FOUNDATION INVESTIGATION AND DESIGN REPORT
SITCH CREEK CULVERT REPLACEMENT
TOWNSHIP OF GILLIES, DISTRICT OF THUNDER BAY, ONTARIO
SITE No. 48W-124/C
HIGHWAY 595

ASSIGNMENT NO. 6015-E-0023

GEOCRES Number: 52A-227
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Report

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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 Sitch Creek Culvert on Highway 595, located in the Township of Gillies, District of Thunder Bay, Ontario.

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

Thurber was retained by the Ministry of Transportation Ontario (MTO) to carry out this foundation investigation under the MTO Retainer Assignment Number 6015-E-0023.

2. SITE DESCRIPTION

The Sitch Creek Culvert site is located on Highway 595, in the Township of Gillies approximately 600 m north of Highway 588, in the District of Thunder Bay, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location and Soil Strata drawing in Appendix D.

Highway 595 runs in the general north-south direction in the area, with the culvert perpendicular to the centreline of the highway. The Sitch Creek is a tributary of the Kaministiquia River and the creek flows from west to east at the culvert site.

The terrain in the culvert area is gently undulating and forested outside of the right-of-way. The existing culvert is a 4.9 m diameter Corrugated Steel Pipe (CSP) culvert approximately 35 m long. The Structural Inspection Report (SIR) prepared by McCormick Rankin, a member of MMM Group and dated January 2014 indicated that the structure is in fair condition.

The MTO Site Plan Drawing, E-1078-595-2, indicates that the existing culvert invert is at approximate Elevation 262.7 m at the inlet and Elevation 262.5 m at the outlet. The stream water level was reported to be at about Elevation 263.0 m at the upstream end and about Elevation 262.8 m at the downstream end in June 2008. At the culvert location, the highway embankment grade is at about Elevation 269.8 m. The depth of cover over the existing culvert is approximately 2.3 m.

Photographs in Appendix C show the general nature of the site and the existing culvert.

Based on published geological information, the culvert lies within a glaciolacustrine plain including deposits of silts and clays with minor sands. The bedrock at the site consists of rocks of Gunflint Formation.

3. INVESTIGATION PROCEDURES

The field investigation and testing program for this project was specified in the Terms of Reference. The field work was carried out on April 10, 11, 29 and 30, 2017 during which time four (4) boreholes designated as Boreholes 17-05 to 17-08 were advanced at the site. Boreholes 17-05 and 17-08 were advanced near the inlet and outlet of the culvert and Boreholes 17-06 and 17-07 were advanced through the highway embankment north and south of the culvert, respectively.

Utility clearances were obtained prior to the start of drilling. A rubber tire buggy mounted drill rig and a track-mounted CME 75 drill rig were used to advance the boreholes at the site using hollow stem augers.

Soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT) procedures as per ASTM D1586. Dynamic Cone Penetration Test (DCPT) was also conducted adjacent to Boreholes 17-06 and 17-07 from the ground surface to refusal and at Borehole 17-05 from a depth of about 12.8 m to refusal.

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

Groundwater conditions were observed in the open boreholes throughout the drilling operations. One standpipe piezometer using 19 mm diameter PVC pipe was installed within the overburden in Borehole 17-05 to permit monitoring of the groundwater level at the site. The piezometer was decommissioned and the borehole was backfilled on April 30, 2017. All other boreholes were backfilled on completion of drilling in general accordance with Ontario Regulation 903, as amended.

The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided by the MTO. The coordinate system MTM NAD 83, Zone 14 was used for the boreholes. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D. The borehole coordinates, ground surface elevations, drilled depths and the completion details are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Coordinates (MTM NAD 83, Zone 14)		Ground Surface Elevation (m)	Termination Depth (m)	Completion Details
	Northing (m)	Easting (m)			
17-05	5,351,237.3	327,055.2	266.9	15.0	Standpipe piezometer was installed in the borehole. After removal of the piezometer the borehole was backfilled with bentonite holeplug and cuttings to ground surface.
17-06	5,351,234.2	327,064.4	269.6	18.2	Bentonite holeplug and cuttings to 0.6 m, cement to 0.1 m then asphalt cold patch to ground surface.
17-07	5,351,222.5	327,063.9	269.9	18.6	Bentonite holeplug to 1.6 m, cuttings to 0.9 m then asphalt cold patch to ground surface.
17-08	5,351,217.6	327,075.2	265.6	11.3	Bentonite holeplug to 2.4 m and cuttings to ground surface.

4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected soil samples were also subjected to grain size distribution analyses (sieve and/or hydrometer) and Atterberg limits test. The results of the 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, two samples of the native soil near the invert level of the culvert, and a sample of the surface water from the creek upstream 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 of this report and are presented in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the "Borehole Locations and Soil Strata" drawing included in Appendix D. 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 subsurface conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill comprising of sand fill and/or silty clay fill overlying a native silty sand to sand which extends to the borehole termination depths. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes 17-06 and 17-07 were drilled through the existing asphalt pavement on Highway 595. The asphalt thickness was about 25 mm at the borehole locations. The thickness of asphalt may vary along the highway.

5.2 Fill

Fill was encountered below the asphalt in Boreholes 17-06 and 17-07 and at the ground surface in Boreholes 17-05 and 17-08. The fill extended to depths of between approximately 1.5 m and 8.1 m (base Elevation 261.8 m to 264.1 m). The fill generally consisted of sand to silty sand and/or silty clay.

5.2.1 Silty Clay Fill

Silty clay fill was encountered in Borehole 17-05 at the surface to a depth of about 0.8 m and from a depth of 2.1 m to 4.6 m; in Borehole 17-06 from a depth of 1.1 m to 1.7 m and from a depth of 5.6 m to 7.7 m; and in Borehole 17-08 from the ground surface to a depth of 1.5 m. The base of the clay fill ranges between Elevations 264.1 m and 261.9 m.

The SPT 'N' values within the silty clay fill ranged from 2 blows to 8 blows per 0.3 m of penetration, indicating a soft to firm consistency. Moisture content in the silty clay fill ranged from 23% to 38%.

The results of grain size analyses and Atterberg Limit testing conducted on selected samples of the silty clay fill are presented on the Record of Borehole sheets included in Appendix A, and on Figure B1 and B2 in Appendix B.

The results are summarized in the following table:

Soil Particle	**Percentage (%)**
Gravel	0 to 2
Sand	29 to 44
Silt	38 to 46
Clay	18 and 23
Measured Limit	**Percentage (%)**
Liquid Limit	35 and 39
Plastic Limit	22

The results of the Atterberg Limits testing indicate that the silty clay fill has a low to intermediate plasticity with group symbol CL to CI.

5.2.2 Sand Fill

Sand fill with varying quantities of silt and gravel was encountered in Borehole 17-05 from a depth of 0.8 m to 2.1 m; in Borehole 17-06 from beneath the asphalt to 1.1 m and from 1.7 m to 5.6 m; and in Borehole 17-07 from beneath the asphalt to 8.1 m below road surface. The base of the sand fill ranges between Elevations 261.8 m and 264.8 m.

SPT 'N' values within the sand fill ranged from 4 blows to 50 blows per 0.3 m of penetration, indicating a loose to dense relative density, predominantly loose to compact. Moisture contents in the sand fill ranged from 7% to 22%.

The results of grain size analysis on selected samples of the sand fill are presented on the Record of Borehole sheets included in Appendix A and on Figure B3 in Appendix B.

The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	6 to 29
Sand	51 to 76
Silt and Clay	18 to 32

5.3 Silty Sand to Sand

A deposit of grey to dark grey silty sand to sand was encountered below the fill in all boreholes and extended to the borehole termination depths of 11.3 m to 18.6 m (Elevation 254.3 m to 251.3 m). The deposit was loose to dense, predominantly compact, as indicated by SPT 'N' values ranging between 7 blows and 42 blows per 0.3 m of penetration. The measured moisture content of the silty sand to sand ranged between 8% and 28%.

The results of grain size analysis on selected samples of the silty sand to sand deposit are presented on the Record of Borehole sheets included in Appendix A and on Figure B4 in Appendix B.

The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0 to 13
Sand	67 to 95
Silt	4 to 29
Clay Size Fines	1 to 4

Approximately 1.0 m to 1.9 m thick interlayer of silt containing some sand was encountered above or within the silty sand to sand deposit in Boreholes 17-07 and 17-08 at depths of 8.1 m and 2.2 m (Elevations 261.8 m and 263.4 m), respectively. SPT ‘N’ values within the silt layer were 1 blow and 3 blows per 0.3 m of penetration indicating a very loose material. The results of grain size analysis on two selected samples of the silt are presented on the Record of Borehole sheet included in Appendix A and on Figure B5 in Appendix B.

The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	16 and 23
Silt	72 and 77
Clay Size Fines	5 and 7

5.4 Auger Refusal

Auger refusal on probable bedrock or boulders was inferred in Boreholes 17-06 and 17-07 at depths of about 18.2 m and 18.6 m (Elevations 251.4 m and 251.3 m), respectively. The DCPT penetration was refused adjacent to these boreholes at the same depths.

5.5 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. A standpipe piezometer was installed in Borehole 17-05 on April 29, 2017 and a groundwater level reading was taken in the piezometer on April 30, 2017. The groundwater levels measured in the open boreholes and in the piezometer are summarized in Table 5.1 below.

Table 5.1 – Groundwater Measurements

Borehole	Date	Piezometer Installation		Water Level (m)		Remark
		Screen Depth / Elevation (m)	Screened Deposit	Depth	Elevation	
17-05	April 30, 2017	9.1 to 12.2 / 275.8 to 254.7	Sand	5.9	261.0	Piezometer

Borehole	Date	Piezometer Installation		Water Level (m)		Remark
		Screen Depth / Elevation (m)	Screened Deposit	Depth	Elevation	
17-06	April 11, 2017	No Piezometer in the Borehole		5.6	264.0	Open borehole
17-07	April 10, 2017	No Piezometer in the Borehole		6.3	263.6	Open borehole
17-08	April 30, 2017	No Piezometer in the Borehole		2.9	262.7	Open borehole

The groundwater level should be assumed to reflect the local creek water level. Water level measurements in the creek were reported on the MTO Site Plan Drawing, E-1078-595-2, which reported measurements of Elevation 263.0 m at the inlet and 262.8 m at the outlet in June 2008. The above groundwater levels 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 during spring and after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

Three samples of the native and fill soils from Boreholes 17-06, 17-07, and 17-08 and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate content. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

Table 6.1 – Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results			
			17-06, SS#7, 7.7 m – 8.2 m	17-07, SS#7, 7.6 m – 8.1 m	17-08, SS#6, 6.1 m – 6.7 m	Sitch Creek
			(Sand)	(Sand Fill)	(Sand)	(Creek Water)
Sulphide	%	mg/L	0.51	0.39	0.53	<0.006
Chloride	µg/g	mg/L	15	59	5.9	2.3
Sulphate	µg/g	mg/L	200	200	68	3.6
pH	No unit	No unit	8.51	8.47	8.22	7.39

Parameter	Units (Soil)	Units (Water)	Test Results			
			17-06, SS#7, 7.7 m – 8.2 m	17-07, SS#7, 7.6 m – 8.1 m	17-08, SS#6, 6.1 m – 6.7 m	Sitch Creek
			(Sand)	(Sand Fill)	(Sand)	(Creek Water)
Electrical Conductivity	µS/cm	µS/cm	173	200	92	89
Resistivity	Ohms.cm	Ohms.cm	5,780	5,000	10,900	11,200
Redox Potential	mV	mV	272	256	152	142

7. MISCELLANEOUS

Thurber obtained the coordinates and ground surface elevations of the boreholes from measurements taken in the field and relative to the topographic plans provided by the MTO.

