



**THURBER** ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT  
LYON CREEK CULVERT NO. 2 REPLACEMENT  
HIGHWAY 602  
DISTRICT OF RAINY RIVER  
TOWNSHIP OF LASH, ONTARIO**

**G.W.P. No. 6324-14-00, W.P. No. 6342-14-01, SITE No. 45-264/C**

**GEOCRES Number: 52C-52**

**Report**

**to**

**HATCH**

Date: January 13, 2017  
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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 Lyon Creek Culvert No. 2 on Highway 602, located south of Emo, in the Township of Lash, in the District of Rainy River, Ontario.

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

Thurber was retained by Hatch Ltd. (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-003.

In the preparation of this report and in addition to the borehole drilled under the current assignment, reference has been made to information on subsurface conditions contained in an earlier preliminary foundation report and a structural design report. The titles of these reports are listed as follows:

- Preliminary Foundation Investigation and Design Report, Lyon Creek Culvert No. 2, Highway 602, District of Rainy River, Township of Lash, prepared by Golder Associates (Golder), dated October 30, 2015; G.W.P. 6342-14-00. (Reference 1). The information presented in this report was reviewed and incorporated in the current report, as appropriate.

- Structural Design Report, Lyon Creek Culvert No. 2, Site No. 45-264C, Highway 602, prepared by Hatch Mott MacDonald and dated December 2015. (Reference 2).

Reference should be made to the Golder report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile and laboratory test results. The Record of Borehole sheets from the Golder report are attached in Appendix E. The subsurface information, including the Record of Borehole sheets and the Borehole Locations and Soil Strata drawings, from both the current investigation and the Golder preliminary Foundation Investigation and Design Report (FIDR) should be included in the contract documents. It should be noted that Golder is solely responsible for the accuracy and quality of the subsurface information provided in the preliminary FIDR.

## **2. SITE DESCRIPTION**

The site is located on Highway 602, approximately 2.6 km south of the junction of Highway 602 and Highway 11 near Emo, within the Township of Lash, in the District of Rainy River, Ontario. The culvert allows Lyon Creek to flow in a south-westerly direction under Highway 602. Highway 602 generally runs in an overall north-south direction, and northwest-southeast direction at the culvert site.

The Structural Design Report (SDR) provided to Thurber by Hatch indicates that the existing structure is a 17 m long, 5.5 m wide, open footing concrete culvert with an unknown construction date. The highway embankment is approximately 4 m high, and there is approximately 1.6 m of fill above the culvert. A Biennial Inspection on November 29, 2013 and a 2015 Ontario Structure Inspection Manual (OSIM) report indicate that the components of the structure are in generally poor condition with up to 50 mm cracking at the centreline of the footing walls and soffit, corroded rebar, efflorescence, and delamination.

The grade level of Highway 602 at the existing culvert is at an approximate Elevation of 343.1 m. The culvert invert is at approximate Elevation 339.3 m. The creek water level was measured at Elevation 339.8 m by others in June, 2014 and the highest water level at Elevation 340.4 m was measured by Golder in February, 2015.

The lands surrounding Lyon Creek and the culvert at the site predominantly consist of agricultural lands with a few forested areas. Lyon Creek discharges into Rainy River approximately 1.3 km south west of the culvert. Rainy River runs in a generally north-south direction near the site. The lands surrounding the site are relatively flat with elevations between 344 m and 346 m.

Selected photographs of the culvert area are included in Appendix C for reference.

Based on published geological information, the culvert lies within an area of glaciolacustrine fine-grained deposits of silt and clay, undifferentiated silty clay to silt till deposits and recent organic deposits of peat, muck and marl. Bedrock at the site is identified as consisting of various metasedimentary rock types.

