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FOUNDATION INVESTIGATION AND DESIGN REPORT
SIMS CREEK CULVERT
HIGHWAY 71
TOWNSHIP OF DOBIE, DISTRICT OF RAINY RIVER, ONTARIO
G.W.P. 6813-14-00, SITE 45-281/C

GEOCRES No.: 52C-55

Report

to

HATCH

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the results of a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the replacement of the Sims Creek Culvert located north of Emo, within the District of Rainy River in the Township of Dobie, Ontario.

The purpose of this investigation was to explore the subsurface conditions in the vicinity of the culvert and based on the findings, to provide a plan of borehole locations, records of boreholes, laboratory test results, a written description of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to Hatch under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-005.

2. SITE DESCRIPTION

The existing culvert carries Highway 71 over Sims Creek, approximately 4.1 km north of the junction of Highway 11 and Highway 71 near Emo. At the existing culvert, Sims Creek flows easterly while Highway 71 runs in a north-south direction. The site is surrounded by low-lying swampy areas with vegetation consisting of tall grass, shrubs and occasional trees. Surrounding the site are forested areas with occasional bedrock outcrops.

The existing structure is a three-span open footing timber culvert with an unknown construction date. Based on an Ontario Bridge Management System (OBMS) inspection report dated November 20, 2014, it is understood that the structure is in overall fair condition.

Photographs included in Appendix D show the general conditions observed at the culvert inlet during the time of investigation.

3. INVESTIGATION PROCEDURES

The field work for this investigation was carried out between August 22 and August 24, 2016 during which a total of four (4) boreholes (16-31 to 16-34) were advanced on site. The approximate locations of the boreholes are shown on the Borehole Location Plan and Soil Strata drawing provided in Appendix G.

The boreholes were drilled using a CME 55 drill rig supplied by RPM Drilling Inc. of Thunder Bay, Ontario using hollow stem augers. Soil samples were obtained at selected intervals of depth with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT) procedure. Field vane shear tests using an MTO “N” size vane were carried out in the soft to firm cohesive soils.

The field work was supervised on a full time basis by members of Thurber’s engineering and technical staff, who staked the boreholes in the field, arranged for the clearance of subsurface utilities, directed the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil samples for transport to Thurber’s laboratory for further examination and testing.

Groundwater conditions in the open boreholes were noted upon completion of drilling. All boreholes were backfilled in general accordance with Ontario Regulation (O. Reg.) 903. A standpipe piezometer was installed in Borehole 16-34 for monitoring of the groundwater level. The backfilling and installation details of the boreholes and standpipe piezometer are presented in the table below.

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
16-31	9.8 / 343.3	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
16-32	14.3 / 341.6	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.1 m, then asphalt to surface.
16-33	14.3 / 341.6	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.1 m, then asphalt to surface.
16-34	9.8 / 343.9	9.8 / 343.9	Sand filter from 9.8 m to 6.4 m, then bentonite holeplug from 6.4 m to ground surface.

4. LABORATORY TESTING

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

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

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A. 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 should be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered in the boreholes on the highway platform consisted of asphalt pavement underlain by embankment fill consisting of gravelly sand to sand, overlying silty clay till. In the boreholes at the culvert inlet/outlet, the subsurface soils generally consisted of a surface layer of topsoil over silty clay till.

More detailed descriptions of the individual strata are provided in the following sections.

5.1 Topsoil / Organics

Topsoil/organics was encountered at the ground surface in Boreholes 16-31 and 16-34 advanced near the inlet and outlet of the culvert. The thickness of the topsoil/organics ranged from 0.7 m to 0.8 m.

5.2 Asphalt

Boreholes 16-32 and 16-33 were drilled through the existing pavement structure of Highway 71 and encountered a surface layer of asphalt having a thickness of about 150 mm.

5.3 Fill

Embankment fill was encountered below the asphalt in boreholes 16-32 and 16-33. The embankment fill consisted of sand to gravelly sand with total thicknesses between 2.1 m and 2.5 m. The base of the fill was at Elevation 353.2 m to 353.6 m.

SPT 'N' values within the fill ranged from 5 blows to 20 blows per 0.3 m of penetration, indicating a loose to compact relative density. The measured moisture contents of selected samples of the fill varied between 3 percent and 4 percent.

The results of grain size distribution analyses carried out on samples of the fill are presented on the Record of Borehole sheets in Appendix A, and on Figure B1 Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	15 to 28
Sand	62 to 68
Silt & Clay	10 to 17

5.4 Silty Clay Till

A layer of silty clay till was encountered below the embankment fill or topsoil in all boreholes. The cohesive till layer was brown to grey in colour and contained some sand and trace amounts of gravel. Organics and rootlets were noted in the upper 0.5 m to 2 m of the till at the inlet and outlet boreholes. In all boreholes, the layer extended to the borehole termination depths of 9.8 m to 14.3 m (Elevation 341.6 m to 343.9 m).

SPT 'N' values within the cohesive till ranged from 0 blow to 12 blows per 0.3 m penetration, indicating a soft to stiff consistency. The 0 blow count was noted near the surface of the till in Borehole 16-34. One field vane shear test measured an undrained shear strength of greater than 100 kPa, indicating a stiff to very stiff consistency. The measured moisture contents of samples of the till varied between 15 percent and 34 percent.

The results of grain size distribution analyses carried out on samples of the cohesive till are presented on the Record of Borehole sheets in Appendix A and on Figures B2 and B3 of Appendix B. The results are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 4
Sand	0 to 36
Silt	26 to 44
Clay	28 to 61

The results of Atterberg Limits analyses carried out on selected samples of the layer are presented on the Record of Borehole sheets in Appendix A and on Figure B4 Appendix B. The results are summarized below:

Index Property	Percentage (%)
Plastic Limit	16 to 42
Liquid Limit	30 to 62

The results of the Atterberg Limits testing indicate the layer to be of typically high plasticity with group symbol CH except a shallow till sample from borehole 16-31 indicating low plasticity (CL).

Glacial tills inherently contain cobbles and boulders.

5.5 Groundwater Conditions

Water levels were observed in the open boreholes upon completion of drilling and prior to backfilling. The open hole water levels are summarized in the table below.

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-31	August 24, 2016	Dry	-	Open borehole
16-32	August 23, 2016	Dry	-	Open borehole
16-33	August 22, 2016	Dry	-	Open borehole
16-34	August 23, 2016	Dry	-	Standpipe piezometer

The groundwater levels observed in the open boreholes are unstabilized very short-term readings and are strongly influenced by the permeability of the deposits and length of time the borehole remains open. Since the boreholes were drilled in clay till and the standpipe piezometer was sealed in the relatively low permeability till, the boreholes remained dry in the short term. The base plan drawing indicated that the creek level was at Elevation 352.8 m in April 2015 and the groundwater level is expected to reflect the creek water level. It should be noted that the groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year such as spring or after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

One representative sample of soil from Borehole 16-34 and a sample of surface water from the creek were submitted to SGS laboratories for chemical analysis related to potential for corrosion of buried steel and sulphate attack on buried concrete. The results are shown in the table below and included in Appendix C.

