



THURBER ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT
SAWMILL CREEK CULVERT REPLACEMENT
HIGHWAY 17
THUNDER BAY DISTRICT, ONTARIO**

G.W.P. No. 6366-14-00, W.P. No. 6366-14-01, SITE No. 48E-50/C

GEOCRES Number: 42D-44

Report

to

HATCH

Date: August 25, 2017
File: 13662

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Sawmill Creek Culvert on Highway 17, located in the Township of Syine, Thunder Bay District, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert location to supplement the existing information obtained during preliminary design of the project and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by Hatch to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-004.

A preliminary foundation investigation carried out at this site was documented in the report titled "Revised Preliminary Foundation Investigation and Design Report, Sawmill Creek Culvert, Highway 17, District of Thunder Bay, Township of Syine", prepared by Golder Associates, dated July 14, 2017; Geocres No. 42D-39. Reference should be made to the Golder report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile, record of borehole sheets and laboratory test results. It should be noted that Golder is solely responsible for the subsurface information provided in the Preliminary Foundation Report. The Record of Borehole sheets and Borehole Locations and Soil Strata drawing from the Golder report have been enclosed in Appendix E of this report for reference, and the subsurface information presented in the Golder report was incorporated in the current report, as appropriate.

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Reference is also made to a Structural Design Report (SDR) titled, "Structural Design Report, Sawmill Creek Culvert, Site No. 48E-050C, Highway 17", prepared by Hatch Mott MacDonald (Hatch), dated December 2015.

2. SITE DESCRIPTION

The site is located on Highway 17, approximately 18 km east of Mill Road in Terrace Bay, Ontario. The culvert allows Sawmill Creek to flow from east to west from Sawmill Lake under Highway 17 to Jackfish Lake. Highway 17 generally runs in a north-south direction at the culvert site.

The SDR indicates that the existing structure is a 27.3 m long, 6.1 m span by 1.8 m high, cast-in-place, rigid concrete box, with a height of fill of 3.5 m over the culvert. The culvert barrel is noted to be generally in fair to poor condition with settlement at the centre, a 130 mm wide crack at midspan, delamination, eroded sections of the walls, spalled faces at the inlet and outlet, exposed rebar, cracking, and deformation of the foundations. Based on the 2014 structural inspection report, about 400 mm of settlement has reportedly occurred at the midpoint of the culvert.

The grade level of Highway 17 at the existing culvert is at approximate Elevation 188 m.

Naturally low-lying areas are present near the inlet and outlet of the culvert, with vegetation consisting of grass, shrubs and frequent trees. Sawmill Lake is located approximately 250 m east of the site, and Jackfish Lake is located approximately 60 m west of the site. Photographs in Appendix C show the general nature of the site and the existing culvert.

Based on published geological information, the culvert lies within an area of lacustrine deposits of varved or massive clay, silt, fine sand and sand, and is bordered by bare bedrock knobs. The bedrock at the site consists of massive granodiorite to granite.

3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out on July 27 and August 9, 2016, and consisted of drilling and sampling a 16.6 m deep borehole, designated as Borehole 16-15. The borehole was located on the east shoulder of Highway 17, approximately 13 m south of the centreline of the existing culvert, near the alignment of the proposed creek diversion pipe.

Utility clearances were obtained prior to the start of drilling. The coordinates and ground surface elevation for the borehole were derived from topographic plans provided to Thurber by Hatch.

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The coordinate system MTM NAD 83, Zone 14 was used for the borehole. The approximate location of the borehole is shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

A track-mounted CME 55 drill rig was used to advance Borehole 16-15 using hollow stem augers to a depth of 12.5 m, followed by an NQ core barrel to advance the borehole into bedrock to a depth of 16.6 m. Soil samples were obtained at selected intervals in the borehole with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT).

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

Groundwater conditions were observed in the open borehole throughout the drilling operations. The borehole was backfilled on completion of drilling in general accordance with Ontario Regulation 903.

Completion details of the Borehole 16-15 are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
16-15	16.6 / 171.3	Bentonite holeplug and cuttings from 16.6 m to 0.18 m and asphalt patch to ground surface.

The previous investigation by Golder included four (4) boreholes, numbered SW-1 to SW-4, which were drilled to depths of 10.1 to 15.8 m. The approximate locations of the Golder boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D, and on the 2015 Golder report's Borehole Locations and Soil Strata Drawing included in Appendix E.

4. LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses

(sieve and/or hydrometer), plasticity testing (Atterberg Limits) and point load testing on bedrock where appropriate. A consolidation test and additional hydrometer and Atterberg Limits tests were also conducted by TBT Engineering Ltd. (TBTE) on a thin-walled tube sample of silty clay from Borehole 16-15. The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing native soil, and a sample of the surface water from the creek upstream of the existing culvert were collected. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendices A and D. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the “Borehole Locations and Soil Strata” drawings included in Appendices D and E. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered in the boreholes from the current and previous investigations consisted of asphalt pavement overlying granular fill and embankment fill, which was in turn underlain by native soil consisting of silty sand, silty clay, silt, gravelly silty sand, and granite bedrock. A thin peat layer was also noted below the fill at one borehole. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes SW-2 and SW-3 were drilled through the existing asphalt lanes on Highway 17. The asphalt thickness measured in the boreholes was 140 mm. Borehole 16-15 was drilled through the asphalt shoulder, where the asphalt thickness was 150 mm.

5.2 Fill

Underlying the asphalt, a 0.75 m thick layer of granular fill consisting of gravelly sand with some silt was encountered in Borehole 16-15, which extended to a depth of 0.9 m (Elev. 187.0 m). The measured moisture content of a sample of the granular fill was 10%. The results of a grain size analysis conducted on a sample the granular fill is presented on the Record of Borehole sheet in Appendix A, and on Figure B1 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	21
Sand	66
Silt and Clay	13

A sand and silt to silt and sand embankment fill containing trace to some gravel, trace clay and trace organics was encountered below the asphalt in Boreholes SW-2 and SW-3, below the granular fill in Borehole 16-15, and at the ground surface in Boreholes SW-1 and SW-4. The embankment fill ranged in thickness from 1.1 to 5.5 m, and extended to depths from 1.1 to 5.5 m (Elev. 182.5 to 184.9 m). SPT 'N' values within the embankment fill ranged from 1 to 10 blows per 0.3 m penetration, indicating a very loose to compact relative density. Higher 'N' values from 12 to greater than 100 blows per 0.3 m penetration were recorded in frozen soils in Boreholes SW-1 to SW-3, and are not considered to be representative of the density of the embankment fill.

The measured moisture content of the embankment fill ranged from 6% to 34%. The results of grain size analyses conducted on samples of the embankment fill are presented on the Record of Borehole sheets included in Appendices A and E, are summarized in the following table. The results from Borehole 16-15 are presented on Figure B2 in Appendix B.

Soil Particle	Percentage (%)
Gravel	0 to 6
Sand	35 to 66
Silt	28 to 60
Clay	3 to 5

5.3 Peat

A 200 mm thick layer of peat was encountered below the embankment fill at a depth of 5.6 m in Borehole SW-2. The peat extended to a depth of 5.8 m (Elev. 182.3 m). A moisture content of 46% was measured in the peat.

5.4 Silty Sand to Sandy Silt

A deposit of silty sand to sandy silt with trace to some clay was encountered below the embankment fill in Boreholes 16-15, SW-1, SW-3 and SW-4. The deposit ranged in thickness from 0.3 to 3.1 m, and extended to depths ranging from 1.4 to 6.8 m (Elev. 181.3 to 182.6 m). The deposit was very loose to loose, based on SPT 'N' values from 1 to 7 blows per 0.3 m of penetration.

Measured moisture contents on samples of the silty sand to sandy silt ranged from 16% to 24%. The results of grain size distribution analyses conducted on a sample of the silty sand to sandy silt are presented on the Record of Borehole sheets included in Appendix E and are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	25
Silt	65
Clay	10

5.5 Silty Clay

Underlying the peat and silty sand to sandy silt deposits, a deposit of silty clay was encountered in all of the boreholes. The silty clay also contained trace sand and trace organics below the peat in Borehole SW-2. The layer ranged in thickness from 3.0 to 5.5 m, and extended to depths from 6.4 to 9.1 m (Elev. 177.1 to 178.8 m), except in Boreholes SW-2 and SW-3, which were terminated in the silty clay at depths of 10.5 and 10.1 m respectively (Elev. 177.6 and 178 m).

Measured SPT 'N' values in the silty clay ranged from 0 (weight of hammer) to 6 blows per 0.3 m penetration. In situ field vane tests measured undrained shear strengths of 12 to 24 kPa in Boreholes SW-1 and SW-4, which were drilled beyond the roadway embankment, and 20 to 35 kPa in Boreholes 16-15, SW-2 and SW-3, which were drilled through the roadway. Therefore, the silty clay is considered to generally have a soft consistency outside of the embankment fill, and a firm consistency below the embankment fill. The sensitivity of the silty clay was measured to range from 1 to 4, indicating low to medium sensitivity. Field vane tests measurements of 62 to greater than 100 kPa were also recorded near Elev. 178 in Boreholes SW-2 and SW-3, near the termination depth of the boreholes, and are likely due to the proximity of the underlying silt to sandy silt deposit. These values are not considered to be representative of the consistency of the entire silty clay deposit.

The measured moisture content of samples recovered from the silty clay ranged from 47% to 65%. The results of grain size analyses and Atterberg Limits tests conducted on samples of the silty clay are presented on the Record of Borehole sheets in Appendices A and E, and are summarized in the following table. The results from Borehole 16-15 are presented on Figures B3 and B5 in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	0
Silt	13 to 37
Clay	63 to 87
Soil Property	Percentage (%)
Liquid Limit	49 to 69
Plasticity Limit	17 to 24

The results of the Atterberg Limits tests indicate that the silty clay is typically of intermediate to high plasticity (CI to CH).

A consolidation test was performed on an undisturbed sample of the silty clay (thin walled tube sample), collected from Borehole 16-15. The results of the testing are presented in Appendix B and are summarized in the following table.

Consolidation Test Results

Borehole	Sample Depth (m)	e _o	C _c	C _r	p _c ' (kPa)	p _o ' (kPa)	OCR	c _v (m ² /yr)
16-15	7.6 – 8.2	1.17	0.30	0.03	110	105	1.05	5 x 10 ⁻⁴

5.6 Silt to Sandy Silt

A deposit of silt with trace to some sand and trace to some clay, ranging to sandy silt with trace clay was encountered below the silty clay in Boreholes 16-15, SW-1 and SW-4. The silt to sandy silt deposit ranged in thickness from 3.4 to 7.4 m, and extended to depths ranging from 11.8 to 14.3 m (Elev. 169.7 to 175.4 m). Borehole SW-1 was terminated upon split spoon refusal at the anticipated base of the deposit at a depth of 11.8 m (Elev. 173.2 m). SPT 'N' values within the silt to silty sand ranged from 1 to 14 blows per 0.3 m of penetration, indicating a very loose to compact relative density. SPT 'N' values of greater than 100 blows per 0.3 m were also recorded at the base of the deposit upon the interface with the underlying very dense deposit or bedrock.

Measured moisture contents within the silt to sandy silt deposit ranged between 15% and 25%. The results of grain size distribution analyses conducted on selected samples of the silt to sandy silt are presented on the Record of Borehole sheets included in Appendices A and E and are summarized in the following table. The results from Borehole 16-15 are presented on Figure B4 in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	4 to 24
Silt	72 to 89
Clay	4 to 9

5.7 Gravelly Silty Sand

A deposit of gravelly silt sand was encountered below the silt to sandy silt in Borehole SW-4. The Borehole was terminated at the anticipated base of the deposit at a depth of 15.8 m (Elev. 168.2 m). An SPT 'N' value of 114 blows per 0.3 m penetration was recorded within the gravelly silty sand deposit, indicating a very dense relative density.

5.8 Bedrock

Granite bedrock was encountered in Borehole 16-15 below the silt to sandy silt deposit at a depth of 12.5 m (Elev. 175.4 m), and was proven by coring 4.1 m into the bedrock. The bedrock is generally described as slightly weathered and grey. Total Core Recovery (TCR) in the bedrock ranged from 80 to 96% with Solid Core Recovery (SCR) ranging from 67 to 92%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 39 to 84%, indicating poor to good rock quality. Average unconfined compressive strengths (UCS) of the rock ranged between 209 and 279 MPa based on correlations with the point load tests (PLT), indicating very strong to extremely strong rock strength.

5.9 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. The groundwater levels measured in the open boreholes are summarized in Table 5.1 below. Groundwater levels reported in the Golder report are also included.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-15	August 9, 2016	3.8	184.1	Open borehole following coring operation
SW-1	March 23, 2015	2.6	182.4	Open borehole
SW-2	March 13, 2015	5.3	182.8	Open borehole
SW-3	March 13, 2015	5.3	182.8	Open borehole
SW-4	March 24, 2015	1.2	182.8	Open borehole

Water level measurements in the creek were reported in the Hatch Structural Design Report and the Golder preliminary investigation, and are summarized in Table 5.1 below. The groundwater level should be assumed to reflect the local creek water level.

Table 5.2 – Creek Level Measurements

Date	Elevation (m)	Source
May 12, 2014	182.9 (outlet)	Hatch Structural Design Report
Nov. 2014	183.1	Hatch Structural Design Report
March 13, 2015	183.9 (outlet)	Golder Preliminary FIDR

The groundwater levels above are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native silty sand from Borehole 16-01, and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B. The results of testing on a sample of surface water are also included in the preliminary FIDR.

Table 6.1 – Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results	
			16-15, SS#4, 10'-12'	Sawmill Creek
			(Silty Sand)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	120	1.0
Sulphate	µg/g	mg/L	1.2	3.9
pH	No unit	No unit	7.85 to 9.32	7.42
Electrical Conductivity	µS/cm	µS/cm	305	87
Resistivity	Ohms.cm	Ohms.cm	3280	11500
Redox Potential	mV	mV	243	289

7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by Hatch.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. Omar Ali and Mr. Tim Sivak of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory, with consolidation and additional geotechnical testing conducted at TBTE's laboratory in Thunder Bay, Ontario. Analytical laboratory testing was carried out by SGS Canada Inc. Interpretation of the field data and preparation of this report was carried out by Mr. Mark Farrant, 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

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for detailed design of the proposed Sawmill Creek Culvert replacement on Highway 17, located east of Terrace Bay, Thunder Bay District, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference and the Structural Design Report (SDR) for the preliminary design of the project, titled "Sawmill Creek Culvert, Site No. 48E-050C, Highway 17", prepared by Hatch Mott MacDonald, dated December 2015. The Structural Design Report provided discussion on the existing structure, discussion of alternatives for the proposed culvert replacement, and recommendations for the preferred alternative.