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. Amir Fereidouni and Ms. Eckie Siu of Thurber. Overall supervision of the field program was provided by Mr. Cory Zanatta, B.A.Sc. of Thurber.

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. 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. Cory Zanatta, EIT and Mr. Mehdi Mostakhdemi, 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 the proposed Sitch Creek Culvert replacement on Highway 595, located in the Township of Gillies, District of Thunder Bay, 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 or design-build contractor. The design-build 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 Inspection Report (SIR) by McCormick Rankin, a member of MMM Group and dated January 2014. The SIR indicated that the structure is in a fair condition. The SIR also indicated that signs of foundation settlement of the culverts were not noticed at the time of the inspection (July 10, 2013).

The existing structures is a Corrugated Steel Pipe (CSP) culvert with a total length of about 35 m and a diameter of about 4.9 m with approximately 2.3 m of fill above the obvert of the pipe. The Bridge Site Plan prepared by the Geomatics Section of the MTO's Engineering Office indicates that the culvert invert Elevation at the inlet is about 262.7 m, and the invert Elevation at the outlet is about 262.5 m. The finished highway grade is indicated at about Elevation 269.8 m.

It is anticipated that the replacement culvert will be constructed at the same location of the existing culvert. It is also anticipated that the highway grades will remain un-changed at the site, except for possible embankment fill placement if the culvert barrels are extended. A Structural Design Report (SDR) and General Arrangement (GA) drawings which typically indicate the preferred replacement option and its dimensions as well as the location of the diversion pipe were not available at the time of preparation of this report.

The discussions and recommendations presented in this report are based on information provided by MTO and on the factual data obtained during the investigation.

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill overlying a compact to dense silty sand to sand. The water level in the stream was measured at about Elevations 263.0 m and 262.8 m at the upstream and downstream ends of the culvert, respectively, in June 2008.

8.1 Culvert Design Alternatives

This section presents discussions on available types of replacement culvert and foundation alternatives, and provides foundation design recommendations.

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

- Concrete box (closed) culverts composed of pre-cast segments;
- Concrete pipe or Corrugated steel pipe (CSP); and
- CSP Arch or Concrete, open footing culverts.

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix E. From a foundations and constructability perspective, use of the CSP or pre-cast box culverts are both feasible options, based on the following considerations:

- Pre-cast box culvert or pipe culverts would require reduced depth of excavation (and consequently reduced spoil disposal volume) compared to 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 are more tolerant of some limited differential settlement along the culvert axis if the highway embankment is widened in the future; and
- Due to the relatively high frost penetration depth at the project site (i.e., 2.2 m), open footing culverts would require deeper excavations and consequently more robust temporary shoring and/or groundwater control compared to the other two alternatives.

The open footing culvert option is not recommended at this site and this option has not been discussed further. Recommendations for the design and installation of CSP and concrete box culverts are presented below.

8.2 Foundation Design for Culverts

Foundation design aspects for the replacement culvert includes subgrade conditions and preparation, geotechnical resistances, settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.

8.2.1 Corrugated Steel Pipe Culvert

Replacement of the culvert with CSPs on the same alignment is feasible from foundation design and constructability perspectives. In order to accommodate the hydraulic requirements, multiple pipes maybe required. The invert of the new culvert should be placed at the same elevation as the existing (i.e., Elevation 262.5 m) or below, which corresponds to the compact silty sand to sand or clay fill subgrade. Any soft soil or loose native soil encountered at the final subgrade elevation should be sub-excavated and backfilled with compacted granular fill to provide a uniformly compacted subgrade condition. The depth of sub-excavation should be decided by the QVE during construction based on visual inspection.

If the CSP option is selected, it 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 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 and placement and compaction of the bedding materials 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. A modulus of subgrade reaction of about 20 MN/m^3 may be used for design of the pipe culvert placed on the existing clay fill or compact sand to silty at the site.

8.2.2 Concrete Box Culvert

Replacement of the existing CSP culvert with a concrete box culvert on the same alignment is a feasible option for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading from the replacement culvert.

In order to provide a uniform foundation subgrade, a minimum 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 and placement and compaction of the bedding material must be carried out in the dry. The prepared surface for support of the box units should have a 75 mm minimum thickness top levelling course consisting of un-compacted Granular A as per OPSS 422. The bedding and the prepared subgrade shall be protected from disturbance during construction, therefore, construction equipment should not travel on the bedding or the prepared subgrade.

The culvert invert should be placed at or below Elevation 262.5 m, which corresponds to the existing clay fill or the compact native silty sand to sand subgrade. Any soft soil or loose native soil encountered at the final subgrade elevation should be sub-excavated and backfilled with compacted granular fill to provide a uniformly compacted subgrade condition. The depth of sub-excavation should be decided by the QVE during construction based on visual inspection.

The following axial geotechnical resistances may be used for design of a box culvert of 5 m to 6 m wide with the culvert founded at the elevations outlined above:

- Factored Geotechnical Resistance at Ultimate Limit State (ULS) of 250 kPa
- Factored Geotechnical Resistance at Serviceability Limit State (SLS) of 150 kPa for a settlement of 25 mm.

The consequence factor of 1 was utilized in this design adopting a “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, in accordance with Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC) 2014.

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

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II should be calculated assuming an ultimate (un-factored) coefficient of friction of 0.45. A resistance factor of 0.8 should be applied for the calculation of the factored sliding resistance in accordance with Table 6.2 of CHBDC 2014 based on a "typical" degree of understanding.

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.

8.2.3 Culvert Headwalls

If headwalls are designed and constructed at the inlet and outlet of the replacement culvert, consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are more tolerant to a limited amount of differential settlement.

The borehole information indicates that the founding conditions at the wall locations generally consist of the existing clay fill or the native compact silty sand to sand.

8.2.3.1 RSS Walls

RSS walls are considered to be a suitable option provided differential settlements are within tolerable limits and adequate factor of safety against global instability is achieved. The performance of an RSS wall when settlement occurs depends primarily on the characteristics of its front facing system. A typical precast panel facing can typically tolerate up to 1 per cent differential settlement and up to 30-40 mm of total settlement.

To provide an acceptable foundation performance, the RSS walls are often placed on a 0.5 m thick engineered (granular) pad to deal with circumstances such as variable subsurface conditions and provide a consistent founding materials under the facing. The pad should extend to 300 mm beyond the outside edge of the facing and then downward at 1 horizontal to 1 vertical (1H:1V) side slope to the native soil. The engineered fill must consist of OPSS PROV Granular A or Granular B Type II compacted to 100% of its SPMDD 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.

The RSS walls should meet the geometry, performance and appearance criteria as outlined in the MTO's RSS Design Guidelines, 2008. RSS walls should be designed and constructed similar to MTO requirements which are provided in MTO Special Provision SP 599S22 (Retained Soil Systems) and SP 599S23 (Retained Soil System – Facing Elements).

The performance of a RSS wall 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 (global instability) of the system. The entire block of reinforced earth must be designed against various modes of failure including bearing, sliding, overturning as well as internal stability.

An RSS wall founded on the compact silty sand to sand at or below about Elevation 262.0 m may be designed using a factored geotechnical resistance at ULS of 250 kPa and a factored geotechnical resistance at SLS of 150 kPa (for 25 mm of settlement).

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

Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.4 for an engineered granular fill subgrade.

Topsoil, organics, 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 and placement and compaction of the granular fill must be carried out in the dry.

A geotextile filter fabric must be incorporated in the RSS design to prevent loss of fines from the granular material behind the wall subject to fluctuating water levels. If the wall is subjected to flooding, the strip lengths may have to be larger than the typical 0.7 times the height of the RSS wall. The RSS supplier/designer of should be alerted of this.

The RSS wall will be founded on native silt/silty sand soil which has a high potential for erosion. Therefore, adequate erosion protection must be provided in front of the base of the RSS wall to prevent the foundation soil erosion and undermining of the wall.

Lateral earth pressures acting on the RSS walls should be computed as described in Section 11. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

8.2.3.2 Foundation for Concrete Walls

Concrete headwalls may be supported on spread footings founded on the compact silty sand to sand subgrade. Any topsoil/organics or soft soil must be removed from the foundation subgrade and replaced with granular fill compacted as per OPSS 501. The walls should be provided with sufficient frost cover (minimum 2.2 m) and founded at Elevation 262 m or below. A factored geotechnical resistance at ULS of 250 kPa and a geotechnical reaction at SLS of 150 kPa (for 25 mm of settlement) may be used for design. A 300 mm thick granular levelling pad should be provided below the footing. Load inclination and eccentricity should also be taken into account according to the CHBDC 2014 Clauses 6.10.3 and 6.10.4.

Resistance to lateral forces / sliding resistance between precast concrete and the underlying silt/sand should be evaluated in accordance with the CHBDC 2014 assuming an ultimate coefficient of friction of 0.3 for the compact silty sand.

Lateral earth pressures acting on the concrete wingwalls should be computed as described in Section 11. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

The concrete wall will be founded on native silt/silty sand soil which has a high potential for erosion. Adequate rock erosion protection must be provided in front of the base of the wall to prevent the foundation soil erosion and undermining of the wall.

8.2.4 Frost Protection

The depth of frost penetration at this site is approximately 2.2 m as per Ontario Provincial Standard Drawing (OPSD) 3090.100 (Foundation Frost Depths for Northern Ontario). Headwall footings, if employed, should be provided with a minimum of 2.2 m of earth cover as protection against frost action. The frost cover requirement does not apply to the base of a CSP or box culvert due to their depth of burial and higher tolerance for differential settlement/heave. The obvert of the existing culvert is below the frost penetration depth at the site. Therefore, the new culvert will not require a frost taper if its obvert is founded at the same elevation as the existing culvert or below. If top of the new CSP or box culvert is above the depth of frost penetration, frost treatment or a frost taper should be provided as per OPSD 803.031 for CSP culverts or OPSD 803.010 for a box culvert.