Parameter	Units (Soil)	Units (Water)	Test Results	
			Borehole 16-34 SS2 (0.8 m to 1.4 m) - Soil	Sims Creek - Water
Corrosivity Index	-	-		
pH	-	-	9.13	7.28
Conductivity	µS/cm	µS/cm	46	147
Resistivity	Ohms.cm	MOhms.cm	21700	3340
Redox Potential	mV	mV	323	299
Chloride	µg/g	mg/L	6.1	2.8
Sulphate	µg/g	mg/L	18	0.19
Sulphide	%	mg/L	< 0.02	< 0.006

7. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained utility locates prior to drilling.

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. Tim Sivak of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

The coordinates and ground surface elevations at the borehole locations were established by measurements taken in the field by Thurber relative to the topographic plans provided by Hatch.

Interpretation of the field data and preparation of this report was carried out by Mr. Michael Eastman, EIT and Mr. Keli Shi, 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 section of the report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for design of the proposed Sims Creek Replacement Culvert located on Highway 71, in the Township of Dobie, District of Rainy River, 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 was obtained from the MTO Terms of Reference and the Ontario Structure Inspection Manual (Inspection Form) Report dated November 20, 2014. According to the MTO Terms of Reference, the existing structure is a three-span timber culvert with a length of 22.1 m, a total width of 4.3 m and a height of 1.22 m. The estimated culvert invert is at Elevation 352.3 m on the west end (inlet) and Elevation 352.2 m on the east end (outlet). The road grade at the culvert location is shown at approximate Elevation 355.9 m, which indicates about 2.4 m of fill cover above the culvert. The inspection report indicated some surface decay and checking in the soffit timbers and significant settlement (250 mm) at mid-span of barrels. The culvert was completely submerged during a 2010 inspection.

Detailed information for the culvert design has not been provided at the time of report preparation. However, it is understood that the invert level and alignment of the replacement culvert will remain the same as those of the existing culvert and no grade raise is proposed at the culvert location.

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

9. CULVERT DESIGN

9.1 Culvert Alternatives

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

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

- Corrugated steel pipe (CSP)
- Concrete box (closed) culvert composed of precast segments
- Concrete open frame culvert on footings

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

- Precast concrete box or CSP culverts would require shallower excavation compared to the open footing culvert; and
- Precast concrete box or CSP segments can often be installed more expeditiously than cast-in-place open footing culvert, resulting in shorter durations for dewatering and construction; and
- Precast concrete box or CSP culverts are generally more tolerant of some longitudinal differential settlement.

The open footing culvert is not recommended at this site due to the low available bearing capacity in the foundation clay till, potential for differential settlement between footings and the need for deeper excavation and additional dewatering effort to construct the footings below the frost depth.

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

9.2 Foundation Design for Culverts

The invert level of the replacement culvert is anticipated to be at approximate Elevation 352.3 m to 352.2 m. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement, except where additional fill may be placed to lengthen the culvert at the inlet/outlet or to construct the headwall/wingwall.

9.2.1 Corrugated Steel Pipe Culvert

If the CSP type culvert is selected, multiple pipes may be required to accommodate the creek flow. The CSP should be placed on native firm to stiff silty clay till at or below Elevation 352.0 m. The pipes 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 the inspection and approval. The subgrade preparation, placement and compaction of bedding 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.

9.2.2 Concrete Box Culvert

Replacement of the existing culvert with a closed concrete box on the same alignment is also a viable alternative.

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 below 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 practical following its inspection and approval. The subgrade preparation, placement and compaction of bedding must be carried out in the dry. The subgrade surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The following geotechnical resistances could be used for preliminary design of a 4 m to 5 m wide box culvert founded at or below Elevation 352.0 m on native undisturbed firm to stiff silty clay till:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Resistance at SLS (for up to 25 mm settlement) of 120 kPa

A consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Sec. 6.9.

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

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

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

9.2.3 Open Footing Concrete Culvert

Spread footings supporting an open frame concrete culvert should be founded on the native undisturbed firm to stiff silty clay till below the frost depth at or below Elevation 350.0 m. The footings should extend below any existing embankment fill and surficial organic materials, where encountered.

The recommended geotechnical resistances at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS) for the above noted founding elevation, are given below for a 2 m wide strip footing:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Resistance at SLS (for up to 25 mm of settlement) of 120 kPa

A consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Sec. 6.9.

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

Resistance to sliding between precast concrete and the underlying silty clay till should be evaluated in accordance with CHBDC (2014) assuming an ultimate coefficient of friction of 0.35.

All organic soil and excessively loose/soft material should be removed from the footing subgrade. The founding surface should be protected from softening during construction by placement of a 75 mm mud slab on the prepared bearing surface as soon as practical following the inspection and approval.

9.2.4 Culvert Headwalls

If headwalls are proposed for the replacement culvert, consideration may be given to using Retained Soil System (RSS) walls or cantilevered concrete walls. RSS walls are more tolerant to some differential settlement.

The borehole information indicates that the founding conditions at the inlet and outlet generally consist of firm to very stiff silty clay till.

9.2.4.1 RSS Walls

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS and, in severe cases, to possible failure of the system. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

The RSS mass should be founded on a minimum 0.5 m thick engineered fill pad resting on the native firm to very stiff silty clay till at or below approximate Elevation 352.0 m. RSS walls founded on this material may be designed using a factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement). Engineered fill pad placed under the RSS mass must consist of OPSS.PROV Granular A or Granular B Type II compacted to 100 percent of its SPMDD at a moisture content within 2 percent of optimum. The engineered pad must be at least 500 mm beyond the limits of the RSS mass and levelling strip.

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

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

Topsoil, 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.

Lateral earth pressures acting on the concrete wingwalls should be computed as described in Section 12. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

9.2.4.2 Foundation for Concrete Walls

From a foundation standpoint, concrete headwalls may be supported on spread footings founded on the firm to very stiff silty clay subgrade. Any organic or soft soil must be removed from the wall subgrade and replaced with granular fill compacted as per OPSS.PROV 501. The walls should be provided with sufficient frost cover and founded at or below Elevation 352.0 m. A factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement) may be used for design. A minimum 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.

The concrete retaining wall must be designed against various modes of failure including sliding and overturning. Resistance to sliding between precast concrete footing and the granular levelling pad should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.40.

Lateral earth pressures acting on the concrete headwalls should be computed as described in Section 12. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

9.2.5 Frost Cover

The depth of frost penetration at this site is approximately 2.3 m. The pipe and box culvert options do not require frost cover/protection.