The existing structure is a 27.3 m long, 6.1 m span by 1.8 m high, cast-in-place, rigid concrete box. The SDR indicates the culvert upstream invert is at approximate Elev. 182.9 m, and the downstream invert is at Elev. 182.5. The top of obvert is at approximate Elev. 184.9. The finished road grade is indicated at Elev. 188.1, which results in approximately 3.2 m of fill above the culvert.

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The 2014 structural inspection report notes that about 400 mm of settlement has occurred at the midpoint of the culvert. As discussed in the preliminary FIDR, the settlement is likely due to loading of the relatively high embankment over the 3.0 to 5.5 m thick, soft to firm silty clay deposit, where primary consolidation has likely already occurred, but long-term secondary (creep) settlement may be continuing.

In the process of the preliminary design the following options for the replacement structure were considered:

- Option 1 – Single-Cell Precast Concrete Closed Box
- Option 2 – Precast Open Footing Metal Box Culvert
- Option 3 – Precast Open Footing Concrete Box Culvert
- Option 4 – Multiple Round Corrugated Steel Pipe Culvert

As described in the SDR, the preferred structure alternative is Option 4, which is reported to satisfy all of the design criteria and results in a favorable aquatic environment while providing a lightweight, cost effective replacement option. With Option 4, the proposed structure would consist of three polymer laminated or aluminized, 33.5 m long, 2.4 m diameter round corrugated steel pipe (CSP) culverts. The SDR also identifies Option 1 (concrete closed box) as a viable culvert replacement alternative, with some advantages over Option 4, although it would be more expensive. Both of the CSP and concrete closed box options are discussed in Section 9 below, as well as other potential replacement alternatives.

The culvert replacement is proposed to be constructed utilizing a traffic staging, which would require installation of a temporary roadway protection system and a temporary stream diversion pipe (CSP).

Preliminary General Arrangement (GA) drawings for both the CSP and concrete closed box options were included in the SDR, which show the proposed replacement culvert and the temporary diversion pipe arrangement. The invert and alignment of the replacement culvert and the finished road grade level will remain largely the same as for the existing culvert. A headwall is proposed at the east end of the culvert (inlet). Lengthening of the culvert by about 6.5 m is proposed at the west end (outlet), which will require placement of additional fill to widen the embankment slope.

The discussions and recommendations presented in this report are based on information provided by Hatch and on the factual data obtained during the course of the current investigation. In addition, the existing subsurface information collected during the preliminary investigation and documented in the Geocres Report No. 42D-39 has been reviewed and incorporated in this report,

where appropriate. The subsurface information, including the Record of Borehole sheets and the Borehole Locations and Soil Strata drawings, from both the current and preliminary investigations should be included in the contract documents.

9. CULVERT DESIGN

9.1 Culvert Alternatives

This section presents discussions on available types of replacement culverts and foundation alternatives, and provides recommendations on preferred foundation options.

Several common culvert types that may be considered for the culvert replacement at this site are listed below:

- Corrugated steel pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete box or metal box, open footing culvert
- Sheet pile walls with precast concrete panels

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix F. From a foundations and constructability perspective, use of the CSP or pre-cast concrete box culverts are preferred over the open footing option, based on the following considerations:

- Pre-cast box or pipe culverts would require shallower depth of excavation compared with the open footing culvert;
- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast in place open footing culverts, resulting in shorter durations for dewatering and construction;
- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis.

The open footing culvert is not recommended at this site due to the low geotechnical capacities in the soft to firm silty clay foundation soils, the greater potential for differential settlement, and the need for deeper excavation and additional dewatering effort to provide adequate frost protection.

The precast cap panels supported on steel sheet piles option is understood to not be preferred by MTO on major highways, such as Highway 17. Additional drilling to greater depths may also be required to confirm sheet pile design if this type of culvert were to be considered. Therefore, recommendations for this type of culvert are not included in this report.

Recommendations for the design and installation of CSP and concrete box culverts are presented below.

9.2 Summary of Subsurface Conditions

In general, the subsurface conditions encountered in the boreholes from the current and preliminary investigations consisted of up to 5.5 m of embankment fill overlying native very loose to loose silty sand to sandy silt, a 3 to 5.5 m thick layer of soft to firm silty clay, and a 3.4 to 7.4 m thick very loose to compact silt to sandy silt deposit. A 200 mm thick peat layer was also encountered beneath the embankment fill in one borehole. A deeper gravelly silty sand deposit and granite bedrock also underlie the site.

Water levels in the open boreholes and the creek ranging from 182.9 to 183.9 m have been reported.

9.3 Foundation Design for Culverts

9.3.1 Corrugated Steel Pipe Culvert

Replacement of the culvert with multiple CSPs on the same alignment is identified in the SDR as the preferred option for this site. In order to accommodate the hydraulic requirements, multiple pipes are required. The proposed invert level of the culverts will be at approximate Elev. 182.5 to 182.9 m. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the replacement culvert, except where additional fill will be placed to lengthen the culvert at the outlet. Settlement due to embankment widening is discussed in Section 9.3.5.

If this alternative is selected, the CSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation must be carried out in the dry. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elev. 182.2 m, which corresponds to a subgrade that varies from loose to very loose silty sand and sandy silt to soft to firm silty clay.

9.3.2 Concrete Box Culvert

Replacement of the culvert with a concrete box culvert on the same alignment is identified in the SDR as a viable alternative for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the replacement culvert, except where additional fill will be placed to lengthen the culvert at the outlet. Settlement due to embankment widening is discussed in Section 9.3.5.

In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, similar to as shown on OPSD 803.010. The bedding material must be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation must be carried out in the dry. The surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elev. 182.2 m, which corresponds to a subgrade that varies from loose to very loose silty sand and sandy silt to soft to firm silty clay.

The following geotechnical capacities could be used for design of a box culvert of 6 to 7 m in width and founded at or below Elev. 182.2 m on the very loose to loose silty sand to sandy silt or soft to firm native silty clay subgrade:

- Factored Geotechnical Resistance at ULS of 140 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement*) of 100 kPa.

*The 25 mm of settlement is based on the embankment loading over the culvert, and does not include the anticipated long-term secondary settlement identified in the preliminary FIDR. Further discussion on settlement is provided in Section 9.3.5.

The consequence factor of 1 was utilized in this design adopting the typical consequence

level. The geotechnical resistance factor of 0.5 for bearing, and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Sec. 6.9.

The ULS resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should therefore be reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an ultimate coefficient of friction of 0.45.

The culvert should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

9.3.3 Culvert Headwall / Wingwalls

The GA drawings in the SDR show a proposed headwall and wingwalls at the inlet of the replacement culvert. If headwalls and wingwalls are required, consideration may be given to using Retained Soil Systems (RSS) walls, which are more tolerant of settlement relative to cantilevered concrete walls. In light of the potential for significant settlement at this site, cantilevered concrete walls are not considered to be a good option.

The borehole information indicates that the founding conditions at the wall locations generally consist of the soft to firm silty clay deposit.

9.3.3.1 RSS Walls

For RSS walls, the contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion

of the RSS and, in severe cases, to possible failure of the system. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

To provide an acceptable foundation performance, the RSS mass should be founded on a 500 mm thick engineered fill pad resting on the soft to firm silty clay subgrade at or below an approximate elevation of 182 m or lower. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 75 kPa and a geotechnical reaction at SLS of 50 kPa (for up to 25 mm of settlement). Minimal fill should be placed above the walls to reduce the potential for significant additional settlement. Engineered fill pads placed under the RSS mass must consist of OPSS PROV Granular A or Granular B Type II compacted to 100% of its SPMD at a moisture content within 2% of optimum. The engineered pad must be at least 300 mm beyond the limits of the RSS mass and levelling strip.

If these geotechnical resistances are not adequate to support the proposed RSS walls, Thurber should be contacted for additional assessment of alternate measures to accommodate an RSS system.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.45 for an engineered granular fill subgrade.

Topsoil, loose fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected and any soft spots sub-excavated and replaced with compacted granular materials prior to placing fill. The subgrade preparation for the RSS wall must be carried out in the dry.

The proprietary RSS system must meet the Ministry's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall must be analyzed by the supplier/designer of the proprietary product selected for this site.

Global stability of the RSS walls must be analyzed once the detailed configurations of the walls are known.

9.3.4 Frost Cover

The depth of frost penetration at this site is approximately 2.2 m. The pipe and box culvert options do not require frost cover/protection.

If required, frost treatment/taper for the culvert should be in accordance with OPSD 803.031 for a pipe culvert and with OPSD 803.010 for a box culvert.

9.3.5 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, peat, organic creekbed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with granular material compacted as per OPSS.PROV 501. The peat noted below the embankment fill in Borehole SW-2 must be removed to expose the underlying native silty clay at or below Elev. 182.2 m.

In the event that subexcavation is required, the width of the subexcavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The subexcavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501.

The work should be carried out in accordance with OPSS 902 and culvert construction and subgrade preparation must be carried out in the dry.

9.3.6 Settlement

Due to the presence of approximately 3.5 m of embankment fill above the existing culvert, which overlies a 3.0 to 5.5 m thick soft to firm silty clay layer, significant settlement in the order of 400 mm has previously been reported at the site. The settlement assessment conducted in the preliminary FIDR indicates that 100% of primary consolidation of the silty clay deposit has likely occurred, however secondary consolidation (creep) is still expected

under the existing embankment loading. The magnitude of creep settlement is estimated in the preliminary FIDR to be in the order of 25 to 50 mm over a 20 year design period.

The preferred culvert replacement option of multiple CSPs in the SDR results in a small net unloading on the silty clay due to the larger overall culvert opening size and the lightweight CSPs relative to the existing concrete box culvert. However, creep settlement in the order of 25 to 50 mm is also still anticipated to occur under the embankment fill and the replacement culvert. The replacement culvert must be designed to tolerate the estimated settlement. One option to accommodate the settlement is to use oversized replacement CSPs.

The GA drawings also show a proposed lengthening of the culvert at the outlet, which includes placement of up to 3 m of additional fill to widen the embankment slope. The additional fill will induce additional long term settlement (both primary and secondary) beyond the existing embankment footprint. Long-term settlement is estimated to be in the order of 250 to 300 mm. If the culvert lengthening is required, the culvert must also be designed to tolerate this additional settlement. One option is to oversize the replacement CSPs. Alternatively, to minimize settlement due to the additional fill, consideration could be given to using a headwall to avoid the culvert extension, maintain the existing embankment footprint, and flatten the slope above the headwall, such as proposed on the GA drawing at the inlet of the culvert.

In lieu of a headwall, another option is to construct the side slopes of the embankment at both ends of the culvert using rock fill in order to steepen the slopes to 1.5H:1V. The rock fill should be keyed into the ground at the toe of slope by 0.5 m and should be benched into the granular fill of the embankment as per OPSD 208.010. The rock fill slope protection should have a minimum thickness of 1.0 m. The 1.5H:1V slopes above the culvert should be gradually transitioned to match the 2H:1V embankment slopes beyond the culvert replacement.

9.4 Construction Considerations

As indicated in the SDR, construction staging will be required to maintain one lane of traffic.

Staged construction sequencing will likely require the following:

- Diversion of the creek will be required for construction. In addition, a suitable dewatering plan will be required to construct the culvert in the dry.

- Temporary roadway protection may be required during all stages of construction, including excavation and removal of the existing culvert, installation of the new culvert and backfilling.
- All culvert subgrade preparation and foundation preparation must be carried out in the dry.

10. EXCAVATION AND GROUNDWATER CONTROL

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native silty sand to sandy silt at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. The native silty clay is considered to be Type 4 soil. Surficial alluvial deposits that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS 902.

Excavations for culvert replacement will be carried out through the existing embankment fill, native silty sand to sandy silt, and extended into the native silty clay deposit.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level, and diversion of the creek flow will be required. Although the permeability of the native silty clay is expected to be relatively low, seepage should be anticipated from the embankment fill and the silty sand to sandy silt adjacent to the creek. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps within an enclosure will be required to maintain dry excavations during the course of staged construction. The groundwater level should be maintained at a depth of at least 0.5 m below the final subgrade level.

The design of an effective dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. Dewatering must remain operational and effective until the culvert is installed and backfilled. Suggesting wording for an NSSP in this regard is included in Appendix G.

11. STREAM DIVERSION PIPE

The Preliminary General Arrangement drawing indicates a CSP stream diversion pipe located approximately 12 m to the east of the centreline of the new culvert. The invert of the diversion pipe is indicated at approximately Elev. 182.7 m, which corresponds to a loose to very loose silty

sand to sandy silt subgrade. Temporary shoring may be required to install the diversion pipe at the proposed depth of approximately 6.4 m.

The CSP should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. The prepared subgrade should be protected from disturbance during construction.

12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 401 for a CSP and OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally 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 below)
γ	=	bulk unit weight of retained soil (see table below)
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 12.1 below.

Table 12.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$		Existing Fill $\phi = 30^\circ$; $\gamma = 20 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive	3.7	-	3.3	-	3.0	-

Note: Submerged unit weight should be used below the groundwater level/high creek level.

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall.

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 culvert.

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site includes a highly plastic, soft to firm, silty clay later of greater than 3 m in thickness. This corresponds to a Seismic Site Class E in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.033 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, 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 13.1 may be used:

Table 13.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I (modified) $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 30^\circ, \gamma = 20 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33	0.36
Passive (K_{PE})	3.6	3.2	2.9
At Rest (K_{OE})**	0.51	0.55	0.58

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

** After Woods

Although the site is underlain by soft to firm silty clay, in view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

14. TEMPORARY PROTECTION SYSTEM

Temporary roadway protection system should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2.

Options for roadway protection are a soldier pile-lagging system or interlocking sheet piles.

The soil parameters in Table 14.1 may apply for design of the temporary roadway protection system with horizontal backfill.

Table 14.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Silty Sand to Sandy Silt	Native Silty Clay
γ	20 kN/m ³	20 kN/m ³	19 kN/m ³
γ_w	10 kN/m ³	10 kN/m ³	9 kN/m ³
K_a	0.33	0.33	0.4
K_p	3.0	3.0	2.5

Full hydrostatic pressure should be considered assuming a water level at least equal to the design creek water level.

The design of temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors have to be considered when

designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

15. EMBANKMENT RESTORATION

The GA drawings in the SDR show that a headwall and a culvert extension are proposed and the embankment side slopes will be flattened. Provided that the embankment is reconstructed with side slopes inclined at not steeper than 2H:1V, the restored embankment slope should remain stable. As discussed in Section 9.3.5 however, settlement of the embankment in the order of 25 to 50 mm should be expected under the existing culvert footprint, and settlement in the order of 250 to 300 mm or greater should be expected due to placement of the additional fill above the culvert extension.