### **3. INVESTIGATION PROCEDURES**

The borehole investigation and field testing program for this project was carried out on July 23 and 24, 2016, and consisted of drilling and sampling four (4) boreholes, designated as Boreholes 16-07 to 16-10. All boreholes were located in the paved section of the Highway 602 northbound lane. Borehole 16-07 was located approximately 10 m north of the centreline of the existing culvert, near the alignment of the proposed creek diversion pipe. Boreholes 16-08 to 16-10 were located on the south side of the existing culvert and drilled at 10 m intervals to assess the existence and extent of any frost taper near the culvert.

Borehole 16-07 was advanced to a depth of approximately 11.3 m (Elevation 331.8 m) below the existing road surface and boreholes 16-08 to 16-10 were advanced to approximately 3.7 m (Elevation 339.4 m) below existing road surface. A Dynamic Cone Penetration Test (DCPT) was carried out in Borehole 16-07 below the sampled portion of the borehole to a cone refusal depth of 23.5 m (Elevation 319.6 m), below the existing grade.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were derived from cross sections and topographic drawings provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 16 was used for the boreholes.

A rubber track mounted CME 55 drill rig was used to advance the boreholes using hollow stem augers. Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane shear testing using an MTO "N" size vane was carried out in cohesive soils.

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

Groundwater conditions were observed in the open boreholes throughout the drilling operations and upon completion of drilling. The boreholes were backfilled in general accordance with Ontario Regulation 903.

Completion details of the boreholes are summarized in Table 3.1.

**Table 3.1 – Borehole Completion Details**

Borehole Number	Sampled Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
16-07	11.3 / 331.8	None installed	Borehole backfilled with bentonite holeplug and auger cuttings, to 0.1 m, then surface patched with asphalt.
16-08	3.7 / 339.4	None installed	Borehole backfilled with auger cuttings, to 0.1 m, then surface patched with asphalt.
16-09	3.7 / 339.4	None installed	Borehole backfilled with auger cuttings, to 0.1 m, then surface patched with asphalt.
16-10	3.7 / 339.4	None installed	Borehole backfilled with auger cuttings, to 0.1 m, then surface patched with asphalt.

The previous investigation conducted by Golder included four (4) boreholes, numbered LY-1 to LY-4. Boreholes LY-1 and LY-4 were advanced at the toe of the slope near the culvert inlet and outlet to depths of approximately 7.5 m (Elevations 333.4 and 333.0 m), and Boreholes LY-2 and LY-3 were advanced from the existing highway platform to depths of approximately 11.6 m (Elevation 331.5 m). The approximate locations of the Golder boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D, and on the 2015 Golder report's Borehole Locations and Soil Strata Drawing included in Appendix E.

#### **4. LABORATORY TESTING**

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

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing native soil, and a

sample of the surface water from the creek upstream of the existing culvert were collected. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

## **5. DESCRIPTION OF SUBSURFACE CONDITIONS**

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

The borehole logs from the previous Golder investigation are presented in Appendix E and are generally consistent with the results of the current investigation.

In general, the subsurface conditions encountered in the boreholes from the current and previous investigation consisted of asphalt pavement overlying granular fill and silty clay to sandy silt embankment fill, underlain by a layer of organic soil and a deposit of native silty clay. Descriptions of the individual strata are presented below.

### **5.1 Pavement Structure**

Borehole 16-07 to 16-10, LY-2 and LY-3 were drilled from the paved platform of Highway 602. The pavement structure consisted of approximately 40 mm to 50 mm of asphalt over approximately 450 mm to 850 mm of granular base material, consisting of gravelly sand to sand and gravel with trace to some silt.

The moisture content measured in samples of the granular base material ranged from 3% to 5%.

The results of grain size distribution analyses tests conducted on selected samples of the granular base material are presented on the Record of Borehole sheets included in Appendix A, and are summarized in the following table. The results are also presented on Figure B1 in Appendix B.