9.2.6 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, organics, peat, streambed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and backfilled with granular material compacted as per OPSS.PROV 501.

In the event that sub-excavation is required, the width of the sub-excavation 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 sub-excavated 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. Subgrade preparation and placement and compaction of granular material must be carried out in the dry.

9.2.7 Settlement

It is anticipated that the replacement culvert will be constructed on the same alignment with similar opening size as the existing culvert and no grade raise above the culvert. Therefore, post-construction settlement is expected be negligible in the firm to stiff silty clay till foundation and will essentially be complete at the end of construction.

9.3 Construction Considerations

Detailed construction sequencing was not available at the time of preparation of this report. However, it is anticipated that one lane of traffic must be maintained, which requires staged construction.

Staged construction sequencing will likely require the following:

- Diversion of the creek is anticipated for construction. In addition, a suitable dewatering plan will be required to construct the culvert in the dry. It should be noted that swampy conditions exist at this site.

- 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; and

- All culvert subgrade preparation and foundation preparation must be carried out in the dry.

10. EXCAVATION AND GROUNDWATER CONTROL

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native silty clay till at this site are classified as Type 3 soils above the water level. Any alluvial or cohesionless soils are considered Type 4 soils below the water level.

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 extend into the native silty clay till deposit.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level and diversion of the creek flow will be required. Seepage should be anticipated from the embankment fill. Depending on the time of construction, a combination of cofferdam enclosures and tributary diversion along with pumping from filtered sumps within an enclosure will be required to maintain dry excavation during the course of staged construction. Dewatering operations should be carried out in accordance with OPSS 517 and OPSS 518.

The design of an effective dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert them to this responsibility and the need to engage a dewatering specialist. Dewatering must remain operational and effective throughout the construction. Suggested wording for an NSSP on dewatering is included in Appendix F.

11. STREAM DIVERSION PIPE

It is understood that a CSP stream diversion pipe may be used at this site. Detail of the diversion pipe were not provided at the time of preparation of this report. The base of the pipe will likely be founded on native clay till. Temporary shoring might be required to install the diversion pipe.

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

12. BACKFILL AND LATERAL EARTH PRESSURE

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

The lateral earth pressures acting on the retaining structures may be assumed to be triangularly distributed and governed by the characteristics of the backfill and/or existing fill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC (2014) but generally are given by the following equation:

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

Where:

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

K = coefficient of lateral earth pressure (see table below)

γ = 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 values are shown in the table below.

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

Loading Condition	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		Existing Fill ϕ = 30°; γ = 20 kN/m^3	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (K_A) (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At-rest (K_O) (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (K_P)	3.7	-	3.3	-	3.0	-

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

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

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

13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy at this site includes predominantly high plastic firm to very stiff silty clay. This corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2,475-year return period seismic event at this site is 0.038 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in the table below may be used:

Loading Condition	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	Existing Fill ϕ = 30°, γ = 20 kN/m^3
Active (K_{AE})*	0.29	0.33	0.35
Passive (K_{PE})	3.6	3.2	2.9

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35°, \gamma = 22.8\ kN/m^3$	OPSS Granular B Type I (modified) $\phi = 32°, \gamma = 21.2\ kN/m^3$	Existing Fill $\phi = 30°, \gamma = 20\ kN/m^3$
At-rest (K_{OE})**	0.49	0.53	0.56

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

Given the firm to very stiff silty clay till foundation and the low seismic activity in the area, liquefaction is not considered to be a concern at this site.

14. TEMPORARY PROTECTION SYSTEMS

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

Options for roadway protection are soldier pile and lagging or interlocking sheet piles.

The soil parameters in the table below may be used for design of the temporary roadway protection system with horizontal backfill.

Soil Parameter	Existing Fill	Native Silty Clay Till
γ (total unit weight)	20 kN/m^3	19 kN/m^3
γ' (effective unit weight)	10 kN/m^3	9 kN/m^3
K_a	0.33	0.36
K_p	3.0	2.8

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

The design of temporary protection system is the responsibility of the Contractor. The actual lateral pressure distribution acting on the protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors should be taken into consideration when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

15. EMBANKMENT RESTORATION

The existing Highway 71 embankment is approximately 2.5 m in height at the culvert location and the existing embankment slopes appear to be stable. 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 post-construction settlement of the embankment is expected to be less than 25 mm.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS.PROV 206 and OPSS.PROV 209. The embankment material may consist of imported Granular A, Granular B Type II or Granular B Type III material. Alternatively, the existing embankment fill may be used above the culvert 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, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel should be conducted.

16. SCOUR AND EROSION PROTECTION

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

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

A concrete cut-off wall and a clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geo-synthetic clay liner may be used in place of a compacted clay seal.

17. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding native soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested.

- The potential for soil or surface water corrosion on metal is considered to be mild.

- Appropriate protection measures are recommended if metal structural elements are used.

18. CONSTRUCTION CONCERNS

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

- A suitable dewatering/unwatering system must be employed to enable culvert construction in the dry and prevent sloughing and instability of the excavation base and sidewalls;
- 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 native till 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 structure or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

19. CLOSURE

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

Thurber Engineering Ltd.

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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.

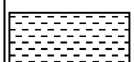
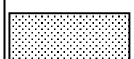
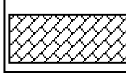
EXPLANATION OF ROCK LOGGING TERMS

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No 16-31

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 940.1 E 237 309.8	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.24 - 2016.08.24	CHECKED BY	MEF

ELEV / DEPTH (m)	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
353.1	GROUND SURFACE							
0.0	**TOPSOIL/ORGANICS**	1	SS	1				
352.3 / 0.8	Silty **CLAY**, some sand, trace organics (rootlets), occasional sand seams Firm to Very Stiff Brown Moist (TILL)	2	SS	5	0	24	44	32
		3	SS	7				
		4	SS	9				
		5	SS	8				
		6	SS	7	0	13	29	58
		7	SS	5				
		8	SS	8				
		9	SS	7	0	12	31	57
343.3 / 9.8	END OF BOREHOLE AT 9.8m.							