As discussed in Section 9.3.6, an alternate approach to mitigating settlement from additional fill placement above the culvert extension, would be to steepen the embankment side slopes to 1.5H:1V by constructing them using rock fill. The rock fill should be keyed into the original ground at the toe of slope by 0.5 m and should be benched into the granular fill of the embankment as per OPSD 208.010. The rock fill slope protection should have a minimum thickness of 1.0 m. The 1.5H:1V slopes above the culvert should be gradually transitioned to match the 2H:1V embankment slopes beyond the culvert replacement. A stability analysis was conducted for rock fill side slopes keyed into the ground in this manner. Figures 1 and 2 in Appendix H show that both the short and long term cases will be stable, with a Factor of Safety of 1.45 for each.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. Alternatively the existing silt and sand to gravelly sand embankment fill may be used, provided it is free of organics, and at a moisture content that it is suitable for compaction.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel should be conducted.

16. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

A concrete cut-off wall or clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 1 m. The material requirements should be in accordance with OPSS PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

17. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the native soil and creek water from the current and preliminary investigations indicates the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding native soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested.
- The potential for soil or surface water corrosion on metal is considered to be mild to moderate.
- Appropriate protection measures are recommended if metal structural elements are used.

18. CONSTRUCTION CONCERNS

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

- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.

- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix G.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

19. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Mark Farrant P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



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Review Principal, Designated MTO Contact

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
 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.

EXPLANATION OF ROCK LOGGING TERMS


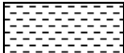



ROCK WEATHERING CLASSIFICATION

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.

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	Approximate Uniaxial Compressive Strength (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

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 % 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.

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			

RECORD OF BOREHOLE No 16-15

1 OF 2

METRIC

W.P. 6366-14-01 LOCATION Sawmill Creek Culvert N 5 409 628.1 E 309 033.1 ORIGINATED BY OA/TS
 HWY 17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2016.07.27 - 2016.08.09 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
187.9	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT: (150mm)							20	40	60	80	100					
0.2	Gravelly SAND, some silt Brown Moist (FILL)		1	GS													21 66 13 (SI+CL)
187.0							187										
0.9	SAND and SILT, trace to some gravel, trace clay Compact to Loose Grey Moist (FILL)		1	SS	10												
			2	SS	10		186										
			3	SS	6												0 51 46 3
184.9							185										
3.0	Silty SAND Loose to Very Loose Grey Wet		4	SS	4												
							184										
			5	SS	2		183										
							182										
181.8			6	SS	0												0 0 37 63
6.1	Silty CLAY Soft Grey Wet (Cl to CH)						181										
			1	TW			180										0 0 13 87
							179										
178.8																	
9.1	SILT, some sand, trace clay Very Loose Grey Wet		7	SS	4												
							178										

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

ONTMT4S 13662-MTO.GPJ 2017TEMPLATE(MTO).GDT 8/15/17

RECORD OF BOREHOLE No 16-15

2 OF 2

METRIC

W.P. 6366-14-01 LOCATION Sawmill Creek Culvert N 5 409 628.1 E 309 033.1 ORIGINATED BY OA/TS
 HWY 17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2016.07.27 - 2016.08.09 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	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 (%)						
							20 40 60 80 100							

ONTMT4S 13662-MTO.GPJ 2017TEMPLATE(MTO).GDT 8/15/17

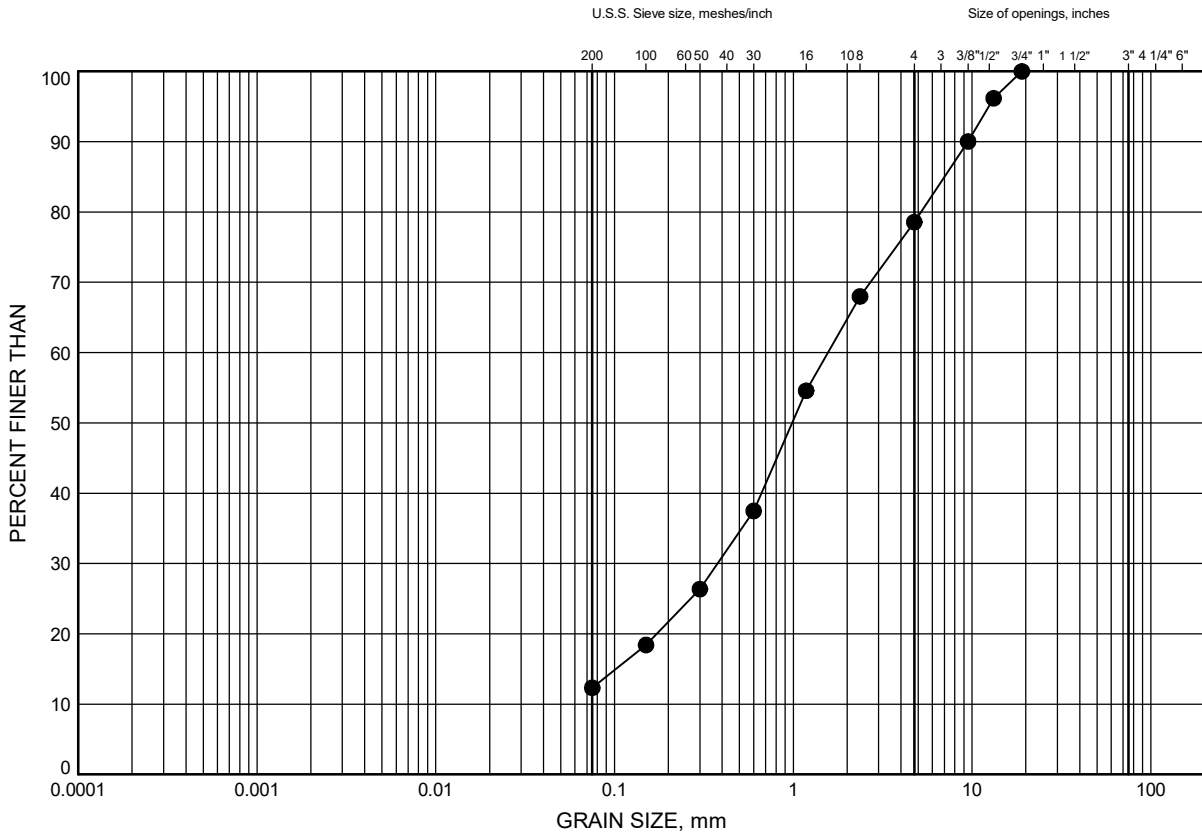
Appendix B

Geotechnical and Analytical Laboratory Test Results

Sawmill Creek Culvert Replacement
GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-15	0.3	187.6

Date August 2017
W.P. 6366-14-01



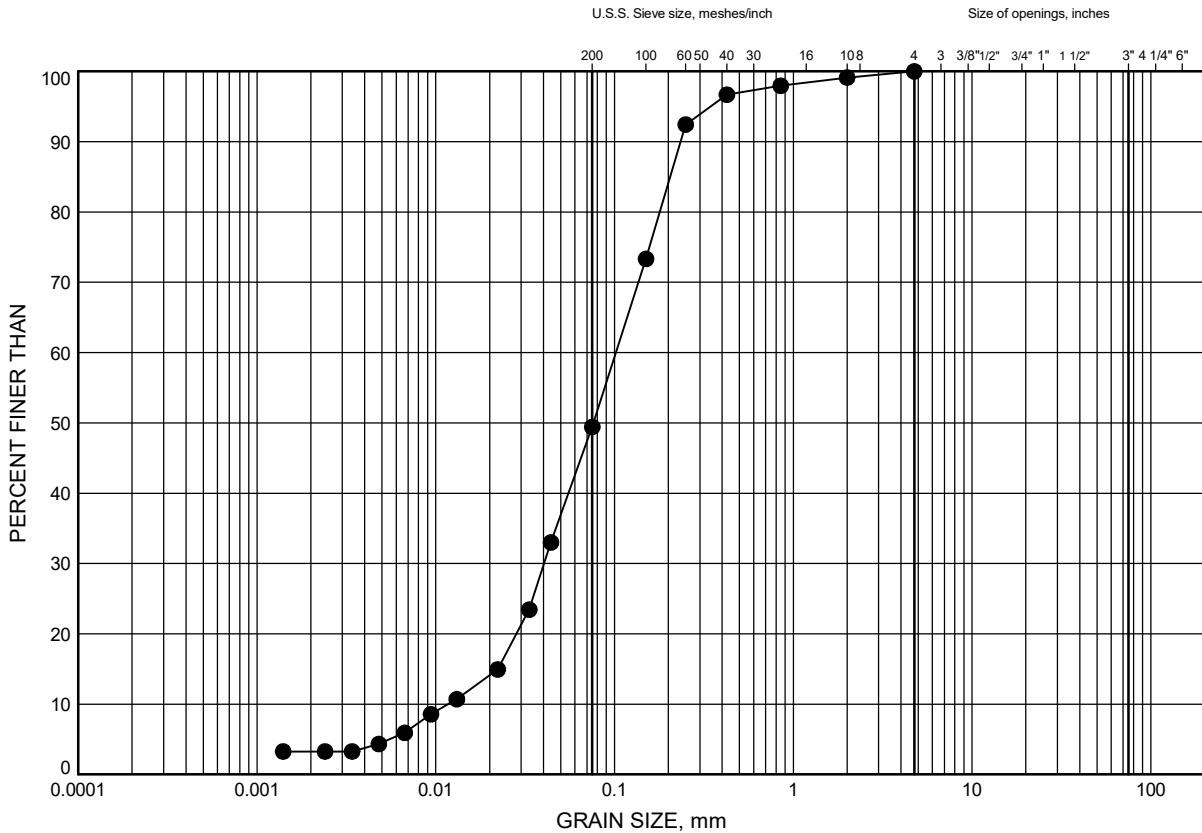
Prep'd MFA
Chkd. MEF

Sawmill Creek Culvert Replacement

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND and SILT FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-15	2.6	185.3