Soil Particle	Percentage (%)
Gravel	22 to 35
Sand	46 to 66
Silt and Clay	12 to 19

## 5.2 Silty Clay Fill

Embankment fill was encountered beneath the road structure in Boreholes 16-07 to 16-10, LY-2 and LY-3 and extended to depths from 1.5 m to 2.3 m below the ground surface (Base Elev. 340.8 m to 341.6 m). The thickness of the embankment fill ranged from 0.6 m to 1.8 m. The fill generally consisted of grey silty clay containing trace to some sand and trace gravel. Locally in Borehole LY-2, the fill consisted of grey sandy silt with trace clay. Occasional wood fragments were also observed in the embankment fill.

The fill was typically stiff in consistency, with SPT 'N' values ranging from 9 to 12 blows for 0.3 m penetration. Higher SPT 'N' values ranging from 19 to 95 blows per 0.3 m of penetration were noted in the frozen fill in Boreholes LY-2 and LY-3. The measured moisture content of the fill ranged from 13% to 31%.

The results of grain size distribution analyses conducted on a selected sample of the silty clay fill are presented on the Record of Borehole sheets included in Appendix E and are summarized in the following table.

Soil Particle	Percentage (%)
	Cohesive Fill
Gravel	1
Sand	7
Silt	56
Clay	36

## 5.3 Topsoil

Topsoil was identified at the ground surface in Borehole LY-1. The topsoil thickness was 75 mm.

The topsoil thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities.

## 5.4 Organic Soil

Organic soils were encountered beneath the embankment fill in Boreholes LY-2 and LY-3 and at the surface in Borehole LY-4. The organic soils generally consisted of black to brown organic clay or organic silt containing trace to some sand and trace gravel. The organic layers were 0.6 m to 1.5 m thick.

The depths to the base of the organic soils was 3.7 m and 3.8 m (Base Elev. 339.4 and 339.3 m) in Boreholes LY-2 and LY-3, and 0.6 m (Base Elev. 339.9 m) in Borehole LY-4.

The organic soils were typically firm to stiff, with SPT 'N' values of 7 to 9 blows for 0.3 m penetration. A higher SPT 'N' value of 12 blows per 0.3 m penetration was also recorded in the frozen surficial organic silt in Borehole LY-4. The measured moisture content in the organic soils ranged from 32% to 38%.

The results of grain size distribution analyses and Atterberg Limits tests conducted on a selected sample of the organic clay are presented on the Record of Borehole sheets included in Appendix E and are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	19
Silt	44
Clay	37
Soil Property	Percentage (%)
Liquid Limit	53
Plasticity Limit	29

The results of the Atterberg Limits testing indicate the organic soil to be of high plasticity with a group symbol of CH.

## 5.5 Silty Clay

Native silty clay with trace to some sand and trace gravel was encountered beneath the embankment fill or organic soils in Boreholes 16-07 to 16-10 and LY-2 to LY-3 at depths of 1.5 m to 3.8 m (Elev. 339.3 to 341.6 m) below the existing road surface. In Boreholes LY-1 and LY-4, drilled at the culvert inlet and outlet, the silty clay was encountered at 0.1 m to 0.6 m depth (Elev. 340.8 and 339.9 m) respectively. All of the boreholes were terminated within the silty clay at

depths ranging from 3.7 m to 11.6 m (Elev. 331.5 to 339.4 m). A DCPT was conducted from the bottom of Borehole 16-07, until reaching refusal of 100 blows per 0.3 m of penetration at a depth of 23.5 m (Elev. 319.6 m).

SPT 'N' values recorded in the silty clay ranged from 4 to 9 blows for 0.3 m penetration, with the exception of an SPT 'N' value of 23 blows per 0.3 m penetration, recorded near the frozen ground surface in Borehole LY-1. Vane shear tests (VST) conducted in the silty clay measured in-situ undrained shear strengths ranging from 55 kPa to greater than 100 kPa. Based on the SPT and VST data, the consistency of the silty clay is typically firm to very stiff. Natural moisture contents ranged from 18% to 38%.