8.2.5 Subgrade Preparation and Protection

Performance of the replacement culvert and any headwalls 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, disturbed soils and any deleterious materials within the replacement culvert and headwall footprint at the subgrade level must be removed and replaced with well compacted granular materials.

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 excavation and backfilling should be carried out in accordance with OPSS 902. The subgrade preparation, placement and compaction of granular material must be carried out in the dry.

Where fine grained soils (silt and clay) are exposed at the foundation subgrade level, they will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that construction equipment be not allowed to travel on the bedding or the prepared subgrade which has to be protected from disturbance during construction.

A separation layer consisting of a non-woven geotextile should be placed between the subgrade and the underside of the bedding material. The geotextile should meet the specifications for OPSS 1860 Class II, and have a Fabric Opening Size (FOS) not greater than 150 micrometres.

8.2.6 Settlement

It is anticipated that the proposed replacement will not result in highway grade raise or re-location of the culverts. Therefore, minimal post construction settlement is expected at this site. It must be noted that any additional load imposed on the culvert replacement, including fill placed adjacent to the extended culvert barrels, will induce immediate settlement and some long term settlement at this site.

8.3 Construction Considerations

Where construction staging is required to maintain one lane of traffic, the following items should be considered in the planning and execution of the staged construction sequencing:

- Diversion of the creek will be required for construction. In addition, a suitable dewatering program will be required to facilitate the construction of 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 and headwall subgrade preparation and foundation preparation must be carried out in the dry.

9. 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 at this site are classified as Type 3 soils. The silt, silty sand to sand below the /groundwater table 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 and extended into the silty sand to sand. Obstructions such as cobbles or debris might be encountered within the fill. Suggested wording for an NSSP on potential obstructions in the fill is included in Appendix F.

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. Seepage should be anticipated from the embankment fill. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps will be required to maintain dry excavations during the course of staged construction.

The dewatering system on site should conform to OPSS 518 (Construction Specifications for Control of Water from Dewatering Operation). 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 F. Additional assessment should be made to determine if a Permit to Take Water (PTTW) is required.

Stockpile of excavated materials and heavy construction equipment should be kept at least the same horizontal distance from the edge of excavation as the depth of the excavation to prevent local instabilities.

10. STREAM DIVERSION PIPE

The highway embankment height above the water level in the creek is about 6.9 m. The installation of the replacement pipe or the diversion pipe may be conducted using the conventional open cut and backfill or trenchless techniques.

For the conventional open cut and backfill installation, temporary shoring may be required to install the diversion pipe at the proposed depth of approximately 7 m to 8 m.

The pipe 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 and compaction of bedding should be carried out in the dry. The prepared subgrade should be protected from disturbance during construction.

Trenchless methods that are typically considered to install pipes under highways include:

- Jack and bore
- Pipe ramming
- Microtunnelling (MTBM)

- Hand Mining
- Horizontal Directional Drilling

Selection of an appropriate trenchless method is the responsibility of the Contractor and will depend on the relative costs and risks associated with each method. The experience of the Contractor is of primary importance for trenchless installation.

The excavation through the water bearing non-cohesive silty sand to sand is considered as flowing conditions for the face of the excavation during the trenchless installation. Therefore, only Pipe Ramming and Microtunnelling are considered feasible methods for this installation.

Horizontal Directional Drilling is also considered feasible from geotechnical/foundation design perspective if the diameter of the pipe is less than 1.5 m and minimum depth of cover to avoid frac-out can be achieved.

The recommended minimum distance between the existing and the new pipes is 1 to 2 times the pipe diameter.

Monitoring of the roadway surface should be carried out during trenchless installation. The settlement monitoring program and condition survey should follow MTO's Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application. A copy of this document is attached in Appendix G.

11. 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 or 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 to be 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 11.1 below.

Table 11.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	**OPSS Granular A or Granular B Type II ϕ = 35°; g = 22.8 kN/m^3**		**OPSS Granular B Type I (modified) ϕ = 32°; g = 21.2 kN/m^3**	
	Horizontal Backfill	**Sloping Backfill (2H:1V)**	**Horizontal Backfill**	**Sloping Backfill (2H:1V)**
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.3	-

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

In general the lateral earth pressure applied to a retaining structure (e.g., headwalls and/or vertical side walls of the culverts) depends on the lateral movement of the structure to activate active, passive or at rest earth pressure. If the wall support does not allow lateral movement (restrained stem) such as in a box culvert configuration, at rest earth pressures should be assumed for geotechnical design. If the wall support allows lateral movements (unrestrained stem) such as in concrete headwalls, active earth pressure should be used in the design of the wall. The minimum lateral movement to allow active pressures to develop within the backfill is outlined in Section C6.12 of the Commentary on CHBDC 2014.

The use of a material with a high friction angle and low active pressure coefficient (e.g., Granular A or 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 lateral pressure representing the compaction surcharge should be added in design of retaining walls and vertical side walls of the culverts. The magnitude of the lateral pressure should be 12 kPa at the top of fill which linearly decreases to zero 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). If the wall is retaining sloping backfill, appropriate earth pressure parameters from Table 11.1 for sloping backfill should be used.

12. SEISMIC CONSIDERATIONS

The stratigraphy of the site is typically loose silt underlain by a compact to dense silty sand to sand to the borehole termination depths. This corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC 2014. The reference peak ground acceleration and velocity, PGA and PGV for a 2%, 5% and 10% probabilities of exceedance (equivalent of return periods of 475, 975 and 2475, respectively) in 50 years for Site Class C at the project site, based on the National Building Code of Canada (NBCC) 2015, are estimated and summarized in Table 12.1 below.

Table 12.1 – Seismic Hazard Values for Reference Ground Conditions Site Class C

Return Period (Years)	Probability of Exceedance	Coefficient of PGA_{ref}	Coefficient of PGV_{ref}
475	10% in 50 Years	0.010	0.007
975	5% in 50 Years	0.018	0.013
2475	2% in 50 Years	0.036	0.025

Retaining structures should be designed using active (K_{AE}) earth pressure coefficient that incorporate the effects of earthquake loading, in accordance with Clause 4.6.5 of the CHBDC 2014. The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total active earth pressure distribution (static plus seismic) may be determined as follows:

$$\sigma_h(d) = K_a \gamma' d + (K_{AE} - K_a) \gamma' (H-d)$$

where $\sigma_h(d)$ = the lateral earth pressure at depth d, (kPa)

K_a = either the static active earth pressure coefficient (K_a)

K_{AE} = the seismic active earth pressure coefficient;
γ' = the effective unit weight of the backfill soil (kN/m^3), taken as soil unit weight given above;
d = the depth below the top of the wall (m); and
H = the total height of the wall above its toe (m).

The coefficients of horizontal earth pressure for seismic loading presented in Table 12.2 may be used:

Table 12.2 – Active Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II ϕ = 35°, γ = 22.8 kN/m^3	OPSS Granular B Type I (modified) ϕ = 32°, γ = 21.2 kN/m^3
Active (K_{AE})*	0.28	0.32

* After Mononobe and Okabe.

The site is underlain by compact to dense silty sand to sand. Liquefaction is not considered to be a concern due to the relatively low PGA for the site.

13. TEMPORARY PROTECTION SYSTEM

The temporary roadway protection system should be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2, provided that any nearby utility/structure can tolerate this magnitude of deformation.

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

Table 13.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Silty Sand/Sand
γ	21 kN/m^3	21 kN/m^3
γ_w	10 kN/m^3	10 kN/m^3
K_a	0.33	0.33
K_p	3.0	3.0
K_0	0.5	0.5

Full hydrostatic pressure should be considered assuming a water level at least equal to the design stream water level. The embankment is over 7 m high. A suitable anchor or bracing system may be required for the roadway protection.

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 retaining system, 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.

14. EMBANKMENT RESTORATION

The existing Highway 595 embankment is approximately 2.3 m above the culvert at the site location and the embankment slopes appear to be performing satisfactorily. Provided that the embankment is reconstructed at the same slope inclination as the existing embankment, but not steeper than 2H:1V, the restored embankment slope should remain stable.

It is anticipated that there will be no grade raise or embankment widening at this site for the culvert replacement, and therefore settlement of the embankment is not a concern. Any settlement due to changes in the culvert configuration is expected to be less than 25 mm. Additional settlement would be induced if the final configuration includes additional fill adjacent to the culvert barrels.

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

In general, surface vegetation, 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.

15. 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 and in accordance with OPSD 810.010, OPSS 511 and OPSS.PROV 1004.

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 at the inlet 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 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used in lieu of a compacted clay seal.

16. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be low due to the low concentrations of sulphate and chloride in the samples tested.
- The potential for soil or water corrosion on metal is considered to be mild.
- Appropriate protection measures are recommended if metal structural elements are used.
- The effect of road de-icing salt should be considered in the choice of concrete and metal structure elements.

17. OTHER 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.

- 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 F.
- 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.

18. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Mehdi Mostakhdemi, 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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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction
1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

▼ Water Level
C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value — Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
(2) DCPT — Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

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			

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-05

METRIC

W.P. ______ LOCATION Sitch Creek N 5 351 237.3 E 327 055.2 ORIGINATED BY AHF

HWY 595 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN

DATUM Geodetic DATE 2017.04.29 - 2017.04.29 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
266.9	GROUND SURFACE								
266.1 / 0.0–0.8	Silty **CLAY**, trace sand, trace gravel, organics, Dark Brown, Wet (FILL)	1	GS						
264.8 / 0.8–2.1	**SAND**, some silt, trace to some gravel, Loose, Brown, Moist (FILL)	1	SS	5	266	6	76	13	5
		2	SS	4	265				
262.3 / 2.1–4.6	Silty **CLAY**, sandy to trace sand, trace gravel, Soft, Brown, Wet (FILL)	3	SS	4		2	29	46	23
		4	SS	2	264, 263				
259.7 / 4.6–7.2	Silty **SAND**, trace gravel, Compact, Dark Grey, Wet	5	SS	13	262				
		6	SS	15	261, 260				
7.2	**SAND**, trace to some silt, Compact, Dark Grey, Wet	7	SS	29	259				
		8	SS	28	258, 257	0	95	4	1

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

Continued Next Page

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

RECORD OF BOREHOLE No 17-05

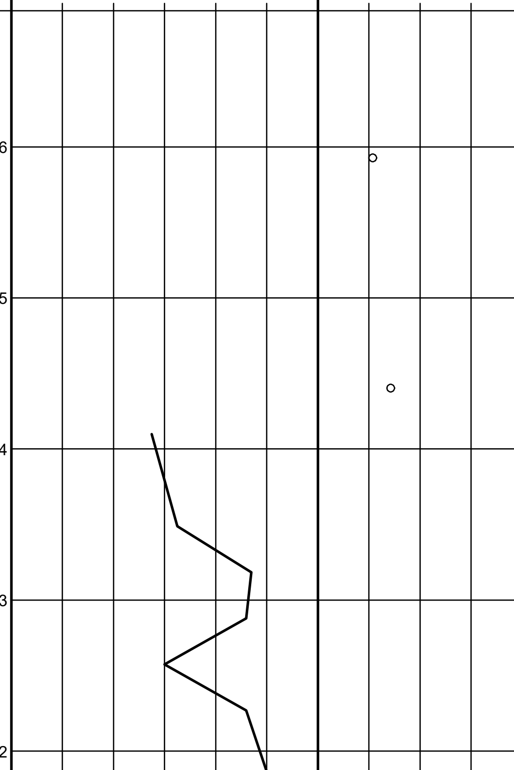
METRIC

W.P. ______ LOCATION Sitch Creek N 5 351 237.3 E 327 055.2 ORIGINATED BY AHF

HWY 595 BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN

DATUM Geodetic DATE 2017.04.29 - 2017.04.29 CHECKED BY CZ

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L – WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
			9	SS	29		256				
							255				
254.1			10	SS	42						
12.8	End of sampling and start of DCPT						254				
							253				
251.9							252				
15.0	END OF BOREHOLE AT 15.0m UPON DCPT REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.										



WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.04.30	5.9	261.0

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-06

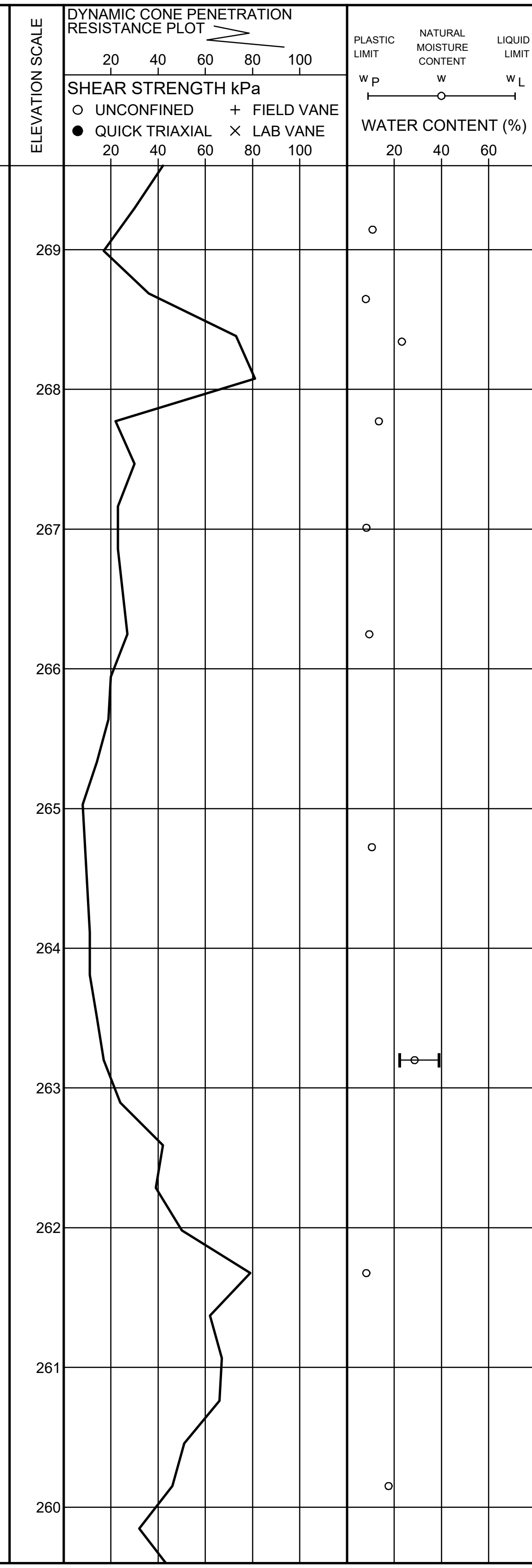
METRIC

W.P. ______ LOCATION Sitch Creek N 5 351 234.2 E 327 064.4 ORIGINATED BY ES

HWY 595 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 0217.04.11 - 2017.04.11 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
269.6	GROUND SURFACE					
0.0	**ASPHALT:** (25mm)					
	SAND, trace gravel, Dense, Brown, Moist (FILL)	1	GS			
		1	SS	39		
268.5 / 1.1	Silty **CLAY**, trace sand, trace gravel, Compact, Brown, Moist (FILL)					
267.9 / 1.7	Silty **SAND**, trace to some gravel, trace clay, Compact to Loose, Brown, Moist (FILL)	2	SS	17		10 58 25 7
		3	SS	16		
		4	SS	17		
		5	SS	6		
264.0 / 5.6	Silty **CLAY**, with sand, Soft, Brown, Moist (FILL)				∇ (approx. El. 264.0)	
		6	SS	3		0 37 40 23
261.9 / 7.7	**SAND**, fine grained, silty to some silt, trace gravel, Compact to Dense, Dark Grey, Moist to Wet	7	SS	26		
		8	SS	19		0 67 29 4



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

ONTMT4S MTO-17840.GPJ 2015TEMPLATE(MTO).GDT 17/6/7

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-06

METRIC

W.P. ______ LOCATION Sitch Creek N 5 351 234.2 E 327 064.4 ORIGINATED BY ES

HWY 595 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

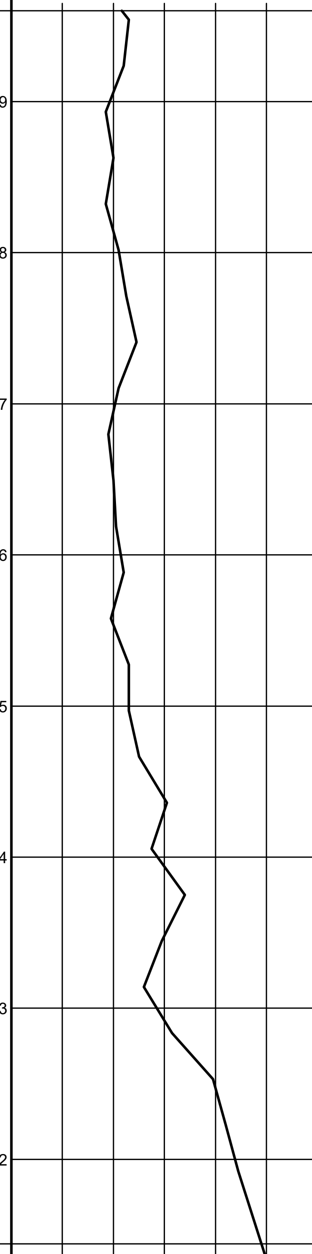
DATUM Geodetic DATE 0217.04.11 - 2017.04.11 CHECKED BY CZ

Continued From Previous Page

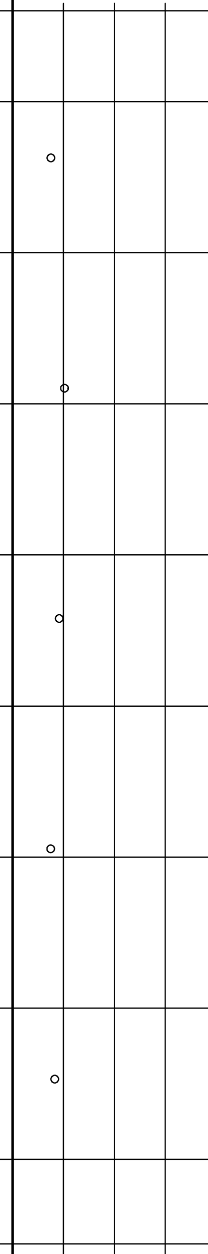
ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
					259				
		9	SS	7					
					258				
		10	SS	12	257				
					256				
		11	SS	22					
					255				
		12	SS	31	254	13	71	12	4
					253				
		13	SS	25					
					252				
251.4									
18.2	END OF BOREHOLE AT 18.2m UPON AUGER REFUSAL. WATER LEVEL AT 5.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CEMENT TO 0.1m, THEN ASPHALT TO SURFACE.								

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

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



PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%) 20 40 60



UNIT WEIGHT γ kN/m3

+3, ×3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-07

METRIC

W.P. ______ LOCATION Sitch Creek N 5 351 222.5 E 327 063.9 ORIGINATED BY ES

HWY 595 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.04.10 - 2017.04.10 CHECKED BY CZ

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100)

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

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
269.9	GROUND SURFACE												
0.0	**ASPHALT:** (25mm)												
	SAND, gravelly to trace gravel, some silt, trace clay Very Dense to Loose Brown Moist (FILL)		1	GS				○					
			1	SS	50		269	○					
			2	SS	48		268	○		29	51	20 (SI+CL)	
			3	SS	10		267	○					
	Trace silt		4	SS	7		266	○					
			5	SS	9		265	○					
			6	SS	5	∇	264	○		9	69	16	6
261.8			7	SS	11		263, 262	○					
8.1	**SILT**, some sand Compact Dark Grey Moist to Wet									0	23	72	5
260.8 9.1	**SAND**, fine grained, trace to some fines Compact Dark Grey Moist to Wet Silt layer (100mm) at 9.3m		8	SS	22		261, 260	○					