Date August 2017
W.P. 6366-14-01



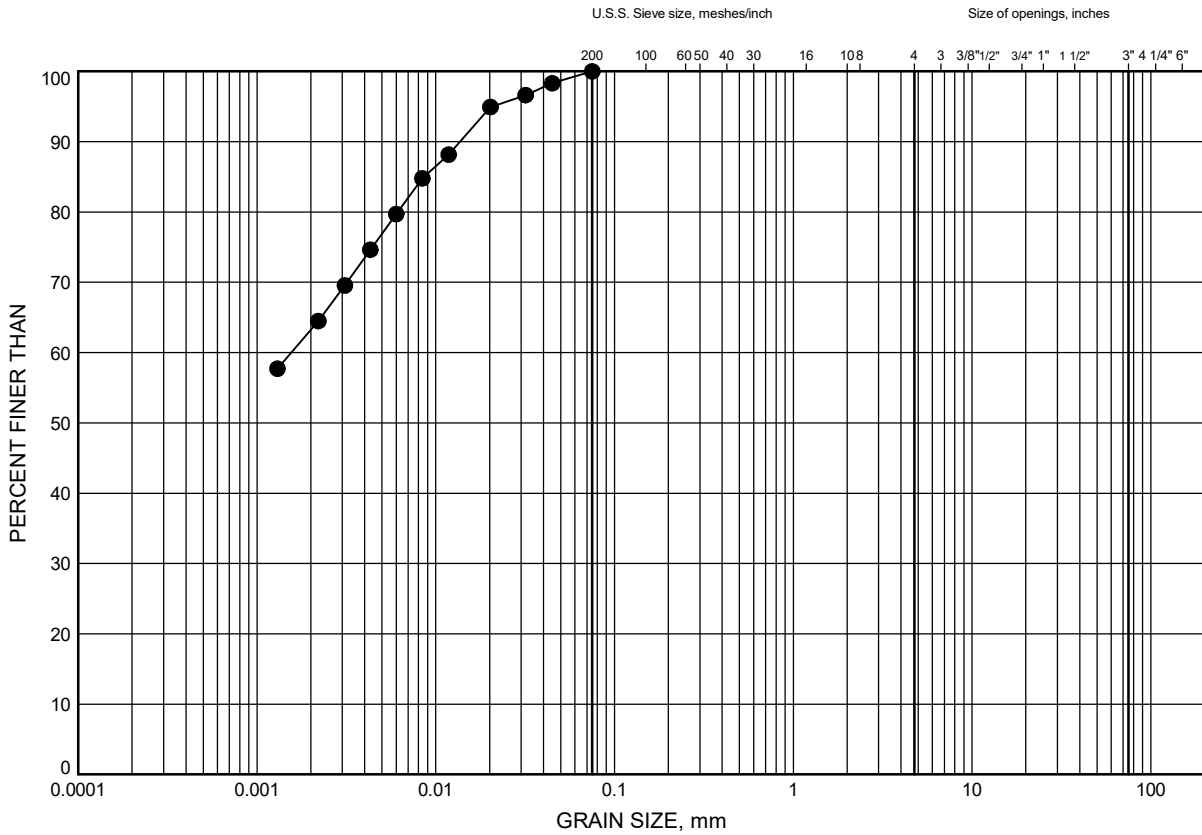
Prep'd MFA
Chkd. MEF

Sawmill Creek Culvert Replacement

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)
●	16-15	6.4	181.5

Date August 2017
W.P. 6366-14-01

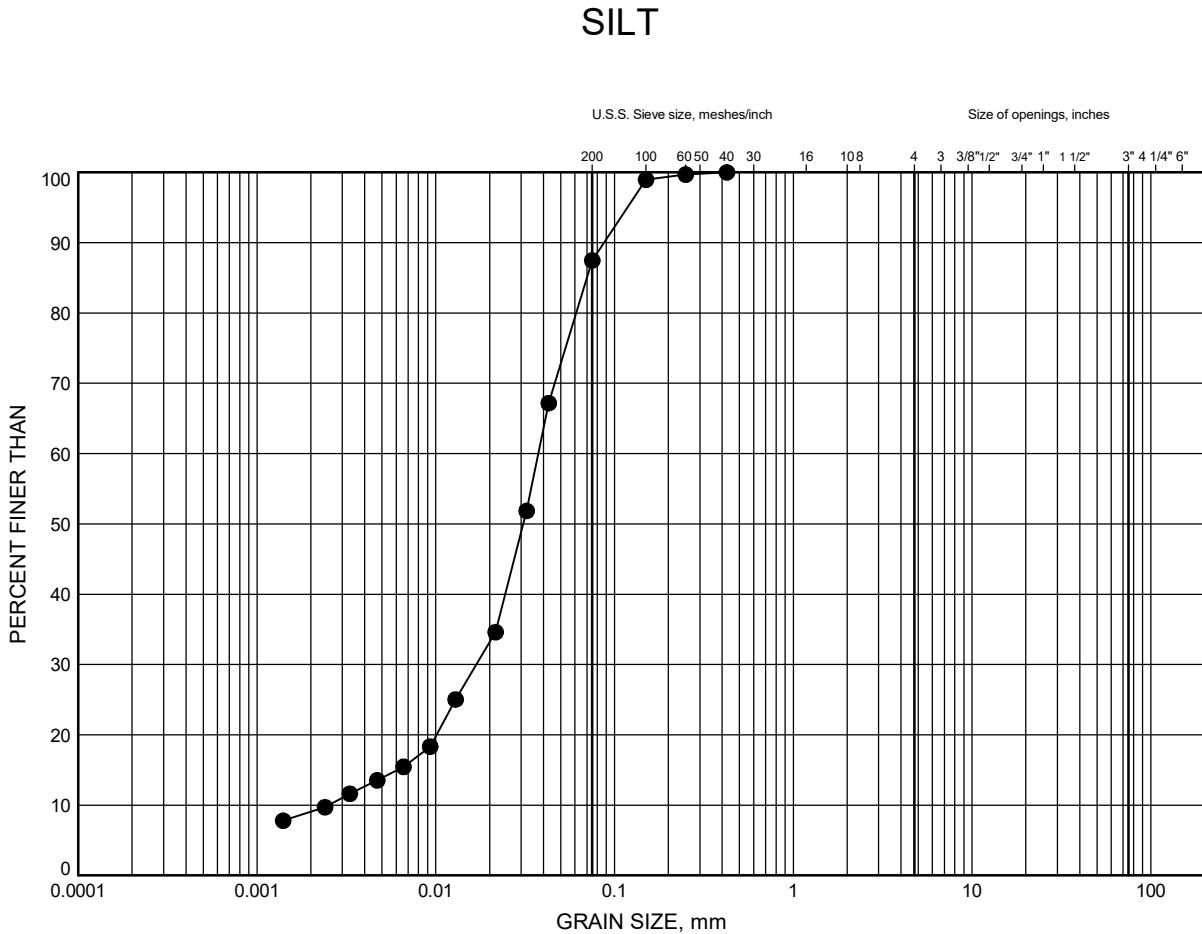


Prep'd MFA
Chkd. MEF

Sawmill Creek Culvert Replacement

GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-15	11.0	176.9

Date August 2017
W.P. 6366-14-01

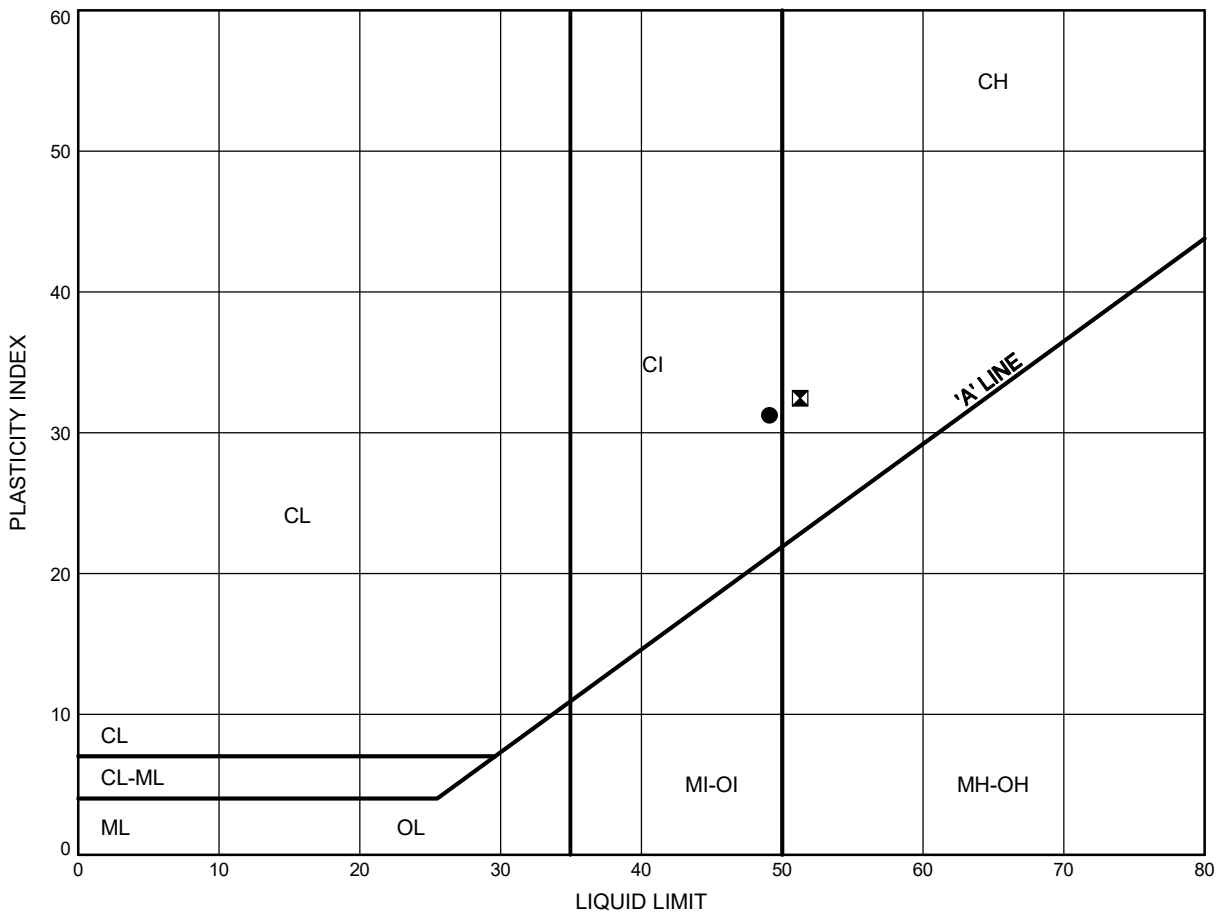


Prep'd MFA
Chkd. MEF

Sawmill Creek Culvert Replacement
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty CLAY



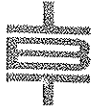
LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-15	6.4	181.5
⊠	16-15	7.9	180.0


Date August 2017
W.P. 6366-14-01



Prep'd MFA
Chkd. MEF



Grain Size Analysis of Soil By Hydrometer

Client:	Thurber Engineering Ltd.	TBTE Project No.:	16-239
Project No.:		Lab No.:	16-1010
Location:	Sawmill Creek Culvert	Borehole No.:	16-15
	Hwy 17, Terrace Bay On Area	Sample No.:	ST 1
Reported To:	Mark Farrant	Depth:	25' - 27'
Sampled By/Date:	Client / N/A	Tested By/Date:	FV / GH / August 23, 2016
Reported By:	Forch Valela	Reviewed By:	Tim Fummerton 

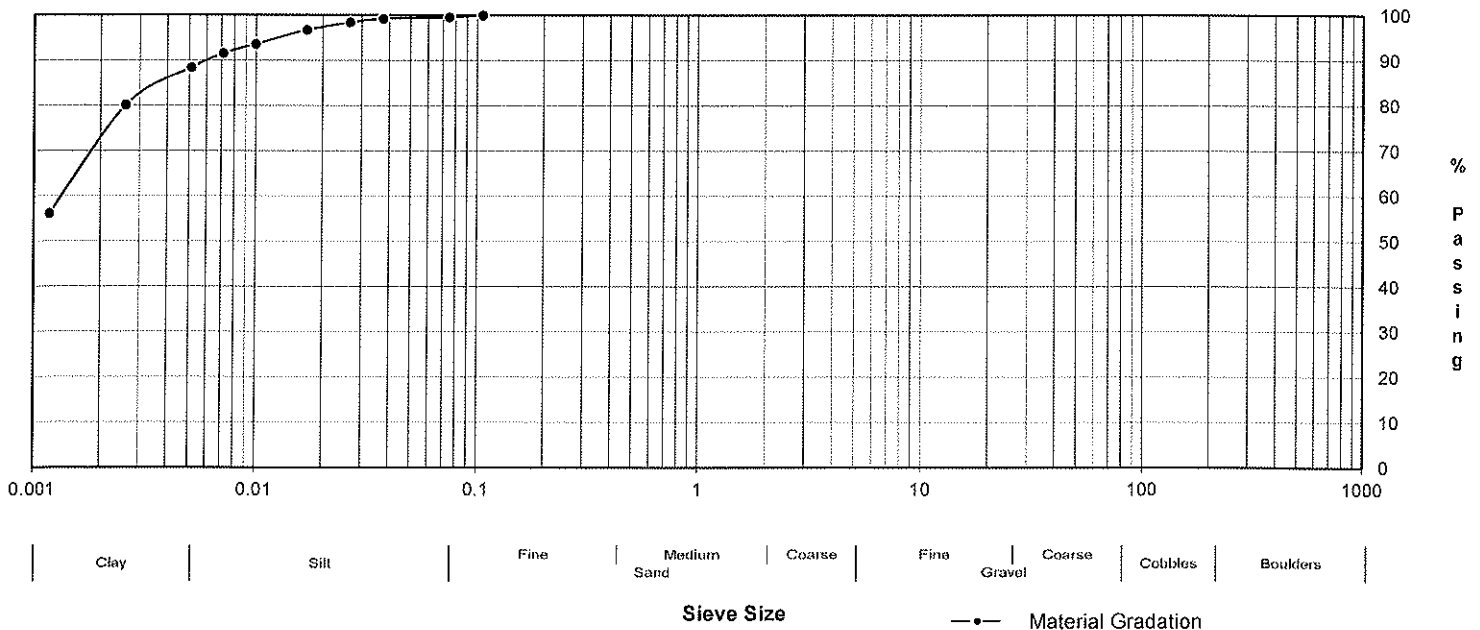
Sieve Analysis

Sieve (mm)	% Passing
50.0	
37.5	
25.0	
19.0	
13.2	
9.5	
4.75	
2.00	
0.850	
0.425	
0.250	
0.106	100.0
0.075	99.6

Hydrometer Analysis

Diameter (mm)	% Finer
0.037541	99.2
0.026657	98.4
0.017000	96.7
0.009965	93.6
0.007143	91.5
0.005123	88.4
0.002593	80.1
0.001182	56.2
5 µm	87.0
2 µm	72.5

Grain Size Analysis



%Gravel		% Silt	12.6	% NMC	47.1	Soil Relative Density	2.625	Soil Classification	CH
% Sand	0.4	% Clay	87.0	PI	32				

Remarks: Test Method LS 701, 702, ASTM D2216, D4318



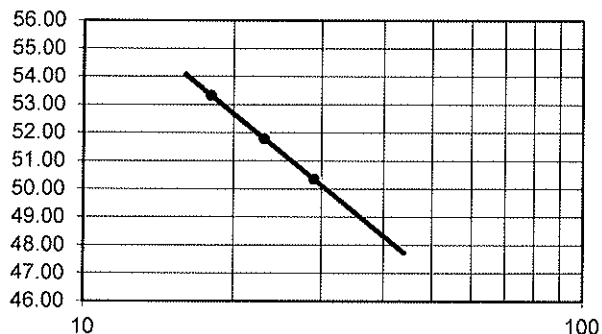
Atterberg Limits

Client:	Thurber Engineering Ltd.	TBTE Project No.:	16-239
Project No.:		Lab No.:	16-1010
Location:	Sawmill Creek Culvert	Borehole No.	16-15
	Hwy 17, Terrace Bay On Area	Sample No.:	ST 1
Reported To:	Mark Farrant	Depth:	25' - 27'
Sampled By/Date:	Client / N/A	Tested By/Date:	G.Homac / August 22, 2016
Reported By:	Forch Valela	Reviewed By:	Tim Fummerton <i>TF</i>

Liquid Limit Determination

Dish No.:	0	uu	ll		Liquid Limit 25 Blows
Wet Soil + Dish:	39.59	41.591	40.423		
Dry Soil + Dish:	35.883	37.084	36.299		
Moisture:	3.707	4.507	4.124		
Dish:	28.521	28.383	28.568		
Dry Soil:	7.362	8.701	7.731		
% Moisture:	50.35	51.80	53.34		
No. of Blows:	29	23	18		
Liquid Limits:	51	51	51		51