Elevation scale: 353, 352, 351, 350, 349, 348, 347, 346, 345, 344

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
Water Content (%): Plastic Limit w_P, Natural Moisture Content w, Liquid Limit w_L; 20 40 60
Unit Weight γ kN/m³
Remarks & Grain Size Distribution (%): GR SA SI CL

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-31

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 940.1 E 237 309.8	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.24 - 2016.08.24	CHECKED BY	MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	NO WATER ENCOUNTERED DURING DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-32

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 952.6 E 237 320.3	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.23 - 2016.08.23	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
355.9	GROUND SURFACE									
0.0	**ASPHALT:** (150mm)									
0.2	**SAND**, some gravel, some silt Compact Brown Dry to Moist (FILL)	1	GS			~1	15	68	17 (SI+CL)	
		1	SS	20	355	~1				
		2	SS	12	354	~2				
353.2 / 2.7	Silty **CLAY**, some sand, trace gravel, occasional sand seams Firm to Very Stiff Brown to Grey Moist (TILL)	3	SS	5	353	~7				
		4	SS	5	352	~14	4	36	32	28
		5	SS	10	351	~27				
		6	SS	8	350 / 349	~27				
		7	SS	6	348	~27				
		8	SS	6	347 / 346	~23 (w_P ~20, w_L ~55)	0	19	31	50

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

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 16-32

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 952.6 E 237 320.3	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.23 - 2016.08.23	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Continued From Previous Page											
						345						
		9	SS	9			~22					
						344						
		10	SS	10			~24					
						343						
						342						
		11	SS	8			~24		0	0	39	61
341.6 / 14.3	END OF BOREHOLE AT 14.3m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN COLD PATCH 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
REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-33

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 943.5 E 237 324.0	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.22 - 2016.08.22	CHECKED BY	MEF

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	GR	SA	SI	CL
355.9	GROUND SURFACE										
0.0	**ASPHALT:** (150mm)										
0.2	Gravelly **SAND**, trace silt Compact to Loose Brown Dry to Moist (FILL)	1	GS				o				
		2	SS	16	355		o	28	62	10 (SI+CL)	
		3	SS	8	354		o				
353.6 2.3	Silty **CLAY**, some sand, trace gravel, occasional sand seams Firm to Very Stiff Brown to Grey Moist (TILL)	4	SS	2	353		o				
		5	SS	3			o	0	26	41	33
					352	+ (field vane)					
		6	SS	8	351		o				
					350						
		7	SS	7	349		o				
		8	SS	6	348		wP—o—wL	0	17	26	57
					347						
		9	SS	6	346		o				

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

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

ONTMT4S 13983-MTO.GPJ 2015TEMPLATE(MTO).GDT 11/16/16

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RECORD OF BOREHOLE No 16-33

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 943.5 E 237 324.0	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.22 - 2016.08.22	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
							+ (field vane, >100)						
		10	SS	6		345		○ (~22)					
						344							
		11	SS	6		343		○ (~25)					
		12	SS	7		342		○ (~27)		0	17	34	49
341.6 14.3	END OF BOREHOLE AT 14.3m. BOREHOLE DRY ON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN COLD PATCH 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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 13983-MTO.GPJ 2015TEMPLATE(MTO).GDT 11/16/16

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-34

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 955.1 E 237 334.9	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.23 - 2016.08.23	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
353.7	GROUND SURFACE									
0.0	**TOPSOIL/ORGANICS**	1	SS	1						
353.0 / 0.7	Silty **CLAY**, some sand Very Soft to Very Stiff Brown to Grey Moist (TILL) Trace organics from 0.7m to 2.1m	2	SS	0	353	~19				
		3	SS	12	352	~23	0	18	32	50
		4	SS	11	351	~26				
		5	SS	10	350	~28				
		6	SS	10	349	~25				
		7	SS	12	348, 347	~23				
		8	SS	9	346	~23				
		9	SS	9	345, 344	~22 (wP ~20, wL ~57)	0	16	36	48
343.9 / 9.8	END OF BOREHOLE AT 9.8m.									

Continued Next Page

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

Groundwater conditions: backfill to ~347.3, screened piezometer from ~347.3 to 343.9.

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

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

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THURBER

RECORD OF BOREHOLE No 16-34

METRIC

WP#	6813-14-00	LOCATION	Sims Creek N 5 393 955.1 E 237 334.9	ORIGINATED BY	TS
HWY	71	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.23 - 2016.08.23	CHECKED BY	MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	BOREHOLE DRY UPON COMPLETION OF DRILLING. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.										

+ 3, × 3: Numbers refer to Sensitivity

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

Appendix B

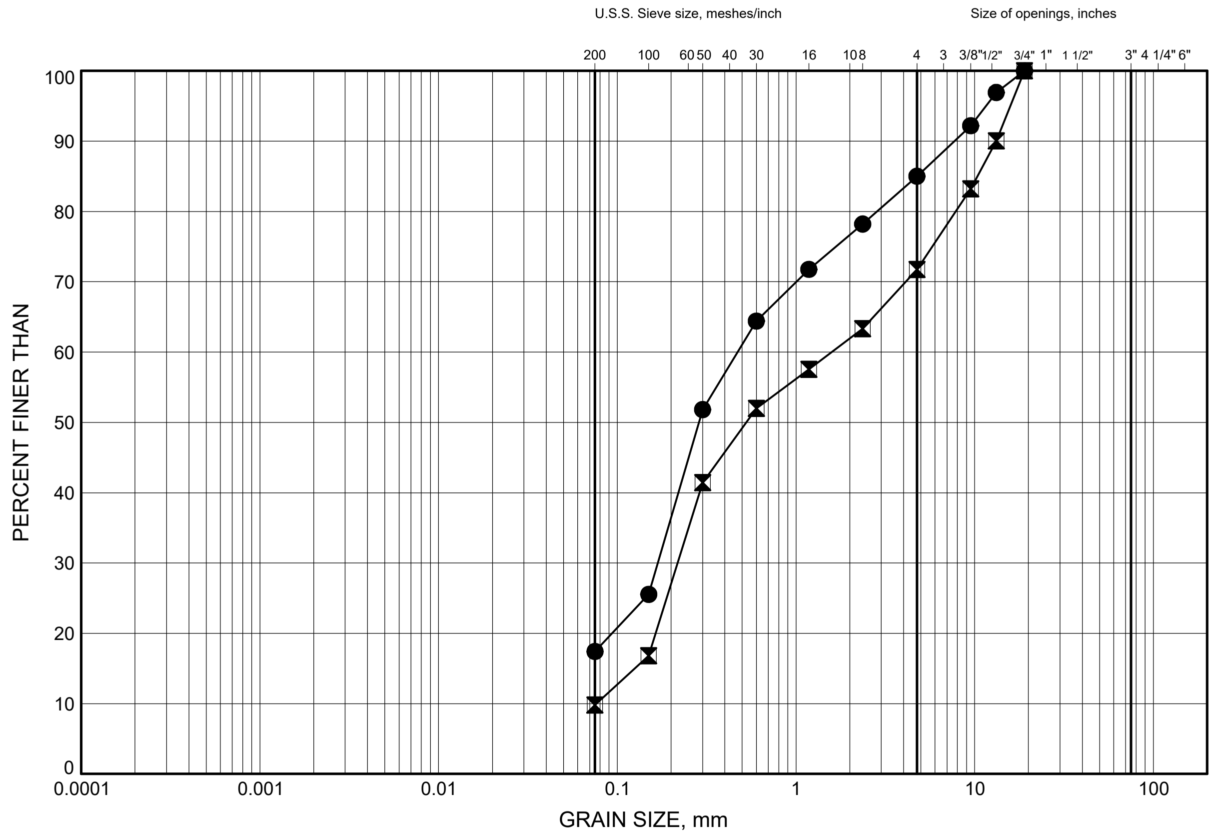
Laboratory Test Results

Sims Creek

GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND to SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-32	0.38	355.52
⧗	16-33	1.07	354.83