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

ONTMT4S MTO-17840.GPJ 2015TEMPLATE(MTO).GDT 17/6/7

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-07

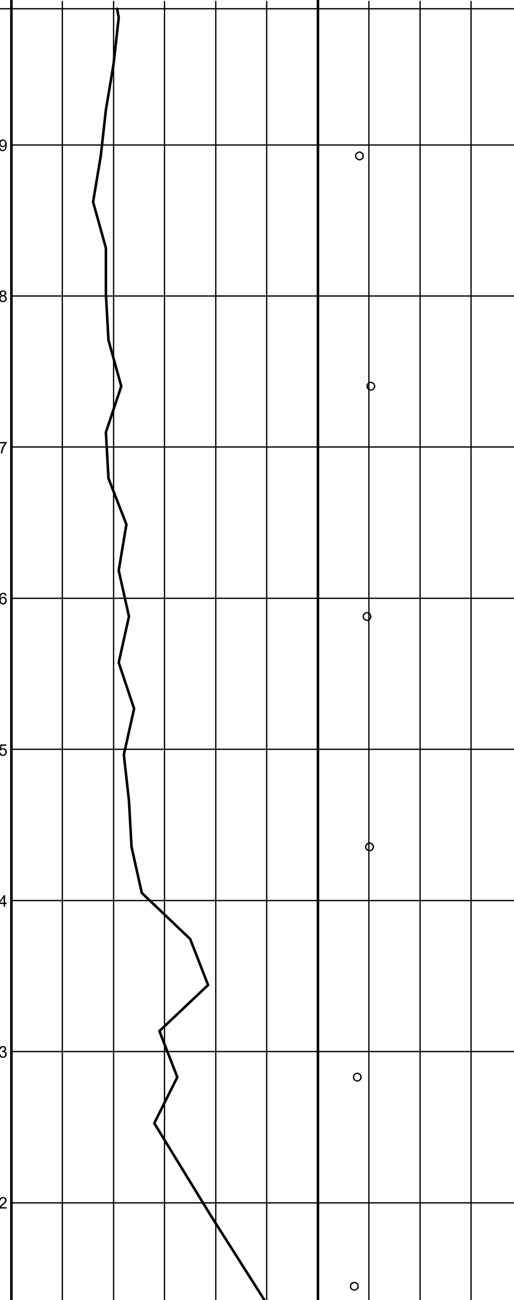
METRIC

W.P.		LOCATION	Sitch Creek N 5 351 222.5 E 327 063.9	ORIGINATED BY	ES
HWY	595	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.04.10 - 2017.04.10	CHECKED BY	CZ

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

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	SAND, fine grained Compact to Dense Dark Grey Wet								
		9	SS	28	259	0	88	9	3
		10	SS	17	258				
		11	SS	38	257 / 256				
		12	SS	37	255				
		13	SS	37	254 / 253				
251.3		14	SS	100/ 0.175	252				
18.6	END OF BOREHOLE AT 18.6m UPON AUGER REFUSAL. WATER LEVEL AT 6.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.6m, CUTTINGS TO 0.9m, CEMENT TO 0.1m, THEN ASPHALT TO SURFACE.								



+ ³, × ³: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-08

METRIC

W.P. ______ LOCATION Sitch Creek N 5 351 217.6 E 327 075.2 ORIGINATED BY AHF

HWY 595 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.04.30 - 2017.04.30 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
265.6	GROUND SURFACE						
0.0	Silty **CLAY**, with sand, trace gravel, roots and rootlets, Firm, Brown, Wet (FILL)	1	GS			265	
		1	SS	8			0 44 38 18
264.1 / 1.5	Silty **SAND**, some gravel, trace clay, Loose, Brown, Wet	2	SS	8		264	
263.4 / 2.2	**SILT**, some sand, Very Loose, Grey, Wet	3	SS	1	∇	263	0 16 77 7
		4	SS	3		262	
261.5 / 4.1	**SAND**, some silt to silty, Compact, Dark Grey, Wet	5	SS	12		261	
						260	
		6	SS	15		259	
		7	SS	17		258	
						257	
		8	SS	20		256	2 79 17 2

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-08

METRIC

W.P. ______ LOCATION Sitch Creek N 5 351 217.6 E 327 075.2 ORIGINATED BY AHF

HWY 595 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.04.30 - 2017.04.30 CHECKED BY CZ

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page						255				
			9	SS	33				o		
254.3 / 11.3	END OF BOREHOLE AT 11.3m. WATER LEVEL AT 2.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 2.4m AND CUTTINGS TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

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

ONTMT4S MTO-17840.GPJ 2015TEMPLATE(MTO).GDT 6/1/17

Appendix B

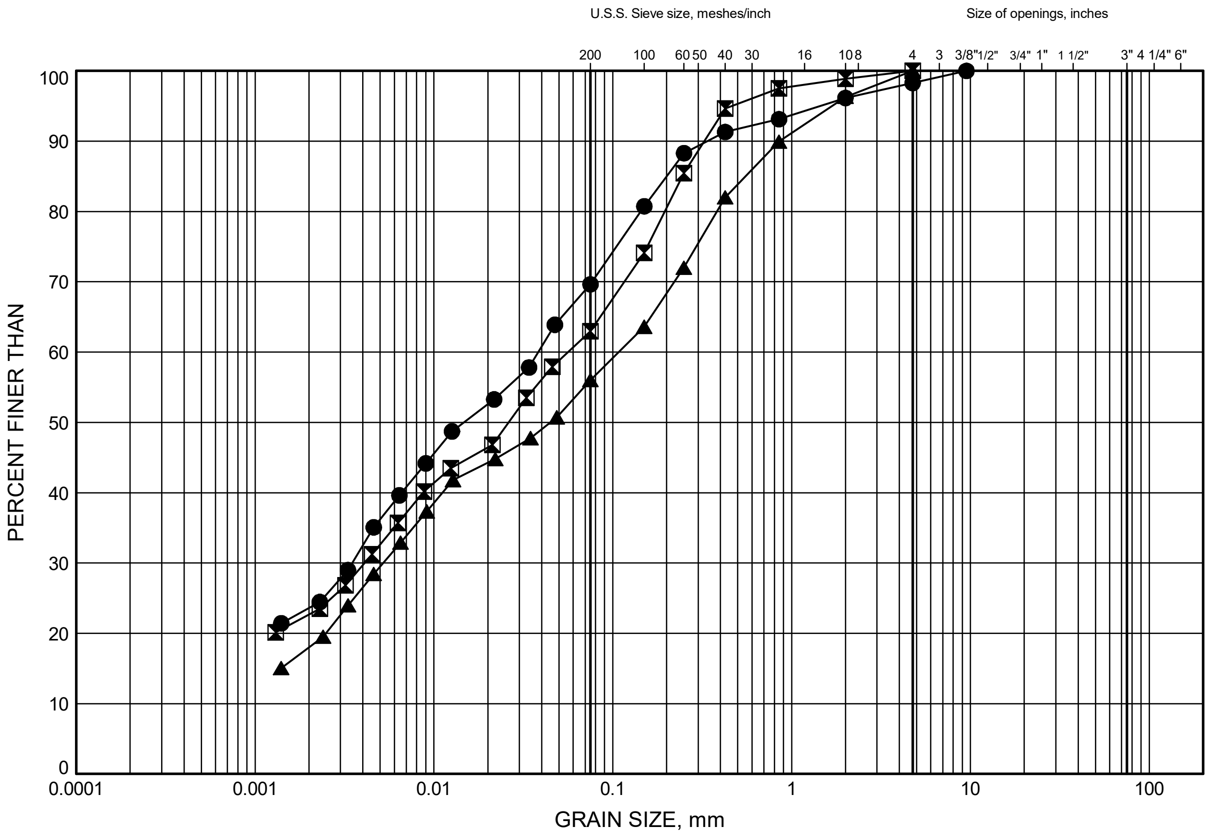
Geotechnical and Analytical Laboratory Test Results

Sitch Creek - Highway 595

GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty Clay Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-05	2.6	264.3
⧗	17-06	6.4	263.2
▲	17-08	1.1	264.5

Date June 2017

W.P.

THURBER

Prep'd MFA

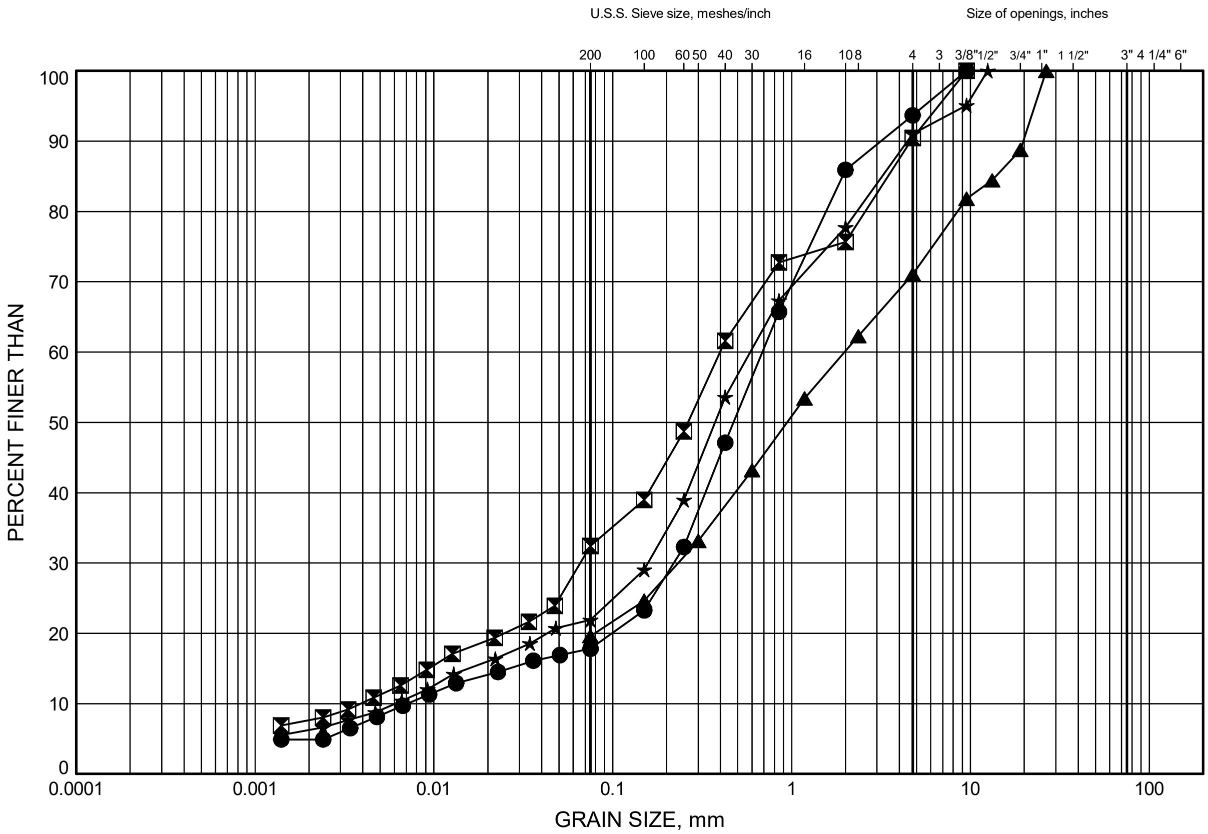
Chkd. CZ

Sitch Creek - Highway 595

GRAIN SIZE DISTRIBUTION

FIGURE B2

Sand Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-05	1.1	265.8
⊠	17-06	1.8	267.8
▲	17-07	1.8	268.1
★	17-07	6.4	263.5

Date June 2017

W.P.