Liquid Limit



Liquid Limit, %:	51
Plastic Limit, %:	19
Plasticity Index:	32

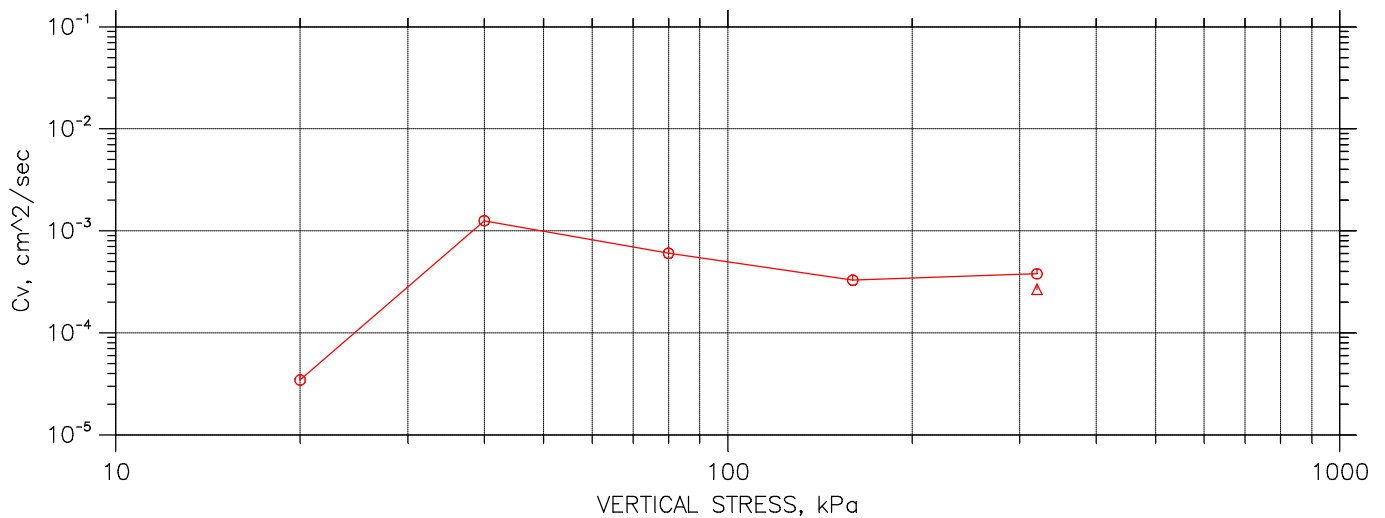
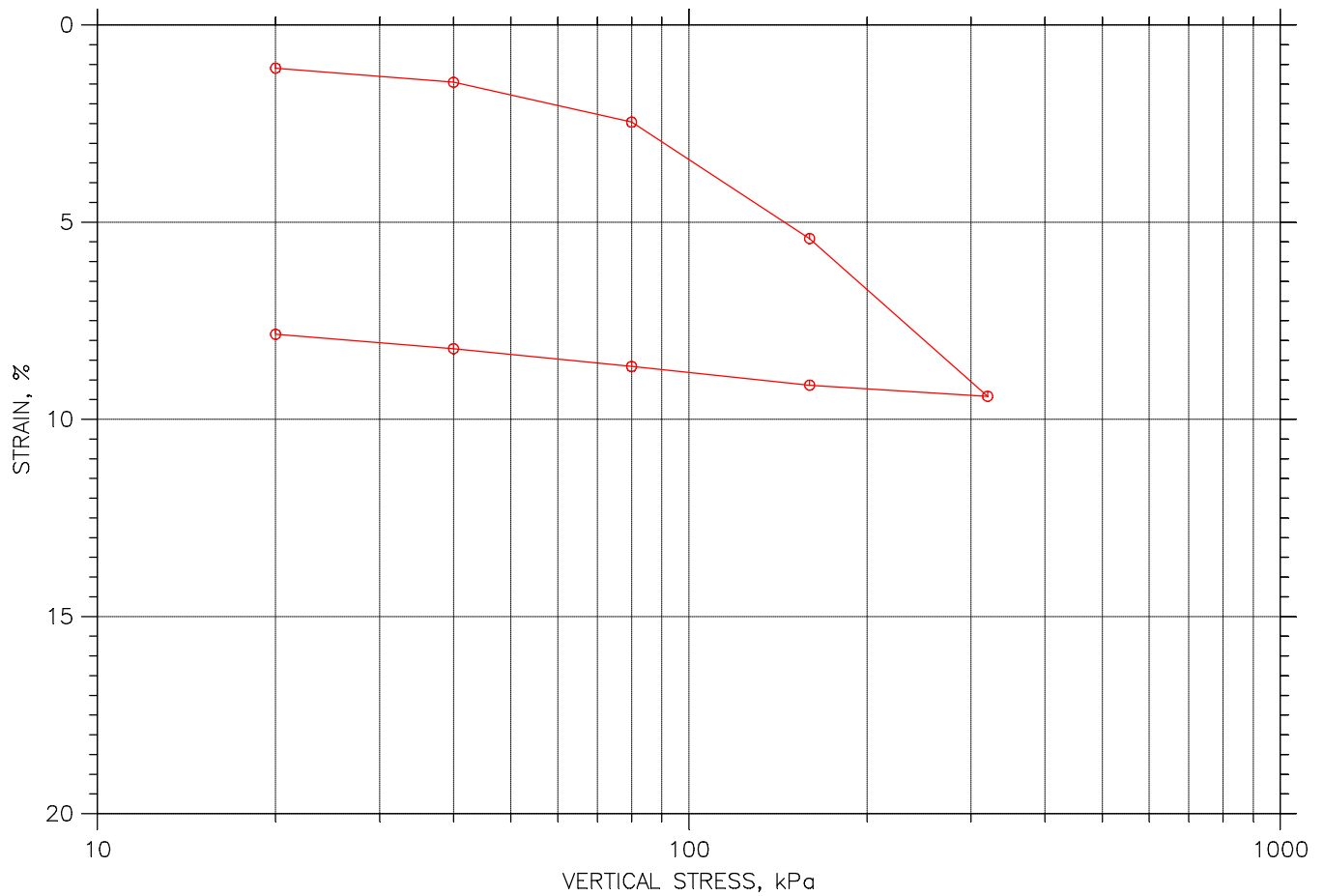
Plastic Limit Determination


Dish No.:	1	2		Natural Moisture
Wet Soil + Dish:	26.859	26.389		184.65
Dry Soil + Dish:	25.69	25.254		164.52
Moisture:	1.169	1.135		20.13
Dish:	19.498	19.216		121.77
Dry Soil:	6.192	6.038		42.75
% Moisture:	18.88	18.80		47.1
Average:		19		

Test Method : ASTM: D4318, D2216

CONSOLIDATION TEST DATA

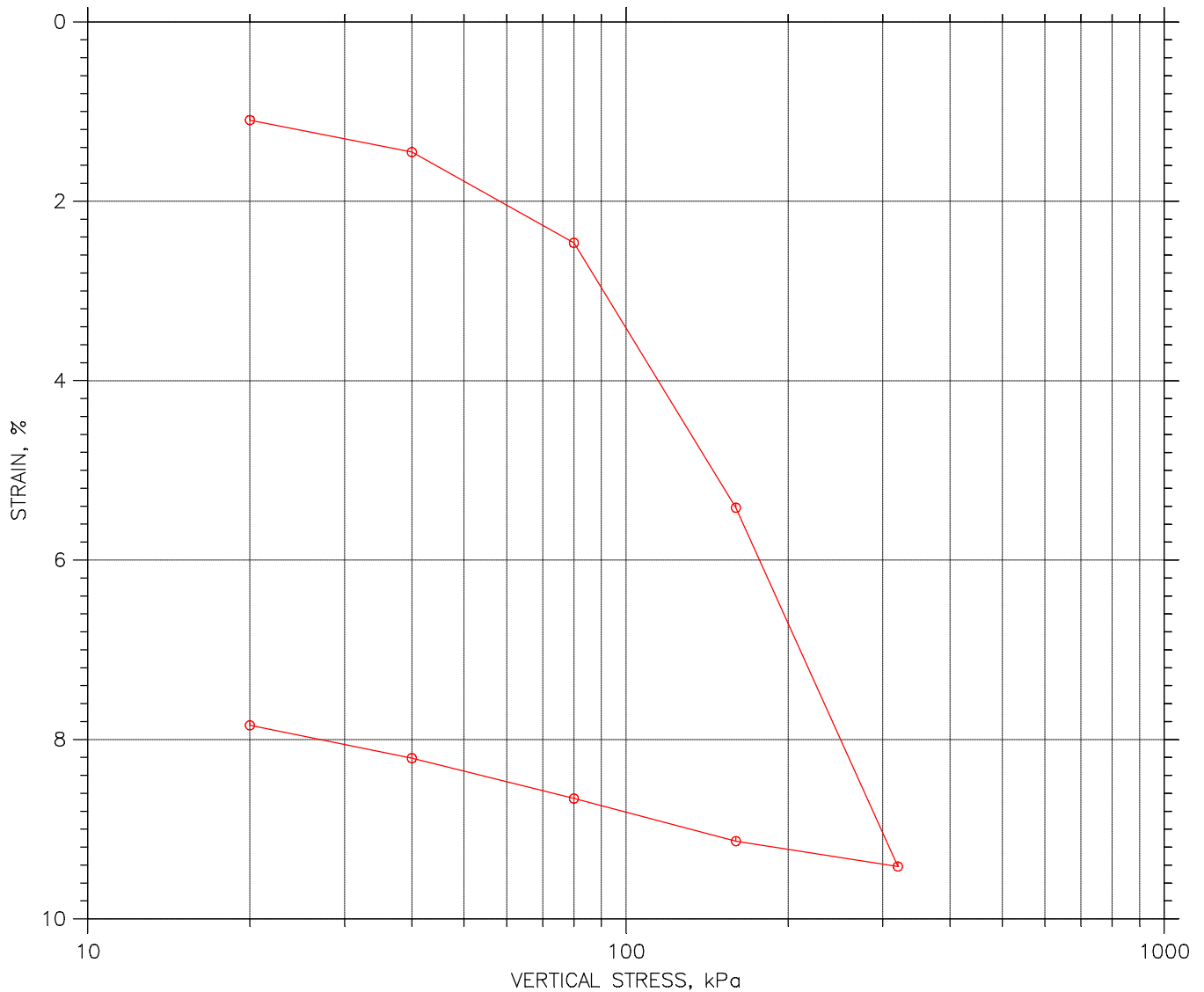
SUMMARY REPORT




	Project: Hwy 17	Location: Sawmill Creek Culvert	Project No.:
	Boring No.:	Tested By: Tim	Checked By: GM
	Sample No.: ST 1	Test Date: Aug 18/16	Depth: 25'-27'
	Test No.: 1	Sample Type: TW	Elevation:
	Description: Soft Grey Clay		
	Remarks:		

CONSOLIDATION TEST DATA

SUMMARY REPORT

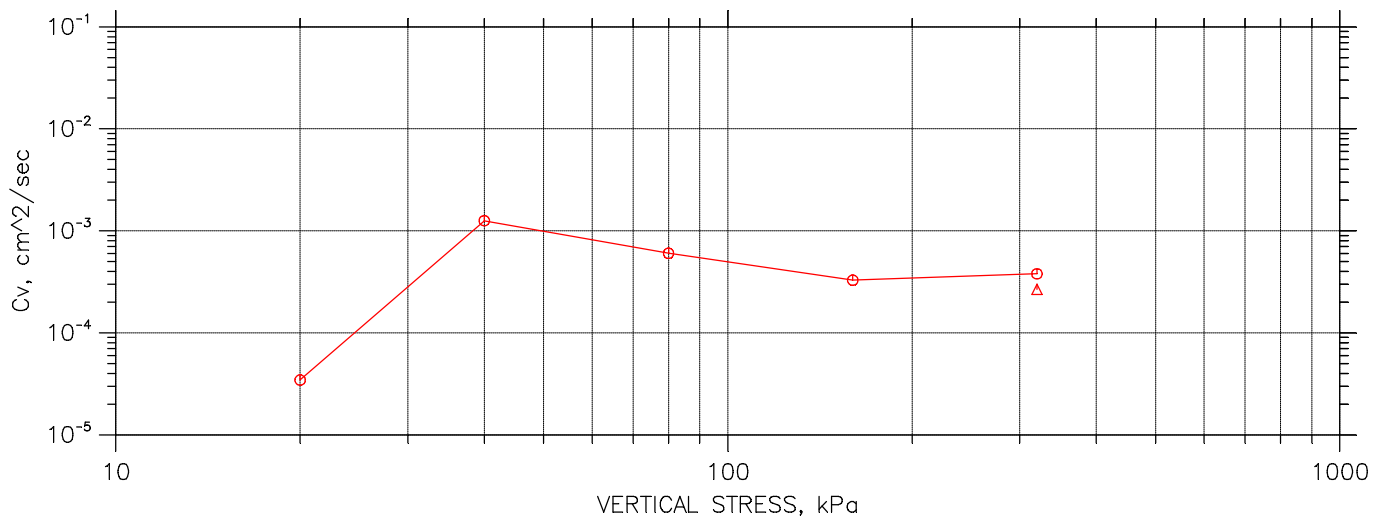
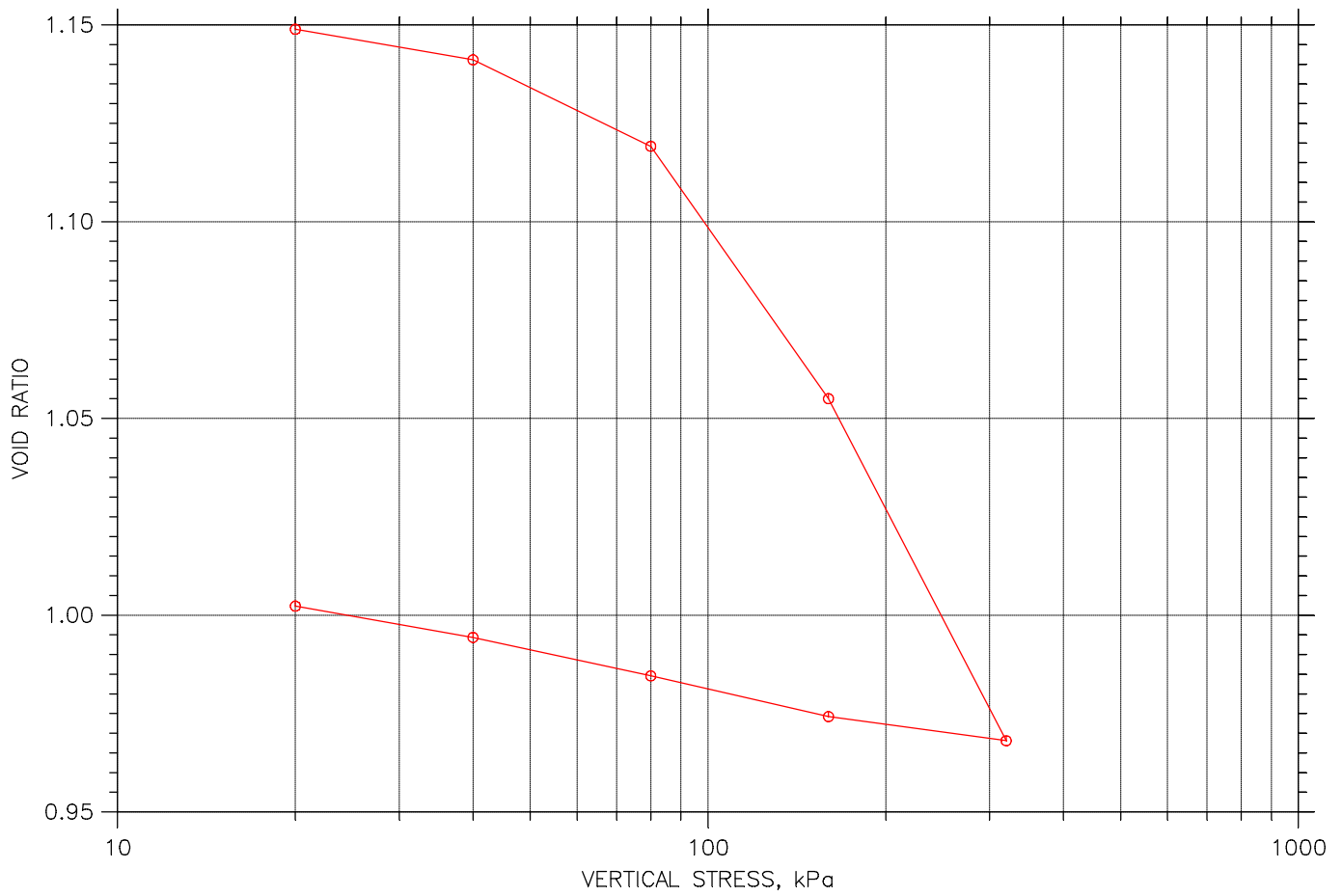



				Before Test	After Test
Overburden Pressure: 0 kPa		Water Content, %		44.32	37.62
Preconsolidation Pressure: 0 kPa		Dry Unit Weight, N/m ³		11850	12860
Compression Index: 0		Saturation, %		99.22	98.53
Diameter: 63.55 mm	Height: 26.04 mm		Void Ratio	1.17	1.00
LL: 51	PL: 19	PI: 32	GS: 2.63		

	Project: Hwy 17		Location: Sawmill Creek Culvert	Project No.:
	Boring No.:		Tested By: Tim	Checked By: GM
	Sample No.: ST 1		Test Date: Aug 18/16	Depth: 25'-27'
	Test No.: 1		Sample Type: TW	Elevation:
	Description: Soft Grey Clay			
	Remarks:			