GRAIN SIZE DISTRIBUTION - THURBER 13983-MTO.GPJ 11/10/16

Date November 2016

W.P. 6813-14-00

THURBER

Prep'd AN

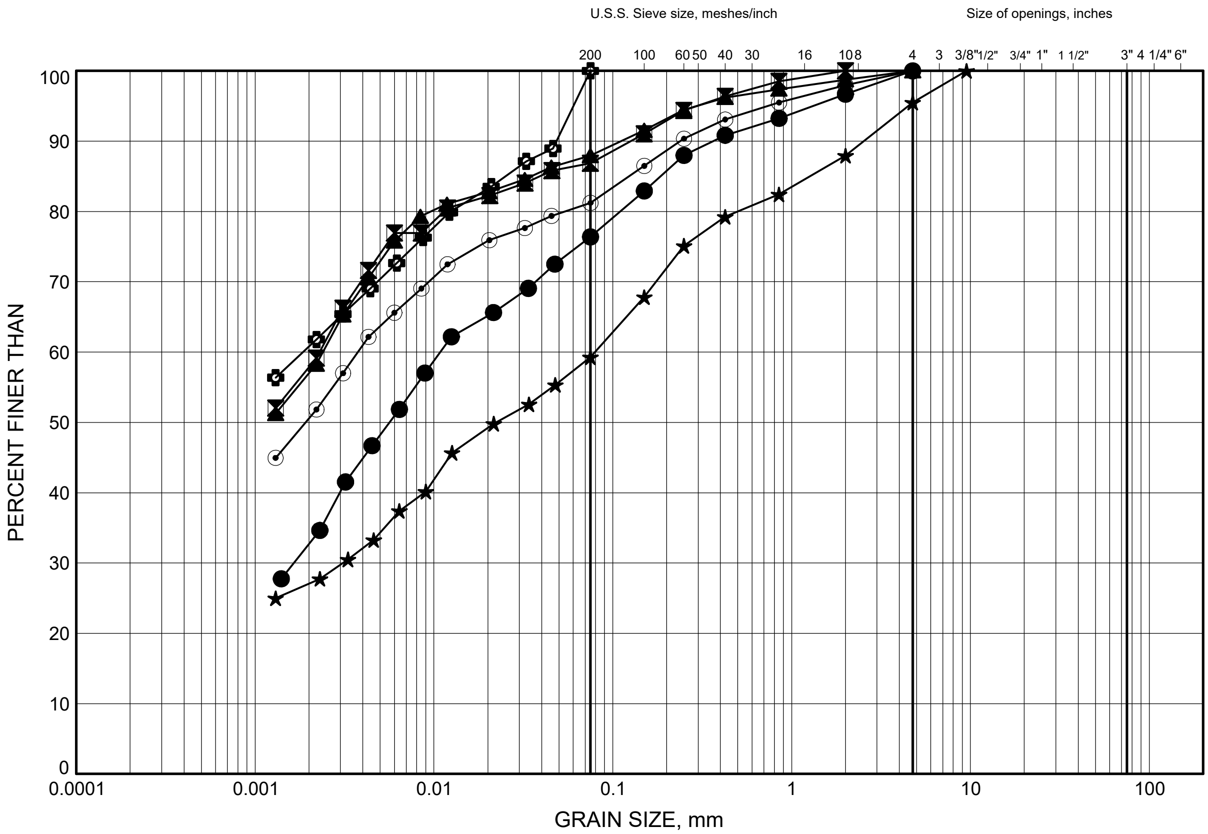
Chkd. KS

Sims Creek

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-31	1.07	352.03
⧗	16-31	4.88	348.22
▲	16-31	9.45	343.65
★	16-32	3.35	352.55
⊙	16-32	9.45	346.45
✿	16-32	14.02	341.88