THURBER

Prep'd MFA

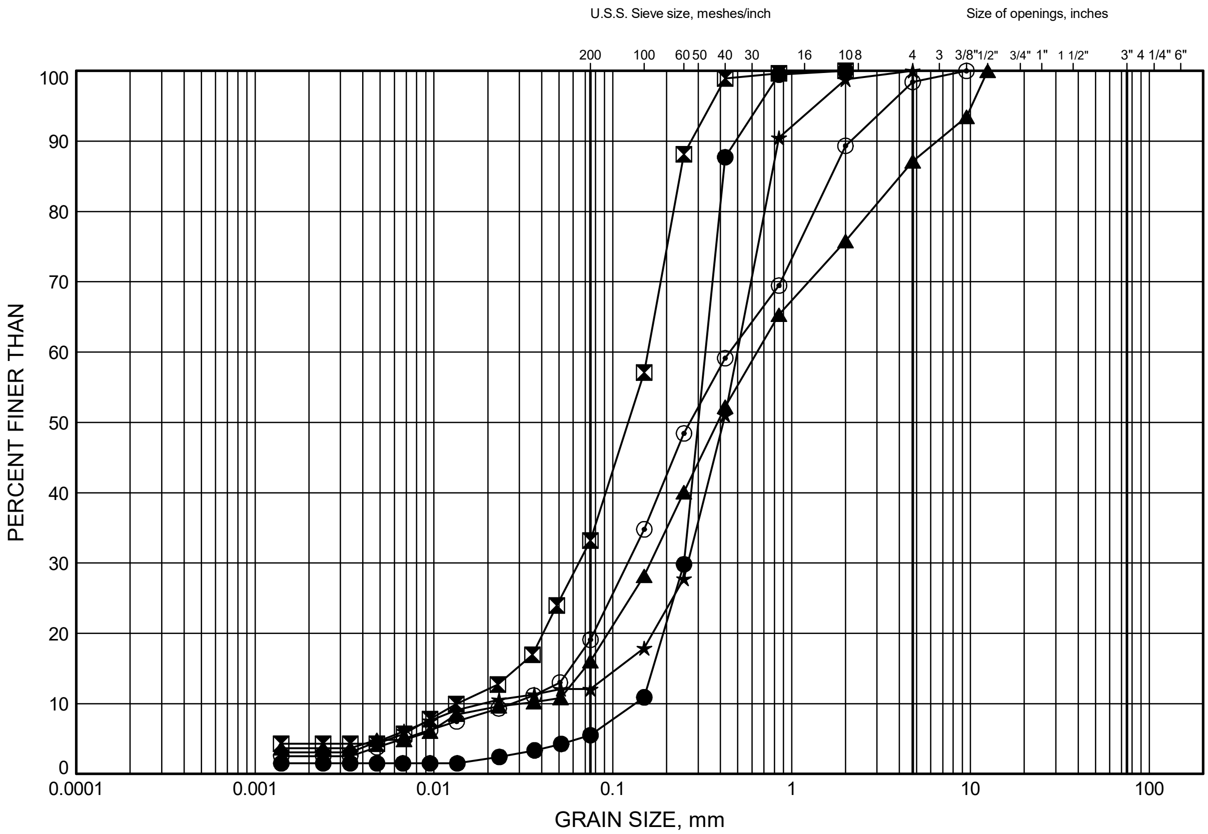
Chkd. CZ

Sitch Creek - Highway 595

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty Sand to Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-05	9.4	257.5
⧗	17-06	9.4	260.2
▲	17-06	15.5	254.1
★	17-07	11.0	258.9
⊙	17-08	9.4	256.2

Date June 2017

W.P.

THURBER

Prep'd MFA

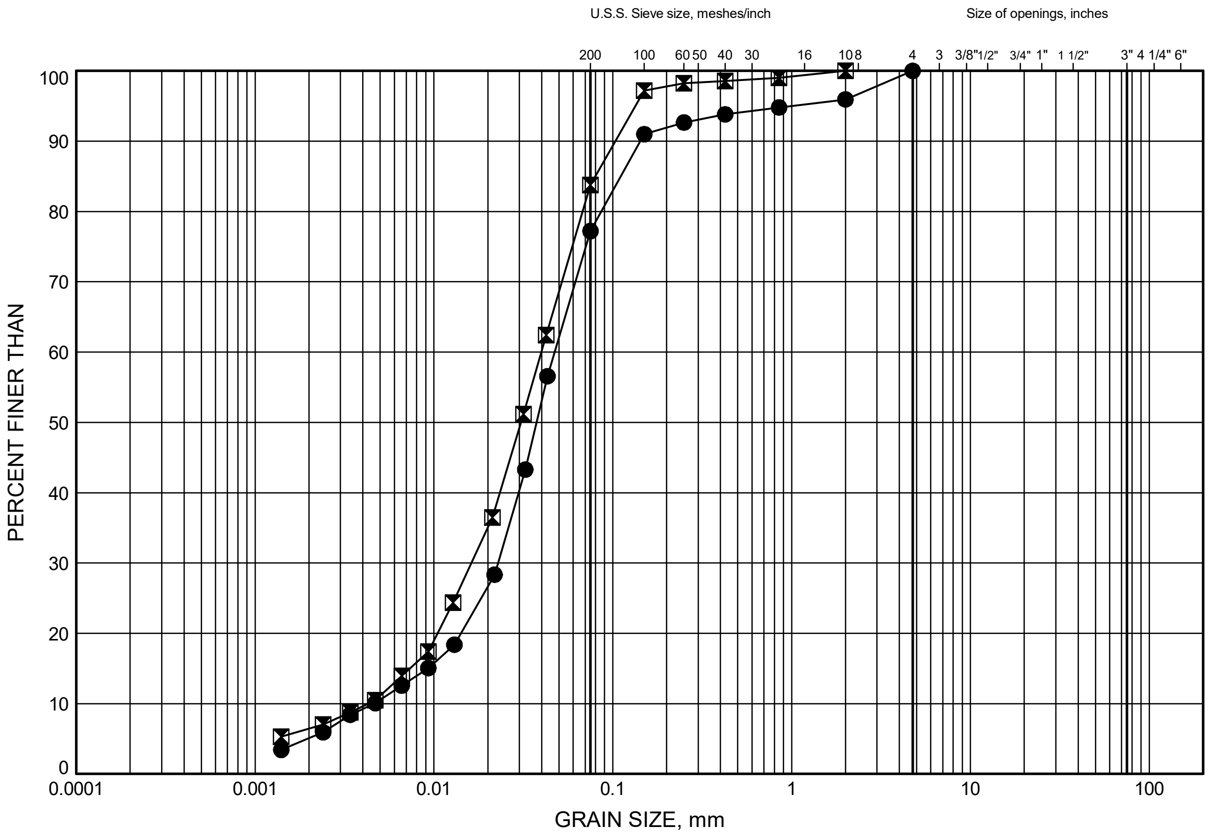
Chkd. CZ

Sitch Creek - Highway 595

GRAIN SIZE DISTRIBUTION

FIGURE B4

Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-07	7.9	262.0
⧖	17-08	2.6	263.0

Date June 2017

W.P.

THURBER

Prep'd MFA

Chkd. CZ

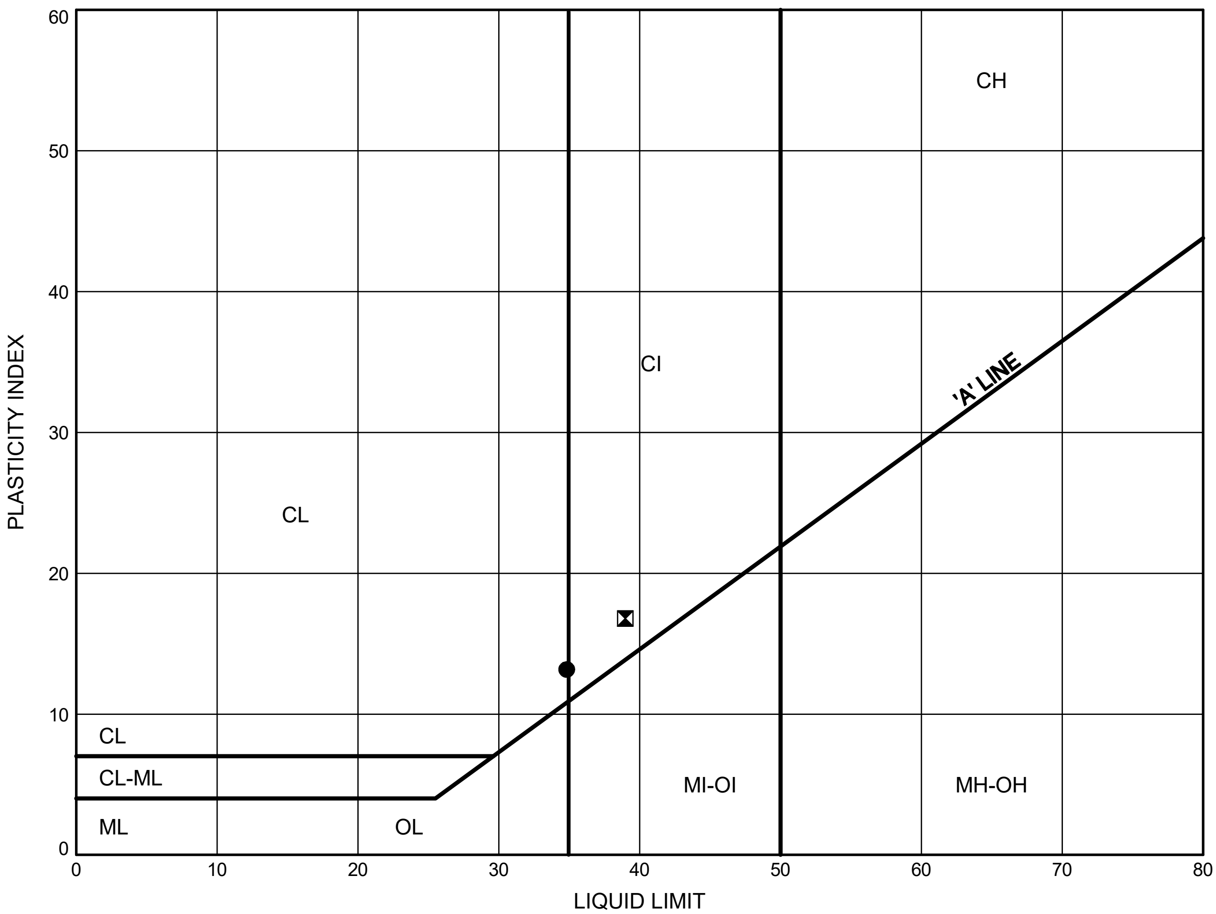
GRAIN SIZE DISTRIBUTION - THURBER MTO-17840.GPJ 6/7/17

Sitch Creek - Highway 595

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty Clay Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-05	2.6	264.3
⧗	17-06	6.4	263.2

THURBALT MTO-17840.GPJ 6/7/17

Date June 2017

W.P.