CONSOLIDATION TEST DATA

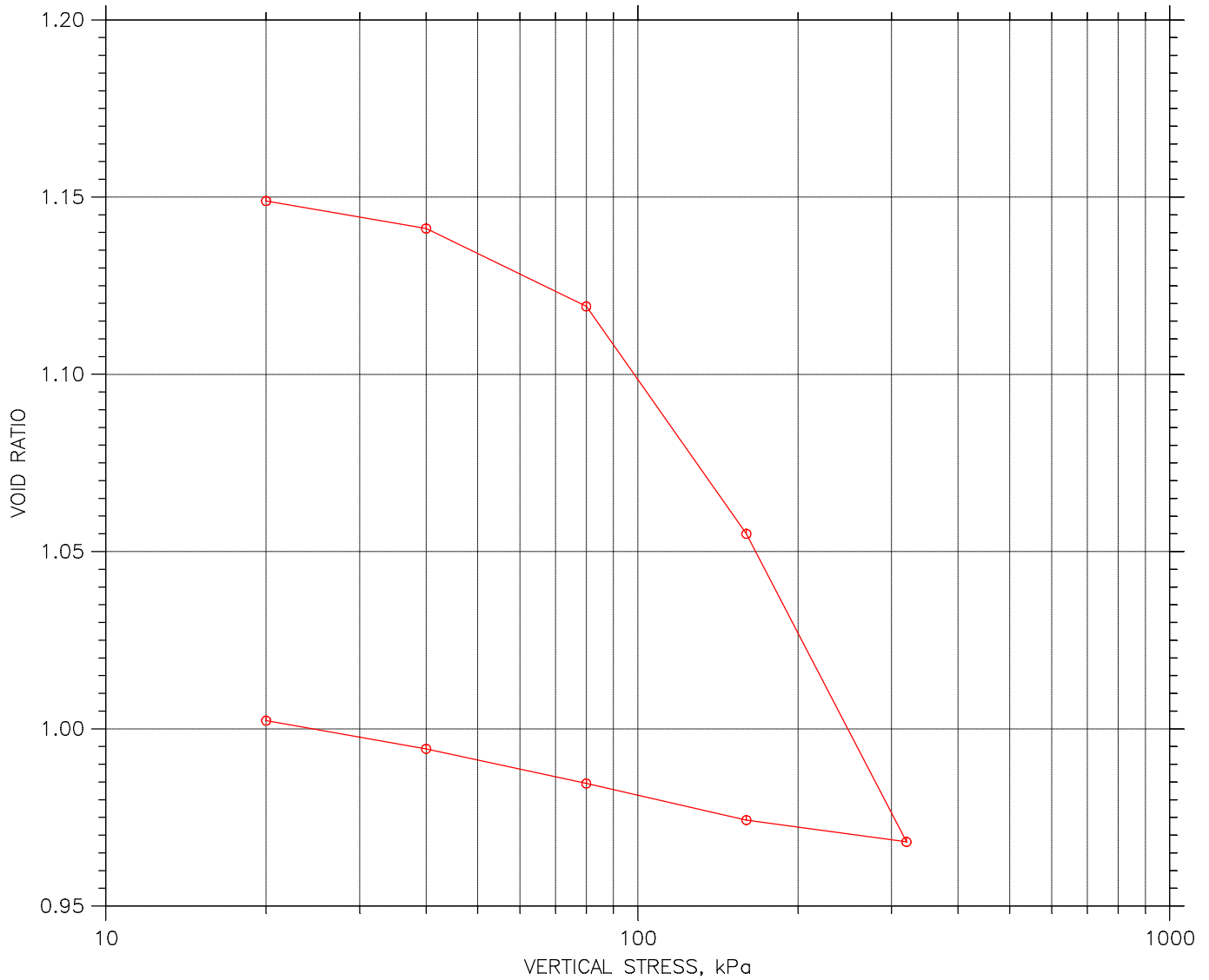
SUMMARY REPORT




	Project: Hwy 17	Location: Sawmill Creek Culvert	Project No.:
	Boring No.:	Tested By: Tim	Checked By: GM
	Sample No.: ST 1	Test Date: Aug 18/16	Depth: 25'-27'
	Test No.: 1	Sample Type: TW	Elevation:
	Description: Soft Grey Clay		
	Remarks:		

CONSOLIDATION TEST DATA

SUMMARY REPORT



				Before Test	After Test
Overburden Pressure: 0 kPa		Water Content, %		44.32	37.62
Preconsolidation Pressure: 0 kPa		Dry Unit Weight, N/m ³		11850	12860
Compression Index: 0		Saturation, %		99.22	98.53
Diameter: 63.55 mm	Height: 26.04 mm		Void Ratio	1.17	1.00
LL: 51	PL: 19	PI: 32	GS: 2.63		

	Project: Hwy 17	Location: Sawmill Creek Culvert	Project No.:
	Boring No.:	Tested By: Tim	Checked By: GM
	Sample No.: ST 1	Test Date: Aug 18/16	Depth: 25'-27'
	Test No.: 1	Sample Type: TW	Elevation:
	Description: Soft Grey Clay		
	Remarks:		

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Project : 13662**09-August-2016****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 228
Fax:

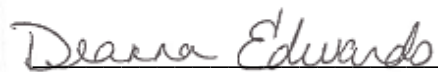
Date Rec. : 03 August 2016
LR Report: CA14112-AUG16
Reference: 13662

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: BH 16-15, SS4, 10'-12'	6:
Sample Date & Time						27-Jul-16
Temperature Upon Receipt [°C]	---	---	---	---		24.2
Corrosivity Index [none]	09-Aug-16	13:29	09-Aug-16	14:28		1
pH [no unit]	08-Aug-16	11:40	09-Aug-16	09:32		7.85
Soil Redox Potential [mV]	08-Aug-16	18:47	09-Aug-16	08:27		243
Sulphide [%]	08-Aug-16	10:07	09-Aug-16	09:35		< 0.02
% Moisture (wet wt) [%]	05-Aug-16	07:02	05-Aug-16	09:08		14.5
pH [no unit]	04-Aug-16	09:56	04-Aug-16	15:49		9.32
Chloride [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15		120
Sulphate [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15		1.2
Conductivity [uS/cm]	04-Aug-16	09:56	04-Aug-16	15:49		305
Resistivity (calculated) [Ohms.cm]	09-Aug-16	12:55	09-Aug-16	14:28		3280


Deanna Edwards, B.Sc, C.Chem
Project Specialist
Environmental Services, Analytical



SGS Canada Inc.

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Phone: 705-652-2000 FAX: 705-652-6365

Project : 13662

LR Report : CA14112-AUG16

Temperature of Samples upon receipt 24 degrees C

No cooling agent present

Custody Seal not present

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

**SGS Canada Inc.**

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Project : 13662**LR Report :** CA14112-AUG16

Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020	ASTM E1918
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013	
pH	ME-CA-[ENV]EWL-LAK-AN-001	SM 4500

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0053-AUG16												
Chloride	0.4	µg/g	<0.4		0	20	109	80	120	111	75	125
Sulphate	0.4	µg/g	<0.4		3	20	101	80	120	101	75	125
Carbon/Sulphur - QCBatchID: ECS0007-AUG16												
Sulphide	0.02	%	<0.02		NV	20	113	80	120			
Conductivity - QCBatchID: EWL0045-AUG16												
Conductivity	2	uS/cm	2		1	10	99	90	110	NA		
pH - QCBatchID: EWL0045-AUG16												
pH	0.05	no unit	NA		0		100			NA		

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Project : 13662

12-April-2017

Thurber Engineering Ltd.

Attn : Mark Farrant

103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 228
Fax:

Date Rec. : 02 August 2016
LR Report: CA13006-AUG16
Reference: 13662

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

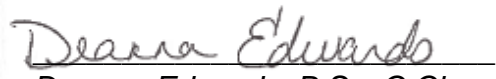
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Sample Date & Time						27-Aug-16 17:00
Temperature Upon Receipt [°C]	---	---	--	--	---	26.0
Corrosivity Index [none]	04-Aug-16	15:49	04-Aug-16	15:49		2
pH [no unit]	03-Aug-16	07:59	04-Aug-16	10:21	0.05	7.42
Conductivity [µS/cm]	03-Aug-16	07:59	04-Aug-16	10:21	2	87
Resistivity (calculated) [Ohms.cm]	03-Aug-16	07:59			---	11500
Redox Potential [mV]	02-Aug-16	17:51	03-Aug-16	12:43	---	289
Chloride [mg/L]	03-Aug-16	08:25	04-Aug-16	09:21	0.04	1.0
Sulphate [mg/L]	03-Aug-16	08:25	04-Aug-16	09:21	0.04	3.9
Sulphide [mg/L]	03-Aug-16	08:00	03-Aug-16	12:20	0.006	< 0.006

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

Temperature of samples upon receipt 26 degrees C

Cooling Agent Present

Custody Seal not used to seal cooler


Deanna Edwards, B.Sc, C.Chem
Project Specialist
Environmental Services, Analytical

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Project : 13662**LR Report :** CA13006-AUG16

Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential		SM 2580
Sulphide by SFA	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

Phone: 705-652-2000 FAX: 705-652-6365

Project : 13662

LR Report : CA13006-AUG16

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank		RPD		LCS / Spike Blank			Matrix Spike / Reference Material		
							Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
					%	Low		High	Low		High	
Anions by IC - QCBatchID: DIO0016-AUG16												
Chloride	0.04	mg/L	<0.04		1	20	95	80	120	NV	75	125
Sulphate	0.04	mg/L	<0.04		0	20	100	80	120	110	75	125
Anions by IC - QCBatchID: DIO0024-AUG16												
Chloride	0.04	mg/L	<0.04		0	20	102	80	120	90	75	125
Sulphate	0.04	mg/L	<0.04		0	20	102	80	120	88	75	125
Conductivity - QCBatchID: EWL0020-AUG16												
Conductivity	2	µS/cm	< 2		0	10	101	90	110	NA		
pH - QCBatchID: EWL0020-AUG16												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0019-AUG16												
Redox Potential	no	mV	NA		1	20	106	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0010-AUG16												
Sulphide	0.006	mg/L	<0.006		ND	20	103	80	120	125	75	125

Appendix C

Site Photographs



Photo 1: Culvert inlet, looking northwest



Photo 2: Culvert outlet, looking southeast



Photo 3: Looking north at west side of north approach embankment



Photo 4: Looking north at east side of north approach embankment



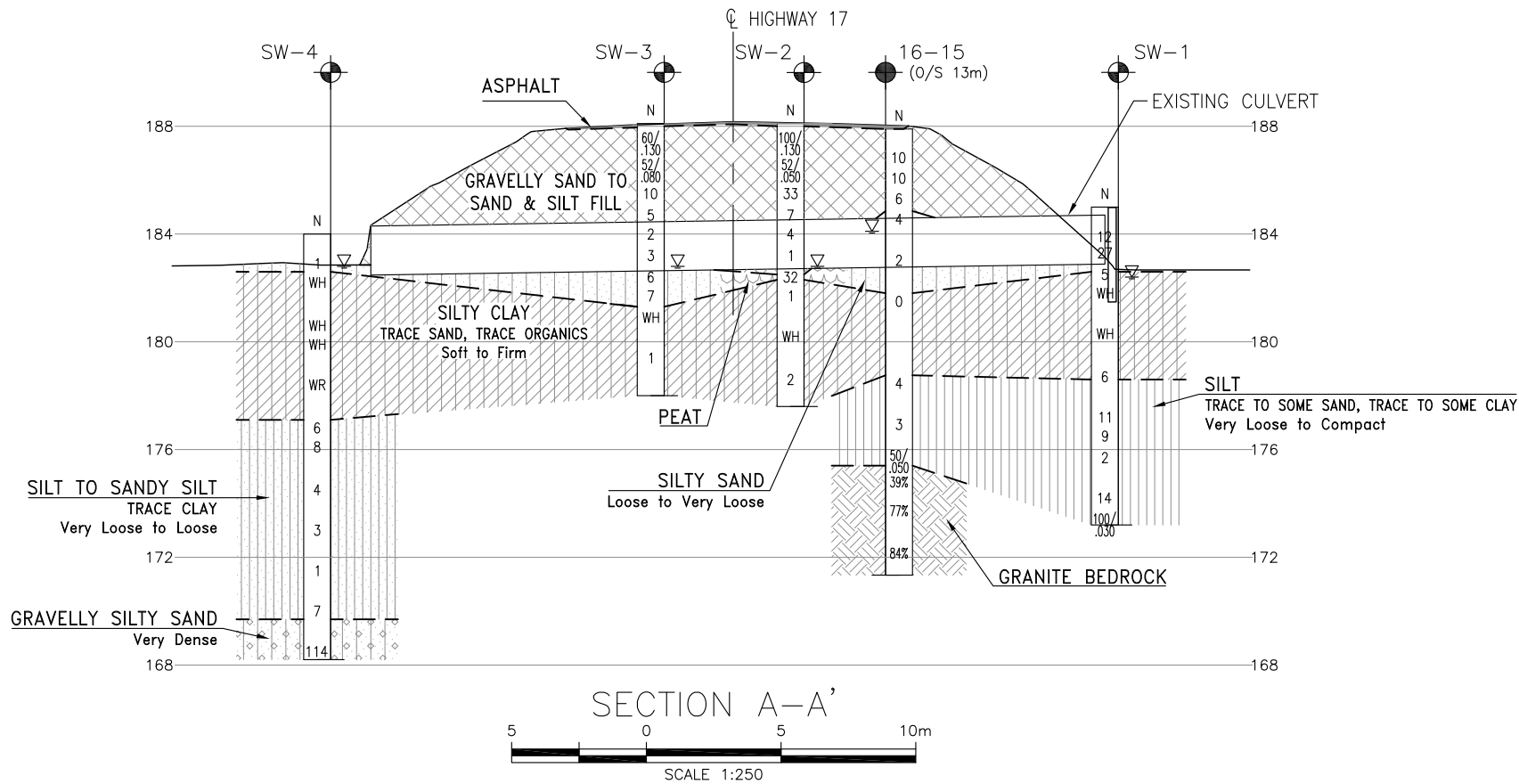
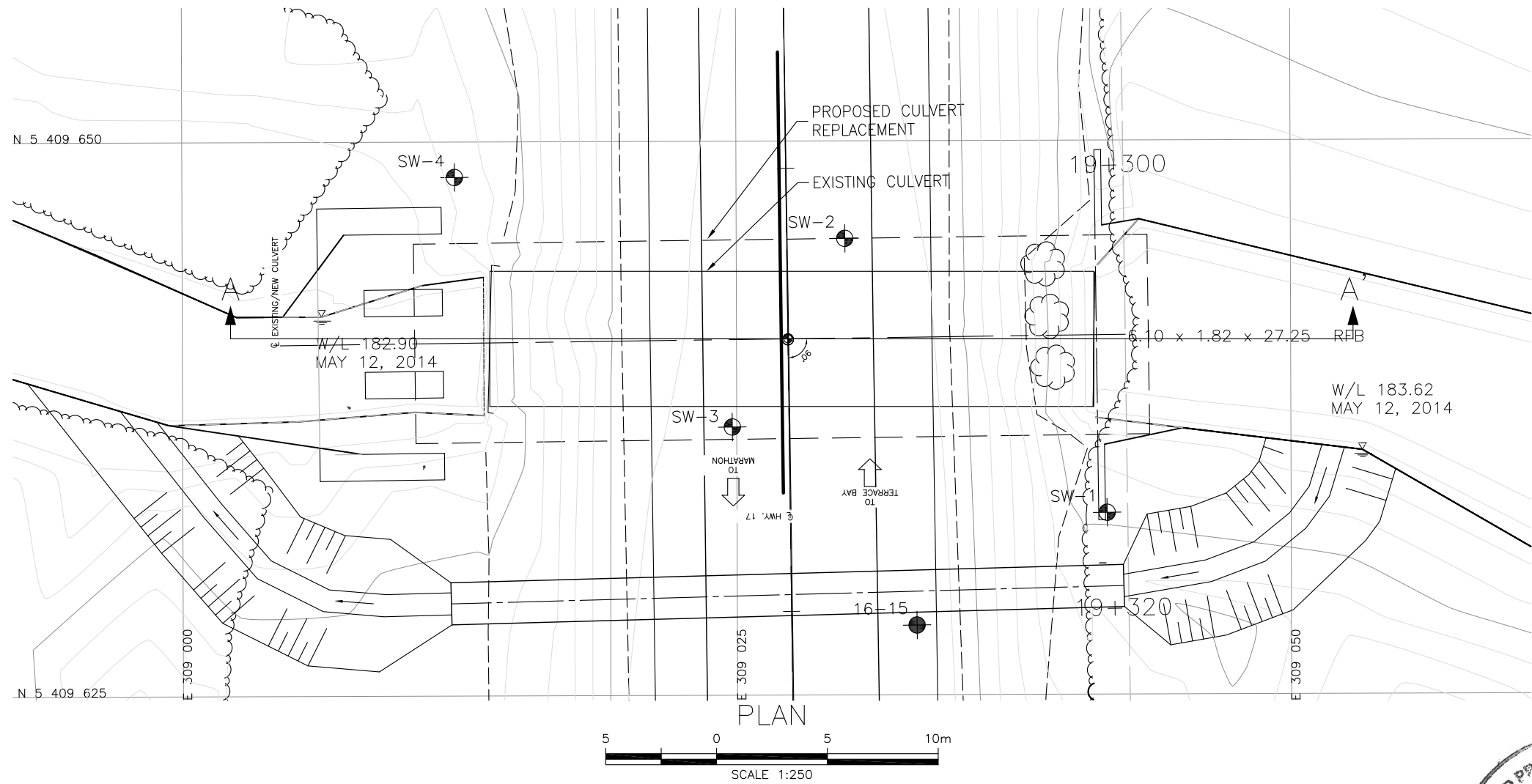
Photo 5: Looking south at east side of south approach embankment