GRAIN SIZE DISTRIBUTION - THURBER 13983-MTO.GPJ 11/10/16

Date November 2016

W.P. 6813-14-00

THURBER

Prep'd AN

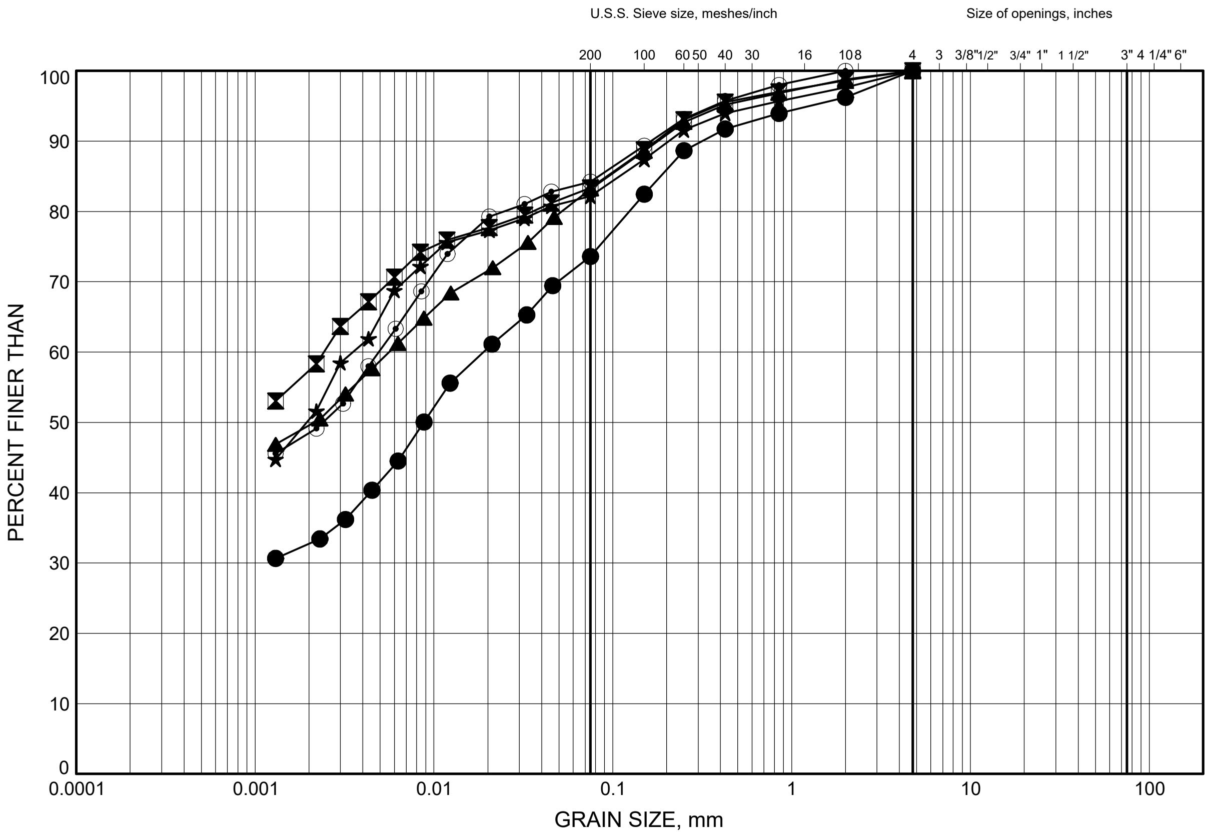
Chkd. KS

Sims Creek

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-33	3.35	352.55
⧗	16-33	7.92	347.98
▲	16-33	14.02	341.88
★	16-34	1.83	351.87
⊙	16-34	9.45	344.25

GRAIN SIZE DISTRIBUTION - THURBER 13983-MTO.GPJ 11/10/16

Date November 2016

W.P. 6813-14-00

THURBER

Prep'd AN

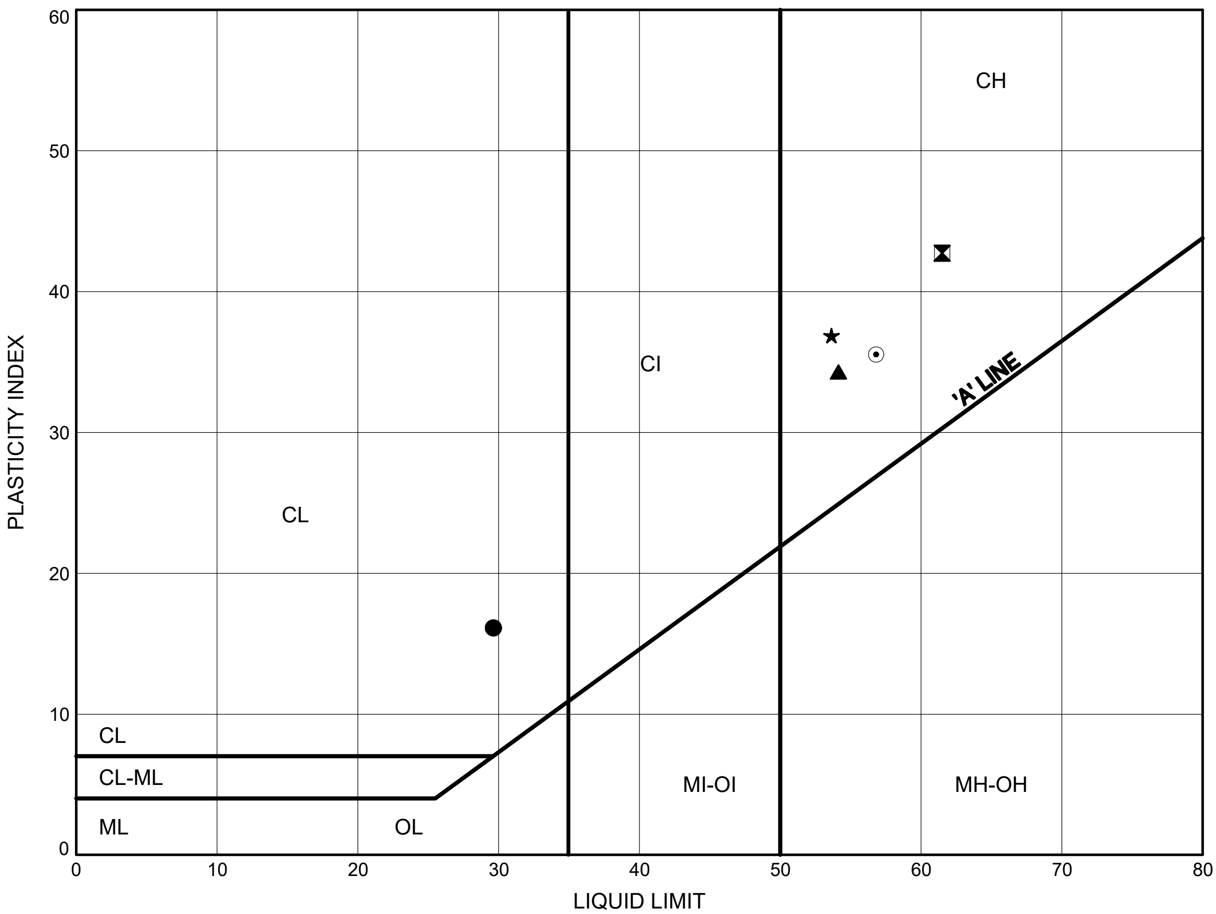
Chkd. KS

Sims Creek

ATTERBERG LIMITS TEST RESULTS

FIGURE B4

Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-31	1.07	352.03
⧗	16-31	4.88	348.22
▲	16-32	9.45	346.45
★	16-33	7.92	347.98
⊙	16-34	9.45	344.25

THURBALT 13983-MTO.GPJ 11/10/16

Date November 2016

W.P. 6813-14-00

THURBER

Prep'd AN

Chkd. KS

Appendix C

Chemical Analysis Results

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

Project : 13983

22-September-2016

Thurber Engineering Ltd.
Attn : Mark Farrant

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

Phone: 905-829-8666 x 228
Fax:

Date Rec. : 16 September 2016
LR Report: **CA14401-SEP16**
Reference: 13983 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**	**6: 16-34 SS#2 2.5'-4.5'**
Sample Date & Time					12-Sep-16
Temperature Upon Receipt [°C]	---	---	---	---	9.0
Corrosivity Index [none]	21-Sep-16	16:51	21-Sep-16	16:51	1
pH [no unit]	19-Sep-16	10:18	19-Sep-16	13:26	7.95
Soil Redox Potential [mV]	19-Sep-16	16:42	20-Sep-16	10:53	323
Sulphide [%]	21-Sep-16	11:12	21-Sep-16	11:40	< 0.02
% Moisture (wet wt) [%]	21-Sep-16	07:55	21-Sep-16	08:50	18.6
pH [no unit]	19-Sep-16	06:59	20-Sep-16	10:41	9.13
Chloride [µg/g]	20-Sep-16	20:39	21-Sep-16	16:30	6.1
Sulphate [µg/g]	20-Sep-16	20:39	21-Sep-16	16:30	18
Conductivity [uS/cm]	19-Sep-16	06:59	20-Sep-16	10:42	46
Resistivity (calculated) [Ohms.cm]	21-Sep-16	10:49	21-Sep-16	10:49	21700

