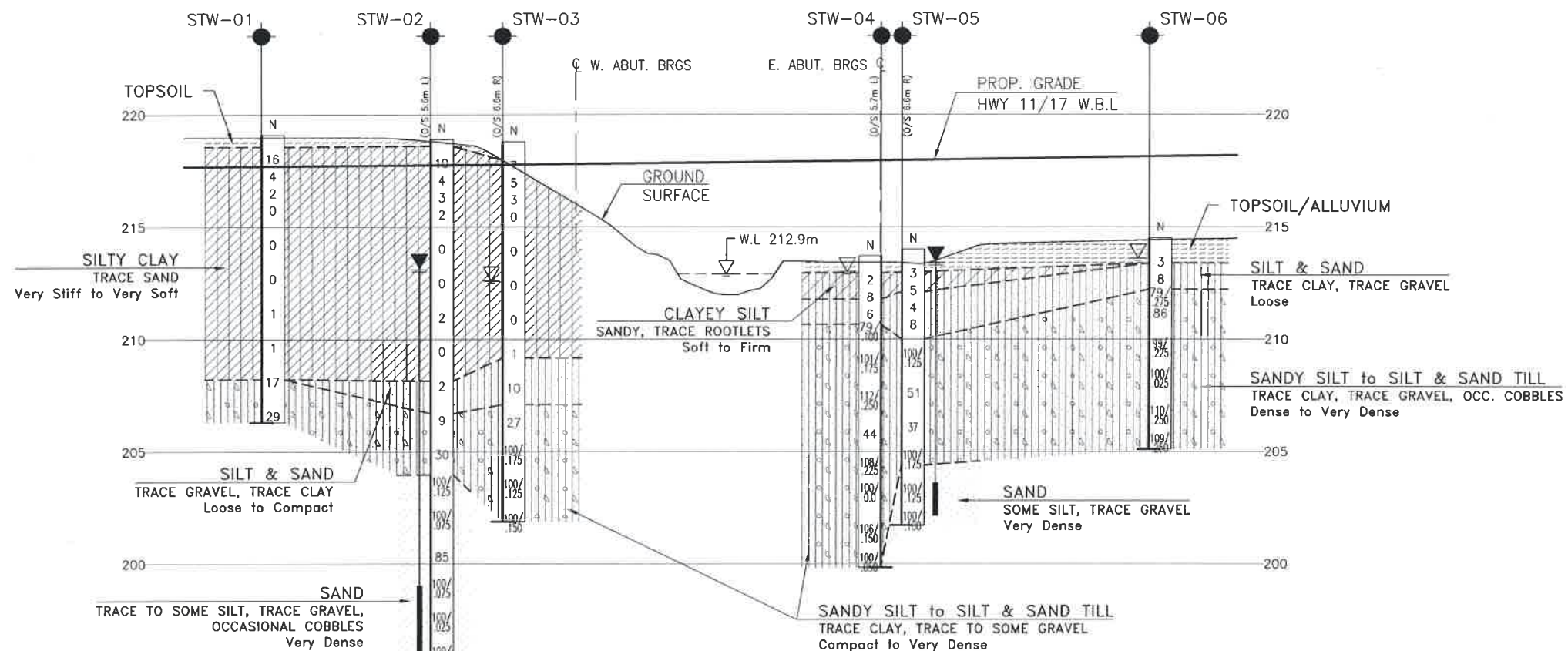
FIGURE 4

## **Appendix G**

### **Borehole Locations and Soil Strata Drawings**



PLAN  
SCALE 1:500



PROFILE ALONG C HWY 11/17 WBL

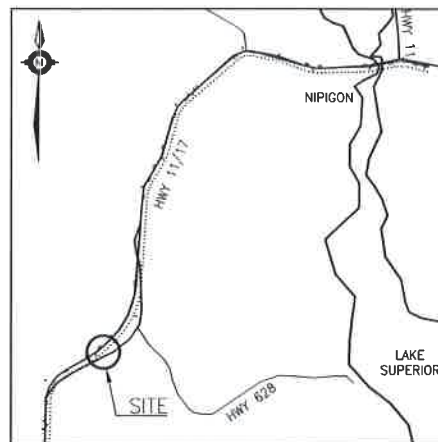
SCALE 1:250

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



CONT No  
GWP No 647-89-00

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



KEYPLAN

LEGEND

- ◆ 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
- W Water Level During Drilling
- W Water Level in Piezometer
- 90% Rock Quality Designation (ROD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
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-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 52A-177

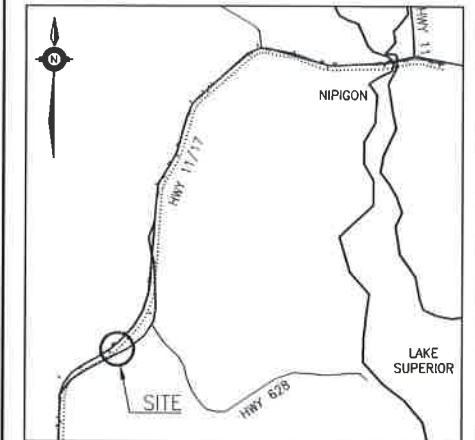
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DESIGN	MEF	CHK	MEF
DRAWN	AN	CHK	MRA
CODE	LOAD	DATE	MAR 2014
SITE	48C-10A	STRUCT	DWG 1

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



CONT No  
GWP No 647-89-00  
HIGHWAY 11/17 FOUR LANE  
SOUTH TROUT CREEK  
WESTBOUND LANE  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN

LEGEND

- ◆ 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
- W Water Level During Drilling
- W Water Level in Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
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-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 52A-177

DATE	BY	DESCRIPTION
DESIGN	MEF	CHK MEF
DRAWN	AN	CHK MRA
DATE	MAR 2014	
FILENAME:	H:\Drawing\19\1805\117\SouthTroutCreek-Plan&Profile\ad5117-SouthTroutCreek(WBL)-Revise-Mar2014.dwg	
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