Photo 6: Looking south at west side of south approach embankment

Appendix D

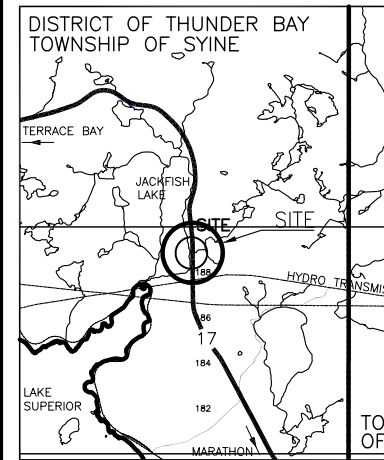
Borehole Locations and Soil Strata Drawing



CONT. No 2016-6009
WP No 6366-14-01

HIGHWAY 17
SAWMILL CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH



KEYPLAN

LEGEND

●	Borehole (by Thurber)
⊙	Borehole (by Others)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⌵	Head Artesian Water
⌵	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-15	187.9	5 409 628.1	309 033.1
SW-1	185.0	5 409 633.2	309 041.7
SW-2	188.1	5 409 645.6	309 029.9
SW-3	188.1	5 409 637.1	309 024.8
SW-4	184.0	5 409 648.4	309 012.3

-NOTES-

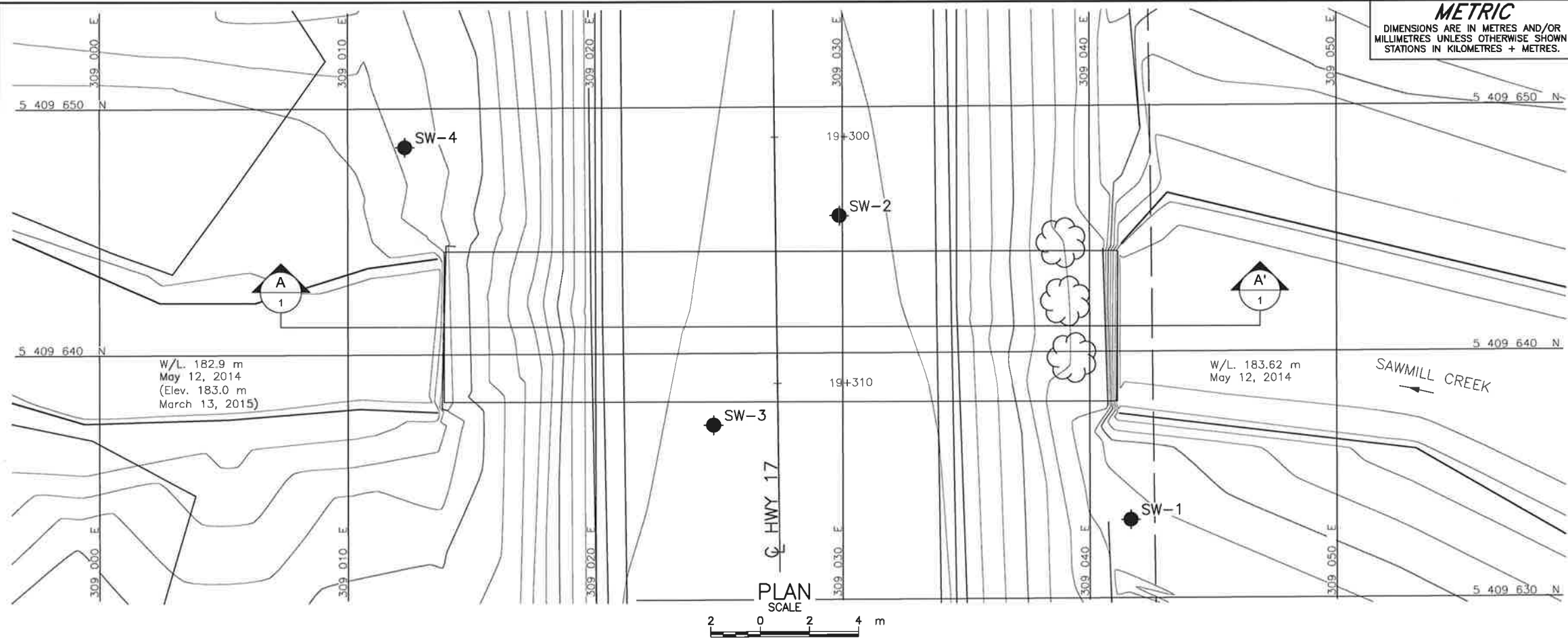
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 42D-44

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		</
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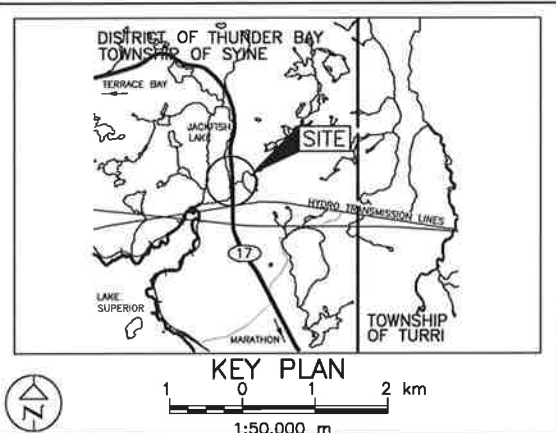
Appendix E

Factual Data from 2015 Golder Foundation Investigation Report



METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. GWP No. 6366-14-00		 SHEET
HIGHWAY 17 SAWMILL CREEK CULVERT STA 19+312 BOREHOLE LOCATIONS AND SOIL STRATA		



LEGEND

- Borehole
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling
- R Refusal

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
SW-1	185.0	5409633.2	309041.7
SW-2	188.1	5409645.6	309029.9
SW-3	188.1	5409637.1	309024.8
SW-4	184.0	5409648.4	309012.3

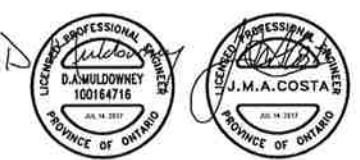
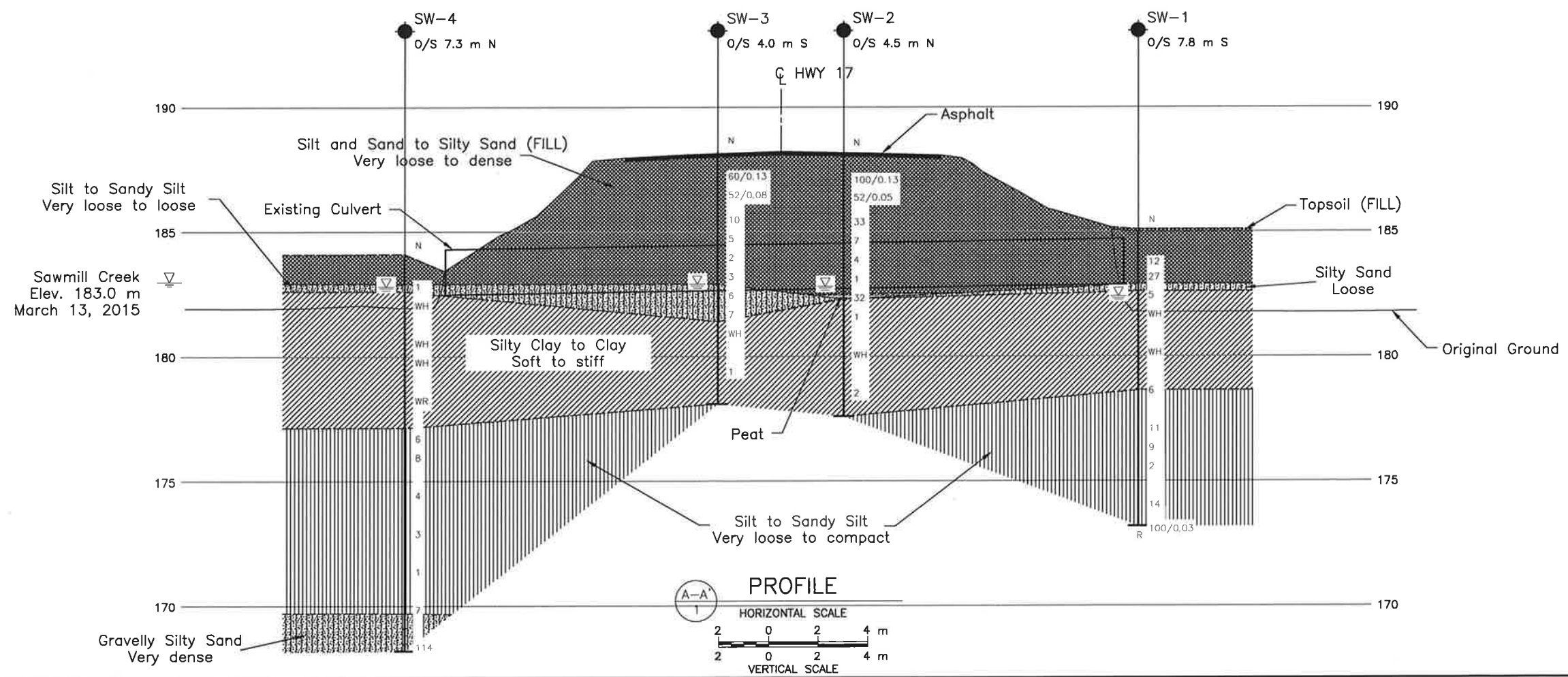
NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by MTO, drawing file no. E581171 (Revised).dwg, dated MAY 2017, received JUN 21 2017.



NO.	DATE	BY	REVISION
Geocres No. 42D-39			
HWY. 17	PROJECT NO. 1411523		DIST.
SUBM'D. AC	CHKD.	DATE: 7/14/2017	SITE: 48E-50/C
DRAWN: TB	CHKD. DAM	APPD. JMAC	DWG. 1

PROJECT 1411523

RECORD OF BOREHOLE No SW-1

1 OF 1 **METRIC**

G.W.P. 6366-14-00

LOCATION N 5409633.2; E 309041.7

ORIGINATED BY RI

DIST HWY 17

BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers, NW Casing

COMPILED BY MT

DATUM GEODETIC

DATE March 22 and 23, 2015

CHECKED BY SEMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
185.0	GROUND SURFACE							20 40 60 80 100				
0.9	Topsail (FILL) Silty sand, some gravel, trace organics (FILL) Brown Frozen*							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED				
								W _p W W _L PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT WATER CONTENT (%)				
184.9			1	SS	12*		184					
182.9			2	SS	27*		183					
182.6	Silty SAND Loose Grey Wet		A 3 B	SS	5		182					
2.4	CLAY Soft Grey Wet		4	SS	WH		181					
			5	SS	WH		180					0 0 27 73
							179					0 4 89 7
178.6	SILT, trace to some sand, trace to some clay Very loose to compact Grey Wet		A 6 B	SS	6		178					
6.4			7	SS	11		177					
			8	SS	9		176					0 16 78 6
	Approximately 2.1 m of heave inside augers at 9.0 m depth. Switched to NW casing.		9	SS	2		175					
			10	SS	14		174					
173.2	Spoon bouncing at 11.8 m depth.		11	SS	100/0.93							
11.8	END OF BOREHOLE SPLIT-SPOON REFUSAL Note: 1. Water level at a depth of 2.6 m below ground surface (Elev. 182.4 m) upon completion of drilling.											