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

OnLine LIMS

0000787761

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

Temperature of Samples upon receipt 15 degrees C
No cooling agent present

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

Temperature of Samples upon receipt 9 degrees C
Cooling agent present
Custody Seal not present

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	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020	ASTM E1918
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-001	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 : 13983

LR Report : **CA14401-SEP16**

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: DIO0260-SEP16												
Chloride	0.4	µg/g	<0.4		1	20	107	80	120	105	75	125
Sulphate	0.4	µg/g	<0.4		0	20	101	80	120	100	75	125
Carbon/Sulphur - QCBatchID: ECS0026-SEP16												
Sulphide	0.02	%	<0.02		4	20	106	80	120			
Conductivity - QCBatchID: EWL0235-SEP16												
Conductivity	2	uS/cm	< 2		ND	10				NA		
pH - QCBatchID: ARD0047-SEP16												
pH	0.05	no unit			0	20	100	80	120			

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

Project : 13983

12-September-2016

Thurber Engineering Ltd.
Attn : Mark Farrant

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

Phone: 905-829-8666 x 228
Fax:

Date Rec. : 06 September 2016
LR Report: **CA15062-SEP16**
Reference: 13983 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: Sims
Sample Date & Time						21-Aug-16
Temperature Upon Receipt [°C]	---	---	--	--	---	23.0
Corrosivity Index [none]	12-Sep-16	17:18	12-Sep-16	17:18		< 1
pH [no unit]	07-Sep-16	06:39	07-Sep-16	15:48	0.05	7.28
Conductivity [µS/cm]	07-Sep-16	06:39	07-Sep-16	15:48	2	147
Resistivity (calculated) [MOhms.cm]	07-Sep-16	14:35	07-Sep-16	14:35	---	3340
Redox Potential [mV]	06-Sep-16	14:30	07-Sep-16	08:34	---	299
Chloride [mg/L]	08-Sep-16	09:42	12-Sep-16	13:27	0.04	2.8
Sulphate [mg/L]	08-Sep-16	09:42	12-Sep-16	13:27	0.04	0.19
Sulphide [mg/L]	07-Sep-16	12:00	08-Sep-16	10:41	0.006	< 0.006

Temperature of Samples upon receipt 23 degrees C
Cooling Agent Present
Custody Seal not Present

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

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

OnLine LIMS

0000779931

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

Project : 13983

LR Report : **CA15062-SEP16**

Method Descriptions

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

OnLine LIMS

0000779931

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

Project : 13983

LR Report : CA15062-SEP16

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: DIO0089-SEP16												
Anions by IC - QCBatchID: DIO0105-SEP16												
Chloride	0.04	mg/L	<0.04		2	20	94	80	120	105	75	125
Sulphate	0.04	mg/L	<0.04		0	20	101	80	120	100	75	125
Conductivity - QCBatchID: EWL0061-SEP16												
Conductivity	2	µS/cm	< 2		0	10	98	90	110	NA		
pH - QCBatchID: EWL0061-SEP16												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0056-SEP16												
Redox Potential	no	mV	NA		2	20	100	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0038-SEP16												
Sulphide	0.006	mg/L	<0.006		ND	20	84	80	120	nv	75	125

OnLine LIMS

0000779931

Appendix D

Site Photographs

Photo 1: Sims Creek Culvert, inlet

Photo 2: Sims Creek Culvert, east side looking north

Photo 3: Sims Creek Culvert, west side looking north

Photo 4: Sims Creek Culvert, west side looking south

Photo 5: Sims Creek Culvert, looking south

Appendix E

Comparison of Foundation Alternatives

THURBER

60 YEARS

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
Advantages: i. Ease of construction. ii. Less stringent requirement for soil geotechnical resistances iii. Segmented pipes can accommodate some potential differential settlement along culvert axis iv. Steel pipes may be more cost effective than concrete box or open footing culverts.	Advantages: i. Relatively rapid installation and less disturbance to subgrade soils if precast segments are used. ii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area. iii. Segmental option can accommodate some potential differential settlement along culvert axis.	Advantages: i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
Disadvantages: i. Steel pipes may have shorter design life than concrete culverts. ii. Multiple pipes needed to meet hydraulic requirements. iii. Temporary roadway protection system 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. Low geotechnical capacities in founding clay to support strip footings, and greater potential for differential settlement. ii. Deeper excavation and potentially longer dewatering requirements.
FEASIBLE	**FEASIBLE**	**NOT RECOMMENDED**

Appendix F

List of OPSSs and OPSDs and Suggested Wording for NSSP

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

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

2. Suggested Wording for NSSP on Dewatering

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

3. Suggested Wording for NSSP on Obstructions

Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.

Appendix G

Borehole Location Plan and Stratigraphic Profile

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

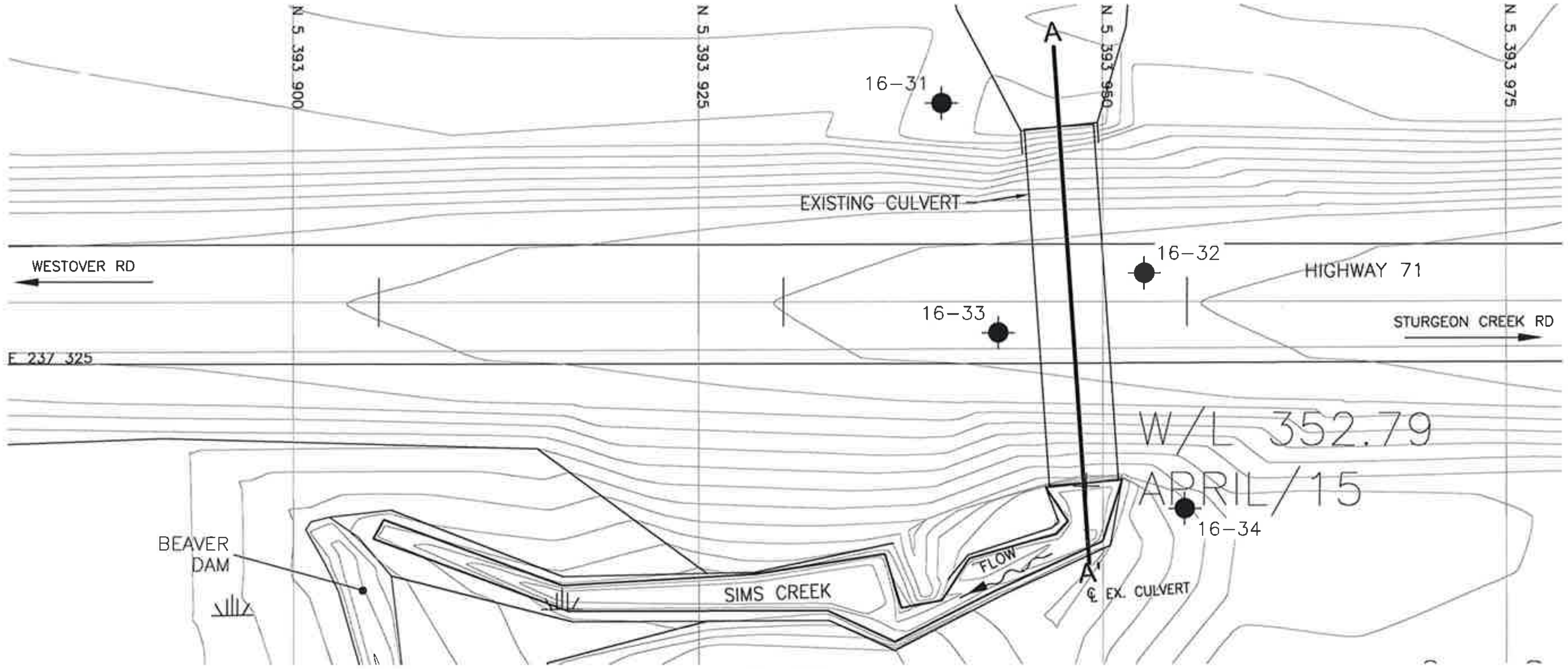
CONT No 6015-E-0018-005
WP No 6813-14-00