The results of grain size distribution analyses and Atterberg Limits tests conducted on selected samples of the silty clay are presented on the Record of Borehole sheets included in Appendices A and E, and are summarized in the following table. The results from the grain size distribution analyses and Atterberg Limits from Boreholes 16-07 to 16-10 are presented on Figures B2 and B3 in Appendix B.

<b>Soil Particle</b>	<b>Percentage (%)</b>
Gravel	0 to 4
Sand	0 to 39
Silt	29 to 41
Clay	23 to 61
<b>Soil Property</b>	<b>Percentage (%)</b>
Liquid Limit	33 to 61
Plasticity Limit	13 to 25

The results of the Atterberg Limits tests indicate that the silty clay typically ranges from medium to high plasticity with group symbols of CI to CH, however one sample from Borehole 16-10 revealed a low plasticity, with a group symbol of CL.

## 5.6 Groundwater Conditions

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

**Table 5.1 – Groundwater Measurements**

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-07	July 24, 2016	10.1	333.0	Open borehole
16-08	July 23, 2016	Dry	-	Open borehole
16-09	July 23, 2016	Dry	-	Open borehole
16-10	July 23, 2016	Dry	-	Open borehole
LY-1	March 15, 2015	Dry	-	Reported by Golder
LY-2	February 13, 2015	Dry	-	Reported by Golder
LY-3	February 13, 2015	Dry	-	Reported by Golder
LY-4	March 15, 2015	Dry	-	Reported by Golder

A water level measurement near the outlet of the creek was reported on the drawings provided by Hatch, which indicate a creek level at Elevation 339.74 m on June 17, 2014. The creek level when frozen, was reported by Golder at Elevation 340.1 on February 13, 2015. The groundwater level should be assumed to reflect the local creek water level.

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

## **6. CORROSIVITY AND SULPHATE TEST RESULTS**

A sample of the native silty clay from Borehole 16-07, and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Units (Water)	Test Results	
			16-07, SS#3B, 2.3 m – 2.9 m	Lyon Creek Culvert
			(Silty Clay)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.02
Chloride	µg/g	mg/L	33	30
Sulphate	µg/g	mg/L	17	<10
pH	No unit	No unit	7.83 to 8.72	7.71
Electrical Conductivity	µS/cm	µS/cm	98	195
Resistivity	Ohms.cm	MOhms.cm	10200	513
Redox Potential	mV	mV	246	290

## 7. MISCELLANEOUS

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

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

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. 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 Ms. R. Palomeque Reyna, P.Eng. The report was reviewed by Mr. Keli Shi, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for detailed design of the proposed Lyon Creek Culvert No. 2 replacement on Highway 602, located south of Emo, within the Township of Lash, in the 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 contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the Structural Design Report (SDR) (Reference 2). The Structural Design Report provided discussion on the existing structure, discussion of alternatives for the proposed culvert replacement, and recommendations for the preferred alternative.

The existing culvert consists of a 17.0 m long, 5.5 m wide, open footing concrete culvert, with an invert elevation of approximately 339.3 m. The top of obvert is at approximate Elev. 341.4 m. The finished road grade at the culvert location is shown at approximate Elev. 343.1 m, which results in approximately 1.7 m of fill above the culvert. The height of the highway embankment is

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approximately 4 m.

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

- Option 1 – Precast Concrete Closed Box Culvert
- Option 2 – Precast Open Footing Metal Box Culvert
- Option 3 – Multiple Round Corrugated Steel Pipe (CSP) Culvert

As described in the SDR, the preferred structure alternative is Option 3, which is reported to satisfy all of the design criteria and results in a favorable aquatic environment while providing a lightweight, cost effective replacement option. For Option 3 (CSP), the structure would consist of two 25.2 m long, 3.0 m diameter round aluminized or polymer laminated corrugated steel pipes. The SDR also identifies Option 1 (Concrete Closed Box) as a viable culvert replacement alternative, with some advantages over Option 3, although it is more expensive. Both of the CSP and concrete closed box options are discussed in Section 9 below, as well as other potential replacement alternatives.