THURBER

Prep'd MFA

Chkd. CZ

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 17840

19-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. : 13 April 2017
LR Report: **CA13586-APR17**
Reference: 17840 Mark Farrant

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: MDL	6: Sitch Creek Culvert Hwy 595
Sample Date & Time						11-Apr-17 16:00
Temperature Upon Receipt [°C]					---	11.0
pH [no unit]	17-Apr-17	13:30	18-Apr-17	08:37	0.05	7.39
Conductivity [uS/cm]	17-Apr-17	13:30	18-Apr-17	08:37	2	89
Resistivity (calculated) [ohms.cm]	19-Apr-17	15:07	19-Apr-17	15:07	---	11200
Redox Potential [mV]	13-Apr-17	13:28	17-Apr-17	12:58	---	142
Chloride [mg/L]	18-Apr-17	06:49	19-Apr-17	14:39	0.04	2.3
Sulphate [mg/L]	18-Apr-17	06:49	19-Apr-17	14:39	0.04	3.6
Sulphide [mg/L]	18-Apr-17	11:00	18-Apr-17	15:43	0.006	< 0.006

Temperature of Sample upon Receipt: 11 degrees C
Cooling Agent Present: Yes
Custody Seal Present and Intact: Yes

Sample Sitch Creek Hwy 595 contains visible sediment

Deanna Edwards

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

OnLine LIMS

0000971495

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Method Descriptions

Parameter	Units	SGS Method Code	Reference Method Code
Anions by IC	mg/L	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	uS/cm	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	no unit	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential	mV		SM 2580
Sulphide by SFA	mg/L	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 17840

LR Report : **CA13586-APR17**

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: DIO0184-APR17												
Chloride	0.04	mg/L	<0.04		8	20	98	80	120	98	75	125
Sulphate	0.04	mg/L	<0.04		10	20	97	80	120	89	75	125
Conductivity - QCBatchID: EWL0199-APR17												
Conductivity	2	uS/cm	< 2		0	10	100	90	110	NA		
pH - QCBatchID: EWL0199-APR17												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0181-APR17												
Redox Potential	no	mV	NA		1	20	104	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0124-APR17												
Sulphide	0.006	mg/L	<0.006		ND	20	85	80	120	NV	75	125

OnLine LIMS

0000971495

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 17742/17840

24-May-2017

Thurber Engineering Ltd
Attn : Cory Zanatta

2010 Winston Park Dr
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 240
Fax:

Date Rec. : 17 May 2017
LR Report: **CA14528-MAY17**
Reference: 17742/17840 Cory Zanatta

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: 17840 17-09 SS9	6: 17840 17-08 SS6	7: 17840 17-06 SS7	8: 17840 17-03 SS5
Sample Date & Time					15-May-17	15-May-17	15-May-17	15-May-17
Temperature Upon Receipt [°C]	---	---	---	---	10.0	10.0	10.0	10.0
Corrosivity Index [none]	24-May-17	13:45	24-May-17	13:45	7.5	4.5	7.5	4.0
Soil Redox Potential [mV]	18-May-17	19:36	19-May-17	14:01	139	152	272	237
Sulphide [%]	23-May-17	12:52	23-May-17	13:09	0.67	0.53	0.51	< 0.02
% Moisture (wet wt) [%]	23-May-17	10:42	23-May-17	10:44	19.3	19.8	9.9	17.9
pH [no unit]	19-May-17	14:44	24-May-17	13:14	8.73	8.22	8.51	8.55
Chloride [µg/g]	19-May-17	12:04	23-May-17	11:42	16	5.9	15	25
Sulphate [µg/g]	19-May-17	12:04	23-May-17	11:42	54	68	200	61
Conductivity [uS/cm]	19-May-17	14:44	24-May-17	13:14	76	92	173	109
Resistivity (calculated) [Ohms.cm]	19-May-17	14:44	24-May-17	13:14	13200	10900	5780	9170

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 17742/17840
LR Report : CA14528-MAY17

Analysis	9: 17840 17-02 SS6	10: 17840 17-07 SS7	11: 17792 17-03 SS3	12: 17792 17-02 SS4
Sample Date & Time	15-May-17	15-May-17	15-May-17	15-May-17
Temperature Upon Receipt [°C]	10.0	10.0	10.0	10.0
Corrosivity Index [none]	7.5	7.5	2.0	1.0
Soil Redox Potential [mV]	200	256	278	315
Sulphide [%]	0.05	0.39	< 0.02	< 0.02
% Moisture (wet wt) [%]	18.9	14.1	20.1	10.9
pH [no unit]	8.68	8.47	7.40	6.03
Chloride [µg/g]	55	59	260	66
Sulphate [µg/g]	110	200	8.3	32
Conductivity [uS/cm]	157	200	384	150
Resistivity (calculated) [Ohms.cm]	6370	5000	2600	6670

Temperature of Sample upon Receipt: 10 degrees C
Cooling Agent Present: Yes
Custody Seal Present: No

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.

Deanna Edwards

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

OnLine LIMS

0001007963

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Method Descriptions

Parameter	SGS Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013
pH	ME-CA-[ENV]EWL-LAK-AN-001

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 17742/17840
LR Report : **CA14528-MAY17**

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: DIO0347-MAY17												
Chloride	0.4	µg/g	<0.4		12	20	97	80	120	97	75	125
Sulphate	0.4	µg/g	<0.4		5	20	97	80	120	86	75	125
Carbon/Sulphur - QCBatchID: ECS0026-MAY17												
Sulphide	0.02	%	<0.02		ND	20	117	80	120			
Conductivity - QCBatchID: EWL0361-MAY17												
Conductivity	2	uS/cm	< 2		0	10	96	90	110	NA		
pH - QCBatchID: EWL0361-MAY17												
pH	0.05	no unit	NA		0		100			NA		

OnLine LIMS

0001007963

Appendix C

Selected Site Photographs

Photograph 1 – Sitch Creek Culvert – HWY 595, West End (Inlet)

Photograph 2 – Sitch Creek Culvert – HWY 595, East End (Outlet)