SHEET

HIGHWAY 71
SIMS CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH

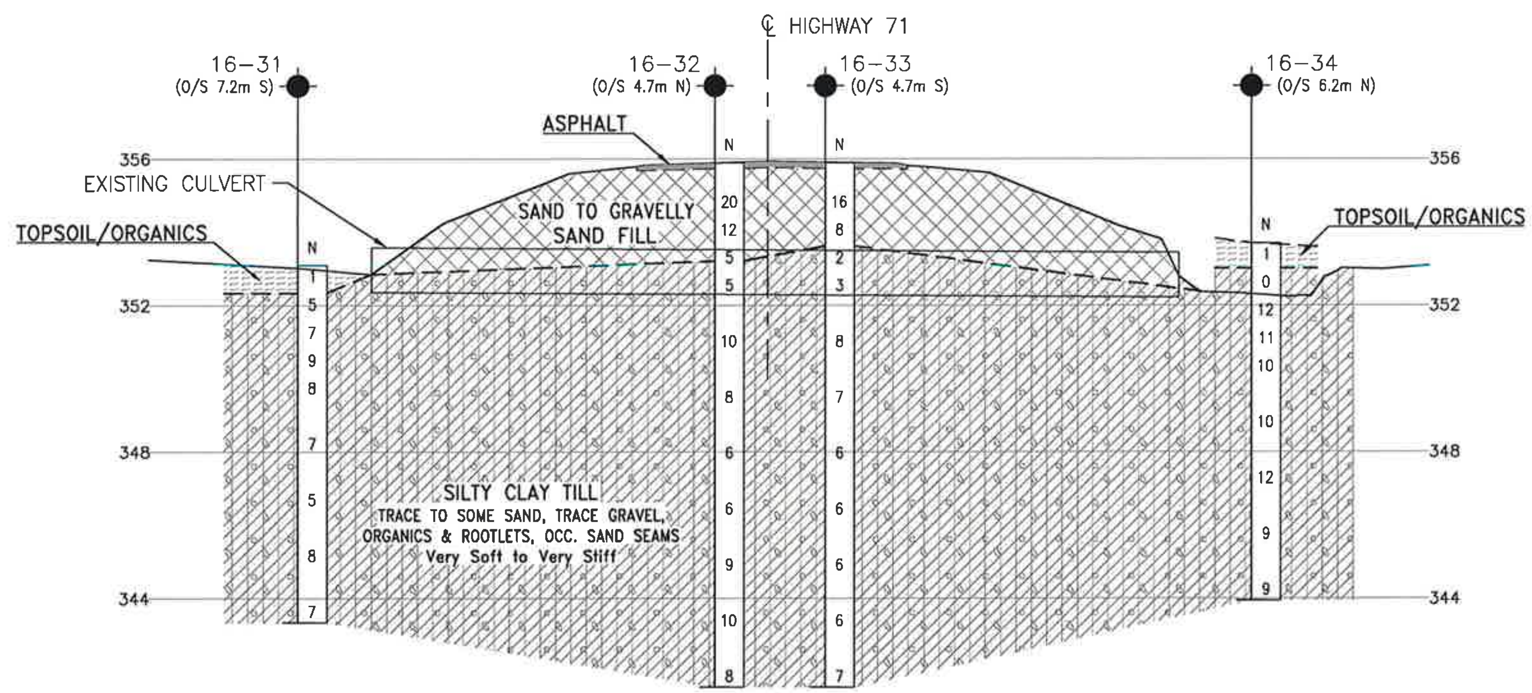
THURBER ENGINEERING LTD.



PLAN

8 0 8 16m

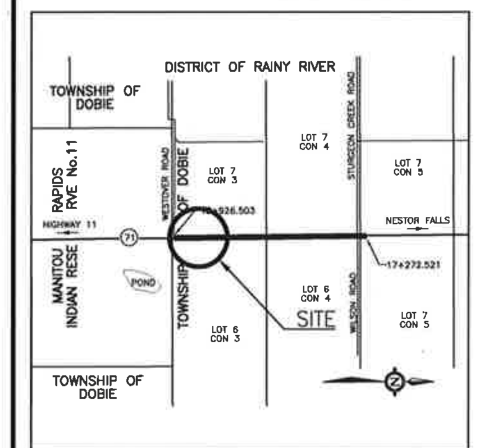
SCALE 1:400



SECTION A–A'

4 0 4 8m

SCALE 1:200



KEYPLAN

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Feb 17/17
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
K. L. SHI
100141639
Feb 17/17
PROVINCE OF ONTARIO

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
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-31	353.1	5 393 940.1	237 309.8
16-32	355.9	5 393 952.6	237 320.3
16-33	355.9	5 393 943.5	237 324.0
16-34	353.7	5 393 955.1	237 334.9

-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.
3) MTM Zone 16 co-ordinate system used to obtain borehole Northings and Eastings.
4) Preliminary general arrangement drawing provided by Hatch in digital format.

GEOCRES No. 52C-55

REVISIONS	DATE	BY	DESCRIPTION

DESIGN MEF	CHK PKC	CODE	LOAD	DATE FEB 2017	
DRAWN MFA	CHK MEF	SITE	STRUCT	DWG 1	

FILENAME: H:\Drafting\13000\13983\TED-13983-BHPP-SC.dwg
PLOTDATE: 2/22/2017 11:43 AM

MINISTRY OF TRANSPORTATION, ONTARIO