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

Preliminary General Arrangement (GA) drawings for both the CSP and concrete closed box options were included in the SDR, which show the proposed replacement culvert. The invert and alignment of the replacement culvert and the finished road grade level will remain largely the same as for the existing culvert. Both GA drawings show that the replacement culvert will be longer than the existing culvert at both the inlet and outlet, which will likely result in the placement of additional embankment fill adjacent to the culvert barrels. No headwalls or wingwalls are proposed.

The discussions and recommendations presented in this report are based on information provided by Hatch and on the factual data obtained during the course of the current investigation. In addition, the existing subsurface information collected during the preliminary investigation and documented in the Draft Preliminary Foundation Investigation and Design Report prepared by Golder (Reference 1) has been reviewed and incorporated in this report, where appropriate.

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

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## **9. CULVERT DESIGN**

### **9.1 Culvert Alternatives**

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

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

- Concrete box (closed) culvert composed of pre-cast segments
- Corrugated steel pipe (CSP)
- Concrete, open footing culvert

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

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

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

### **9.2 Foundation Design for Culverts**

Based on the SDR, the invert level of the replacement culvert will be similar to the invert of the existing culvert, and no grade raise or significant embankment widening is proposed, with the exception of possible embankment fill placement adjacent to the extended culvert barrels. There is approximately 1.7 m of fill above the existing culvert. Foundation design aspects for the replacement culvert includes subgrade conditions and preparation, geotechnical capacities,

settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.

### **9.2.1 Corrugated Steel Pipe Culvert**

Replacement of the culvert with twin CSPs on the same alignment is identified in the SDR as the preferred option for this site. In order to accommodate the hydraulic requirements, multiple pipes are required. The proposed invert level of the CSPs is Elev. 339.0 m. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the replacement culvert.

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

The underside of the bedding layer should be placed at or below Elev. 339.0, which corresponds to stiff to very stiff silty clay subgrade.

### **9.2.2 Concrete Box Culvert**

Replacement of the culvert with a concrete box culvert on the same alignment is identified as a viable alternative for this site. The proposed invert level of the concrete box is Elev. 339.0 m. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the replacement culvert.

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

to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 339.0 m, which corresponds to stiff to very stiff silty clay subgrade.

The following geotechnical capacities could be used for design of a box culvert of 5 to 6 m in width founded at or below Elev. 339.0 m on the stiff to very stiff silty clay subgrade:

- Factored Geotechnical Resistance at ULS of 250 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 165 kPa.

The consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing, and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Sec. 6.9.

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

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

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II 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

Strip footings supporting an open footing concrete culvert should be founded on the stiff to very stiff silty clay below the frost depth (2.3 m) at or below Elev. 337.0 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 footing widths of 1 to 2 m:

- Factored Geotechnical Resistance at ULS of 250 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 165 kPa.

The above assumes that there is no grade raise. The consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing, and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Sec. 6.9.

The 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 lateral forces / sliding resistance between precast concrete and the underlying silty clay should be evaluated in accordance with the 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 inspection and approval.

Scour and erosion protection must be provided for the footings.

#### **9.2.4 Culvert Headwalls**

The GA drawings in the SDR do not show proposed headwalls at the inlet and outlet of the replacement culvert. However, if headwalls are required, consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are more tolerant to settlement.

The borehole information indicates that the founding conditions at the wall locations generally consist of stiff to very stiff silty clay.

#### 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.

To provide an acceptable foundation performance, the RSS mass should be founded on a 500 mm thick engineered fill pad resting on the native stiff to very stiff silty clay subgrade at or below an approximate elevation of 338.8 m or lower. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 125 kPa (for up to 25 mm of settlement). Engineered fill pads placed under the RSS mass must consist of OPSS PROV Granular A or Granular B Type II compacted to 100% of its 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 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 RSS walls 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 stiff 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 501. The walls should be provided with sufficient frost cover (minimum 2.3 m) and founded at Elev. 337.0 m or lower. A factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 125 kPa (for up to 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 silty clay till should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for stiff to very stiff silty clay.