Appendix D

Borehole Locations and Soil Strata Drawing

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No

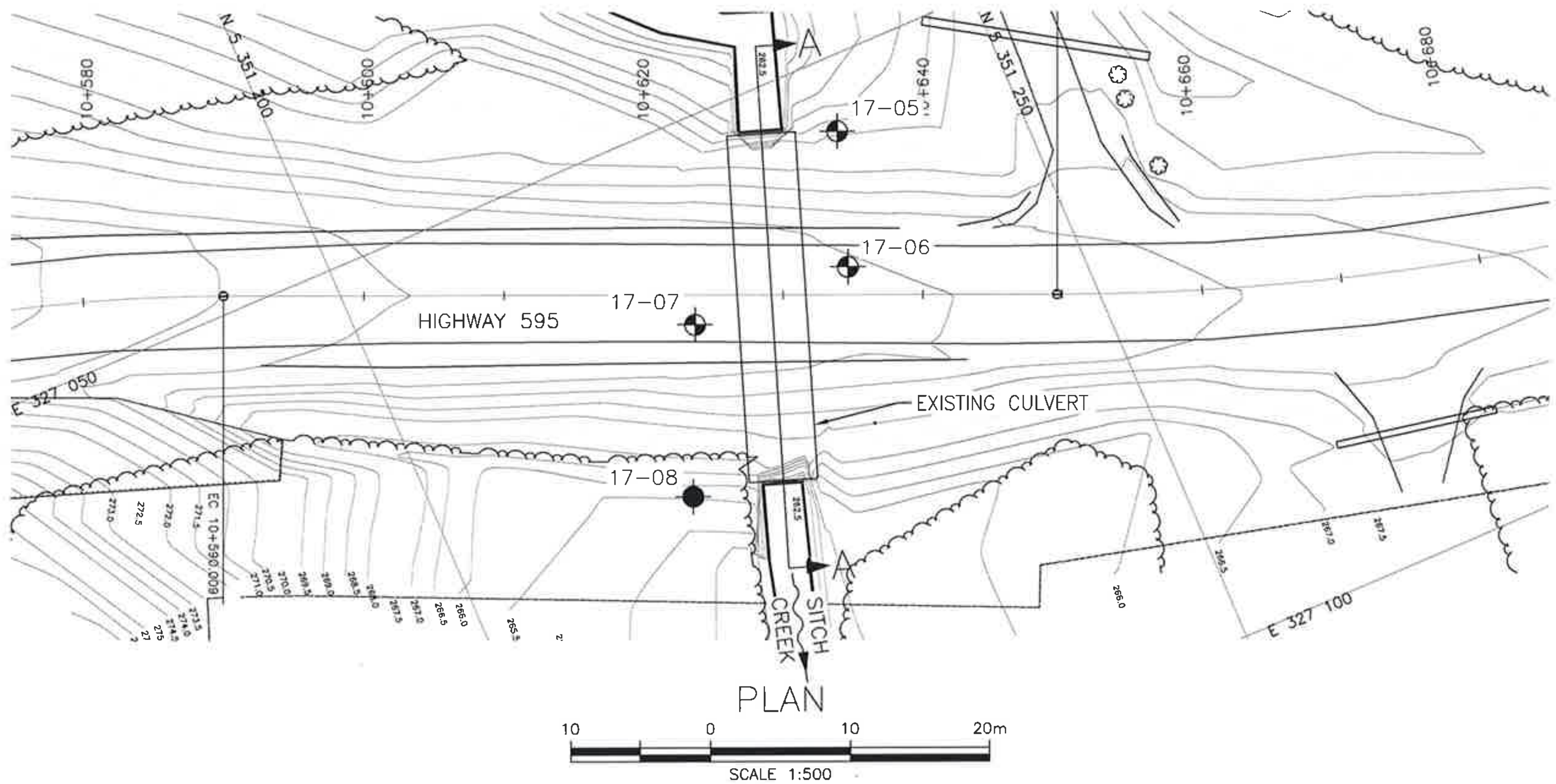
WP No

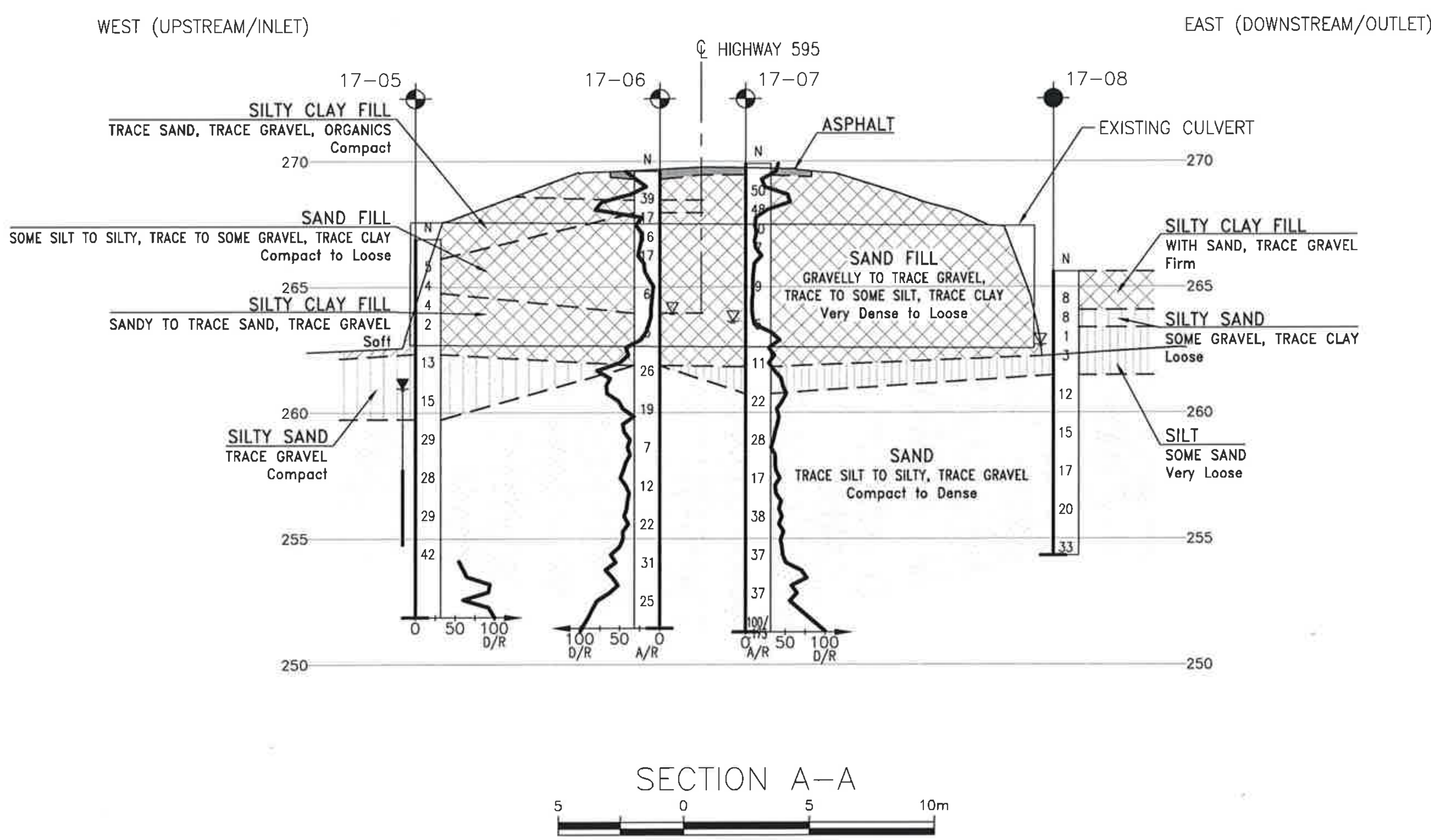
HIGHWAY 595
SITCH CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

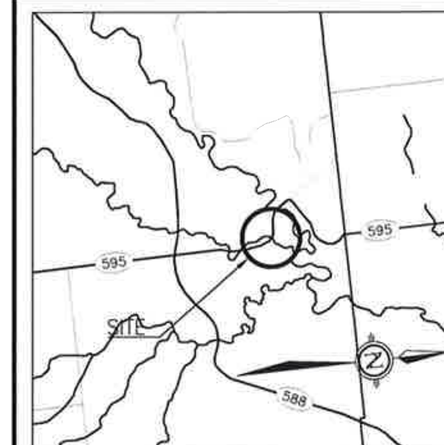
SHEET

Ontario

THURBER ENGINEERING LTD.







KEYPLAN

LEGEND

⯁	Borehole
⯁	Borehole and Cone
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
ǀ	Piezometer
A/R	Auger Refusal
D/R	DCPT Refusal

NO	ELEVATION	NORTHING	EASTING
17-05	266.9	5 351 237.3	327 055.2
17-06	269.6	5 351 234.2	327 064.4
17-07	269.9	5 351 222.5	327 063.9
17-08	265.6	5 351 217.6	327 075.2

LICENSED PROFESSIONAL ENGINEER
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-NOTES-

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

GEOCRES No. 52A-227

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN MM	CHK PKC	CODE	LOAD	DATE JUL 2017	
DRAWN MFA	CHK MM	SITE	STRUCT	DWG 1	

FILENAME: H:\Drafting\17000\17840\TED-17840-BHPP-SC1.dwg
PLOTDATE: 7/25/2017 3:11 PM

Appendix E

Comparison of Foundation Alternatives

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
Advantages: i. Ease of construction. ii. Segmented pipes can accommodate some potential differential settlement along culvert axis.	Advantages: i. Relatively rapid installation and less disturbance to subgrade soils if precast segments are used. ii. Segmental option can accommodate some potential differential settlement along culvert axis.	Advantages: i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
Disadvantages: i. Multiple pipes may be needed to meet hydraulic design (capacity) requirements. ii. Temporary roadway protection system is required.	Disadvantages: i. More expensive than a CSP culvert. ii. Relatively large excavation required to install culvert. iii. Temporary roadway protection system required.	Disadvantages: i. Greater potential for differential settlement. ii. Deeper excavation and potentially longer dewatering requirements. iii. More extensive roadway protection is required compared to the other two options. iv. More disturbance of creek.
FEASIBLE	**FEASIBLE**	**NOT RECOMMENDED**

Appendix F

List of Specifications and Suggested Wording for NSSP

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

- OPSS.PROV 206
- OPSS.PROV 209
- OPSS.PROV 422
- OPSS.PROV 501
- OPSS.PROV 539
- OPSS.PROV 804
- OPSS.PROV 902
- OPSS.PROV 1004
- OPSS.PROV 1010
- OPSS.PROV 1205
- OPSS.511
- OPSS.1860
- OPSD.802.010
- OPSD.803.010
- OPSD.810.010

2. Suggested Wording for NSSP

- Suggested Text 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, or shallow bedrock. Such obstructions may impede excavation progress and/or sheetpile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.”

- Suggested Text for NSSP on “Groundwater and Dewatering”

"The Contractor is notified that the site has high groundwater levels and that these levels may be higher than the water levels shown in the Foundation Investigation Report prepared for this site. While reference should be made to that report for a description of the encountered conditions, the Contractor must satisfy himself regarding the groundwater levels likely to prevail at the time of construction and be prepared to implement dewatering procedures.

The Contractor is further notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance.

Design and provision of an effective dewatering system is the responsibility of the Contractor. Subgrade preparation, culvert construction and backfilling must be carried out in the dry.

Appendix G

Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application

These guidelines specify MTO's minimum requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and do not cover all the design requirements.

The complexity ratings of Foundations Engineering services are defined in Table 1.

Table 1: Complexity ratings for tunnelling specialty services

Highway Classification	Tunnel Excavation Diameter (ϕ)					
	≤ 1 m		>1 m & ≤ 2 m		>2 m	
	Minimum Overburden Cover * (m)					
	$\geq 3\phi$ (or 1.5 m whichever is greater)	$< 3\phi$ (or 1.5 m whichever is greater)	$\geq 3\phi$	$< 3\phi$ (or 1.5 m whichever is greater)	$\geq 3\phi$	$< 3\phi$ (or 1.5 m whichever is greater)
Kings Highway	**Low**	**Medium**	**Medium**	**High**	**High**	**High**
400 Series Freeway	**Medium**	**High**	**High**	**High**	**High**	**High**

*Minimum overburden cover is the vertical distance measured from the lowest ground elevation to the crown of the tunnel.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Consultant services shall be provided in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

Services include, but are not restricted to, conducting a site investigation that shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

Minimum requirements for Subsurface Investigation and Recommendations

A minimum of one borehole shall be advanced at each end of tunnel crossing. The boreholes shall be located outside but within 2 m of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not the by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered.

Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic protection in accordance with MTO requirements shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

Minimum Laboratory Testing Requirements:

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limit plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

Borehole Log Preparation and Foundation Drawing:

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

Minimum Requirements for the Foundation Investigation and Design Report:

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

- The Foundation Investigation component of the report shall contain:
- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The consultant shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The consultant shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling (if economically feasible), utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD)and cut and cover methods.

The consultant shall identify and present overview assessments of the advantages, disadvantages, costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Consultant shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations
- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;

- relative rosts; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of consultant except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The consultant is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments. .

The consultant shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The consultant is responsible for preparing Traffic Control Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling consultant shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling consultant that the design package submitted to MTO have been reviewed by the tunnelling consultant and that all recommendations have been satisfactorily incorporated in the contract package.

APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING

The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.

Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

Surface Monitoring Points

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.

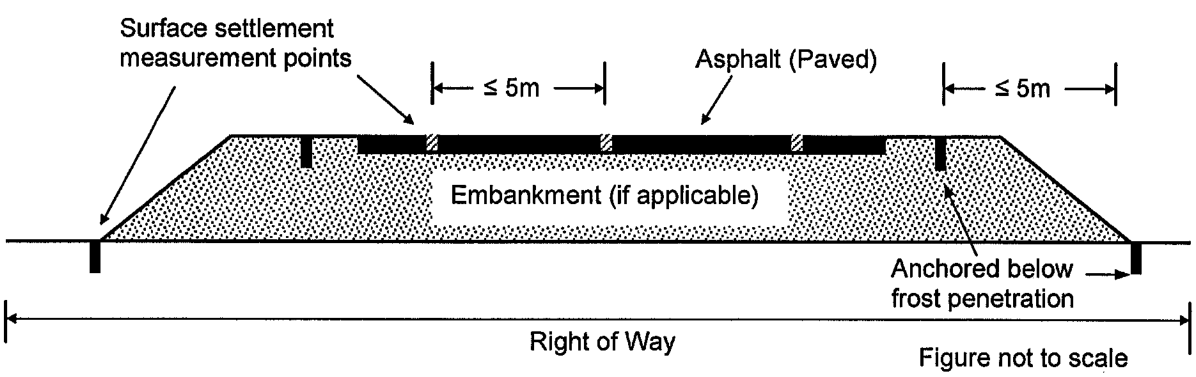

Figure 1: Typical configuration of surface settlement monitoring points along the tunnel alignment.

Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

Review of Contractor's Proposed Method

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

Contractor's Responsibility For Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.