SUD-MTO 001: 1411523.GPJ GAL-MISS.GDT 14/07/17 DATA INPUT:

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 1411523

RECORD OF BOREHOLE No SW-2

1 OF 1 **METRIC**

G.W.P. 6366-14-00

LOCATION N 5409645.6; E 309029.9

ORIGINATED BY RI

DIST HWY 17

BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers

COMPILED BY MT

DATUM GEODETIC

DATE March 13, 2015

CHECKED BY SEMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
							○ UNCONFINED	+	FIELD VANE						
							● QUICK TRIAXIAL	×	REMOULDED						
188.1	GROUND SURFACE						20	40	60	80	100	20	40	60	GR SA SI CL
0.0	ASPHALT (140 mm)														
0.1	Silty sand, trace to some gravel, trace clay, trace organics (FILL) Very loose to dense Brown Frozen* to wet		1	SS	100/ 0.13*										
			2	SS	52/ 0.05*										
			3	SS	33										3 66 (31)
			4	SS	7										
			5	SS	4										
			6	SS	1										
182.5	Auger grinding at 5.3 m depth on inferred cobbles.		A	SS	32										6 62 28 4
5.8	PEAT Black Wet		7 B C												
	CLAY, trace sand, trace organics Firm to stiff Grey Wet		8	SS	1										
			9	SS	WH										
			10	SS	2										
177.6															
10.5	END OF BOREHOLE														
	Note: 1. Water level at a depth of 5.3 m below ground surface (Elev. 182.8 m) upon completion of drilling.														

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 14/07/17 DATA INPUT:

+ 3, x 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 1411523

RECORD OF BOREHOLE No SW-3

1 OF 1 METRIC

G.W.P. 6366-14-00

LOCATION N 5409637.1; E 309024.8

ORIGINATED BY RI

DIST HWY 17

BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers

COMPILED BY MT

DATUM GEODETTIC

DATE March 13, 2015

CHECKED BY SEMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	
188.1	GROUND SURFACE												
0.0	ASPHALT (140 mm)												
0.1	Silt and sand, trace gravel, trace clay, trace organics (FILL) Very loose to compact Brown to grey Frozen* to wet		1	SS	60 0.13*		188						
			2	SS	52 0.08*		187						
			3	SS	10		186						
			4	SS	5		185						
			5	SS	2		184						1 35 60 4
			6	SS	3		183						
182.8	Sandy SILT, trace to some clay Loose Grey Wet		7	SS	6		182						0 25 65 10
			8	SS	7		181						
181.3	CLAY Firm Grey Wet		9	SS	WH		180	2 +	2 +				
6.8			10	SS	1		179	2 +	2 +				
178.0	END OF BOREHOLE						178						
10.1	Note: 1. Water level at a depth of 5.3 m below ground surface (Elev. 182.8 m) upon completion of drilling.												

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 14/07/17 DATA INPUT:



PROJECT 1411523

RECORD OF BOREHOLE No SW-4

1 OF 2 METRIC

G.W.P. 6366-14-00

LOCATION N 5409648.4; E 309012.3

ORIGINATED BY RI

DIST HWY 17

BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers

COMPILED BY MT

DATUM GEODETIC

DATE March 23 and 24, 2015

CHECKED BY SEMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × REMOULDED						
								20 40 60 80 100						
184.0	GROUND SURFACE													
0.0	Silt and sand, trace clay, trace gravel, some organics (FILL) Grey Frozen													
182.9			A											
182.6	Silty SAND Very loose Grey Wet		1 B	SS	1		183							2 40 53 5
1.4			2	SS	WH		182							
	SILTY CLAY to CLAY Very soft to soft Grey Wet						181	2 +						
	Trace organics in Sample 2.		3	SS	WH		180	+						
			4	SS	WH		179	2 +						
			5	SS	WR		178	2 +						
							177	1 + 2 +						
177.1			6	SS	6		176							
			7	SS	8		175							
			8	SS	4		174							
			9	SS	3		173							0 24 72 4
			10	SS	1		172							
			11	SS	7		171							
169.7							170							
14.3														

Continued Next Page

+ 3, X 3

Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 14/07/17 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No SW-4		2 OF 2 METRIC	
G.W.P. 6366-14-00		LOCATION N 5409648.4; E 309012.3		ORIGINATED BY RI	
DIST _____ HWY 17		BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers		COMPILED BY MT	
DATUM GEODETIC		DATE March 23 and 24, 2015		CHECKED BY SEMP	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT <div><div><div>20406080100</div><div><div><div></div><div></div><div></div></div></div></div></div>	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
	--- CONTINUED FROM PREVIOUS PAGE ---												
168.2	Gravelly Silty SAND Very dense Grey Wet		12	SS	114								
15.8	Approximately 1.8 m of heave noted in augers at a depth of 15.2 m. END OF BOREHOLE Notes: 1. Water level at a depth of 1.2 m below ground surface (Elev. 182.8 m) upon completion of drilling. 2. Moved 1.2 m west of borehole and retrieved Shelby Tube samples at depths of 2.4 m, 3.0 m and 4.9 m below existing ground surface.												

Appendix F

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Ease of construction. ii. Less stringent requirement for soil geotechnical resistances iii. Segmented pipes can accommodate some potential differential settlement along culvert axis iv. Steel pipes may be more cost effective than concrete box or open footing culverts. 	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area. iii. Segmental option can accommodate some potential differential settlement along culvert axis. 	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. Steel pipes may have shorter design life than concrete culverts. ii. Multiple pipes needed to meet hydraulic requirements. iii. Large excavation through over 4 m of fill required to install pipes. iv. Relatively high roadway protection system required. 	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. More expensive than a CSP culvert. ii. Large excavation through over 4 m of fill required to install culvert. iii. Relatively high roadway protection system required. 	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> i. Low geotechnical capacities in founding clay to support strip footings, and greater potential for differential settlement. ii. Deeper excavation and potentially longer dewatering requirements.
FEASIBLE	FEASIBLE	NOT RECOMMENDED

Appendix G

List of OPSSs and OPSDs and Suggested Wording for NSSP

1. List of OPSS and OPSD Documents Relevant to this Project

- OPSS PROV 206
- OPSS PROV 209
- OPSS 422
- OPSS PROV 401
- OPSS PROV 501
- OPSS PROV 539
- OPSS PROV 804
- OPSS 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSS 1860
- OPSD 208.010
- OPSD 802.010
- OPSD 803.010
- OPSD 803.031

2. Suggested Wording for NSSP on Dewatering

Effective dewatering shall be designed and provided by the Contractor during structure excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level will lead to subgrade softening. The dewatering system must be effective to maintain the water level at a minimum depth of 0.5 m below the final subgrade level throughout construction. The dewatering system must remain operational and effective until the culvert is installed and backfilled.

3. Suggested Wording for NSSP on Obstructions

Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall

be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths. Vibrating equipment is not permitted for installation of sheet piles.

Appendix H

Figures

Title: Sawmill Creek Culvert
 Comments: Stability Assessment
 Name: 3a - Rock Fill Slope w/ Key (Short Term)

New Rock FILL	19 kN/m ³	0 kPa	42 °
Existing Silty Sand FILL	19 kN/m ³	0 kPa	30 °
Silty SAND	19 kN/m ³	0 kPa	30 °
Silty CLAY (TSA)	17 kN/m ³	0.22	20
SILT	19 kN/m ³	0 kPa	32 °

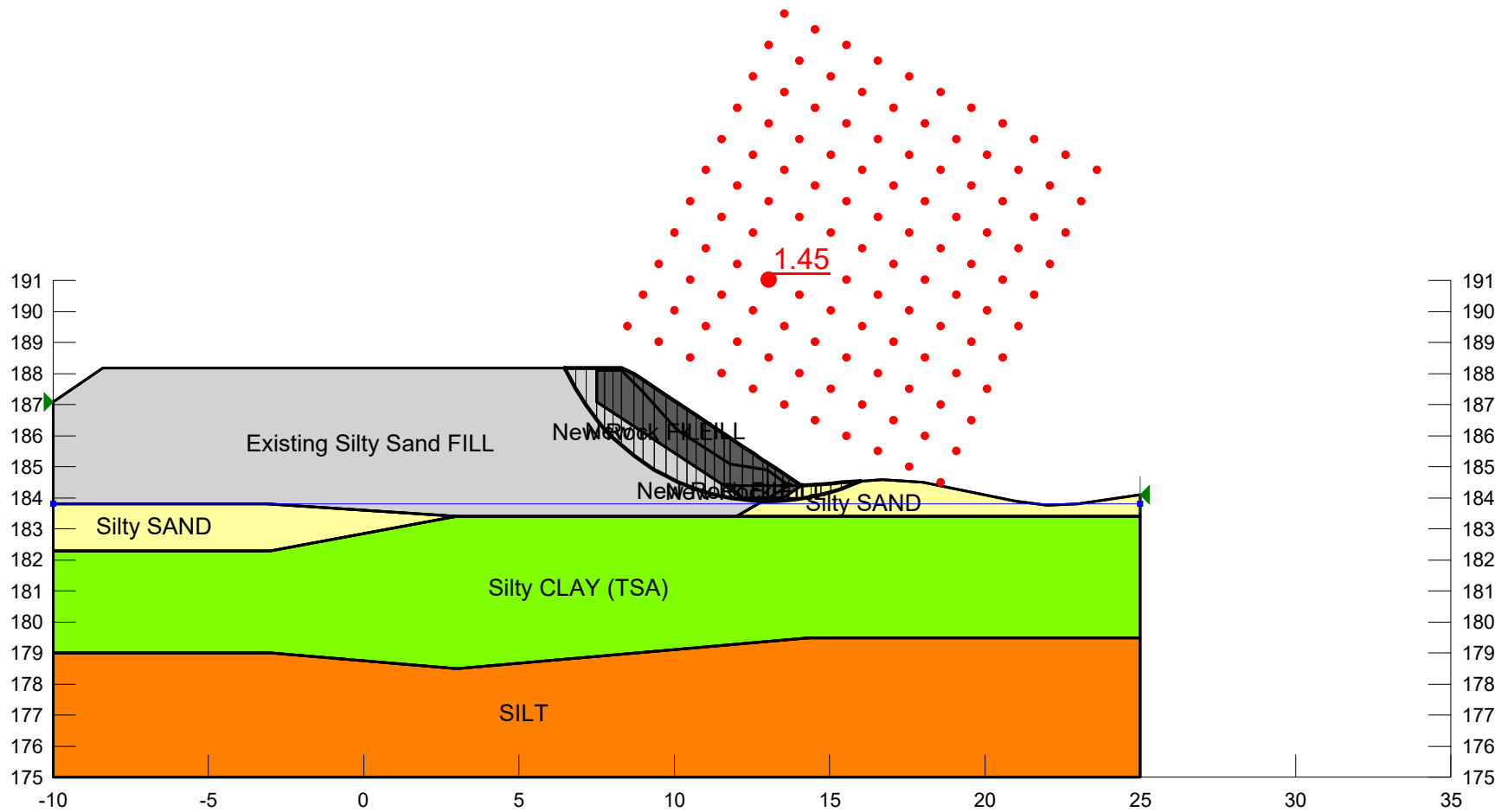


Figure 01

Title: Sawmill Creek Culvert

Comments: Stability Assessment

Name: 3b - Rock Fill Slope w/ Key (Long Term)

New Rock FILL	19 kN/m ³	0 kPa	42 °
Existing Silty Sand FILL	19 kN/m ³	0 kPa	30 °
Silty SAND	19 kN/m ³	0 kPa	30 °
Silty CLAY (ESA)	17 kN/m ³	0 kPa	23 °
SILT	19 kN/m ³	0 kPa	32 °

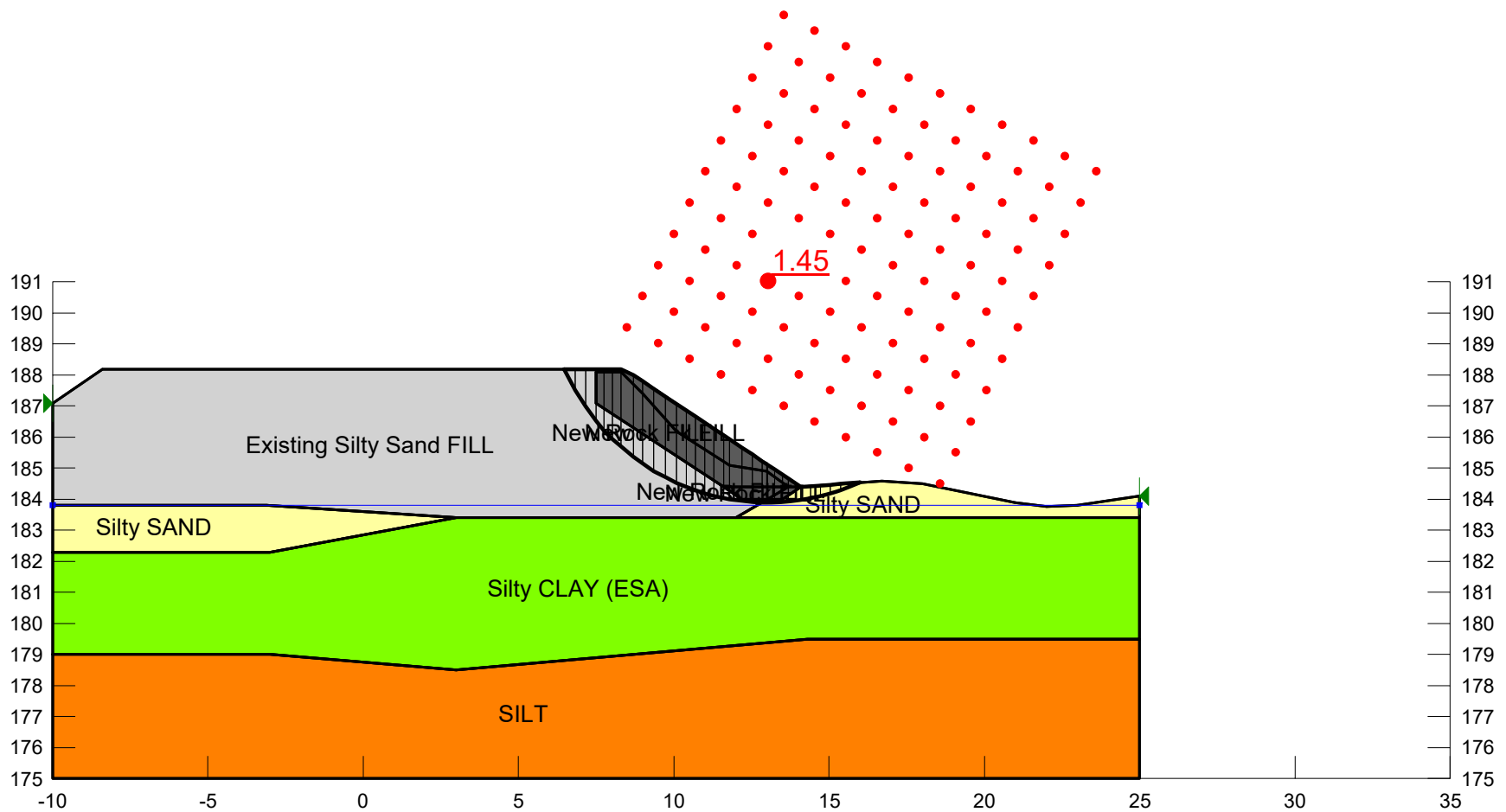


Figure 02