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.

#### **9.2.5 Frost Cover**

The depth of frost penetration at this site is approximately 2.3 m. The base of open footing concrete culvert or headwall footings, if employed, should be provided with a minimum of 2.3 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.

The frost taper investigation in Boreholes 16-08 to 16-10 indicated the presence of 0.8 to 0.9 m of granular fill overlying silty clay fill to at least 35 m south of the centreline of the existing culvert. Borehole 16-07 also included granular fill to a depth of 0.8 m, extending at least 10 m north of the centreline of the existing culvert. The purpose of the granular fill was likely for road base material, and does not appear to have been placed as a frost taper. Frost susceptible soils in the form of silty clay fill, organic clay/organic silt, and native silty clay were noted within the depth of frost penetration in all of the boreholes. As the top of the

CSP or box culvert will be above the depth of frost penetration, frost treatment or a frost taper will be required as per OPSD 803.031 for a CSP culvert or OPSD 803.010 for a box culvert.

### **9.2.6 Subgrade Preparation**

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. The organic soils observed in Boreholes LY-2, LY-3 and LY-4, down to Elev. 339.3 to 339.9 m must be removed to expose the underlying competent silty clay subgrade. Any remaining fill, topsoil, peat, creekbed deposits, 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 work should be carried out in accordance with OPSS 902 and culvert construction and all subgrade preparation and placement and compaction of granular material must be carried out in the dry.

### **9.2.7 Settlement**

Based on the GA drawings in the SDR, the replacement culvert will have approximately the same alignment and opening size as the existing culvert with no grade raise. Since there is no grade raise or widening, 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 consolidation settlement of the cohesive soils (stiff to very stiff silty clay) at this site.

## **9.3 Construction Considerations**

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

Staged construction sequencing will likely require the following:

- Diversion of the creek will be required for construction. In addition, a suitable dewatering plan will be required to construct the culvert in the dry.
- Temporary roadway protection may be required during all stages of construction, including excavation and removal of the existing culvert, installation of the new culvert and backfilling.
- All culvert and headwall 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 at this site are classified as Type 3 soils. Organic soils, cohesionless soils and surficial alluvial deposits that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

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

Excavations for culvert replacement will be carried out through the existing embankment fill and extended into the native organic soils and the silty clay deposit. 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 G.

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 within an enclosure will be required to maintain dry excavations during the course of staged construction.

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

## **11. STREAM DIVERSION PIPE**

If a temporary stream diversion pipe is required, the invert of the diversion pipe should be placed at approximately Elev. 339.2, where the soil consists stiff to very stiff silty clay. Temporary shoring may be required to install the diversion pipe at the proposed depth of approximately 4 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.

## **12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES**

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 401 for a CSP 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 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)
	$\gamma$	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

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

**Table 12.1 – Lateral Earth Pressure Coefficients (K)**

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ ; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$	
	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.

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

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

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

### 13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site is typically a stiff to very stiff silty clay with an average undrained shear strength between 50 and 100 kPa. 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% probability of exceedance in 50 years 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 2014, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 13.1 may be used:

**Table 13.1 – Earth Pressure Coefficients for Earthquake Loading**

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I (modified) $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active ( $K_{AE}$ )*	0.29	0.33
Passive ( $K_{PE}$ )	3.6	3.2
At Rest ( $K_{OE}$ )**	0.49	0.54

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

\*\* After Woods

The site is underlain by stiff to very stiff silty clay and liquefaction is not considered to be a concern at this site.

#### 14. TEMPORARY PROTECTION SYSTEM

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

Options for roadway protection are a soldier pile-lagging system or sheet piles, although the sheet piles may be difficult to drive in the fill, which could include obstructions such as cobbles and boulders.

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

**Table 14.1 –Soil Parameters for Temporary Protection System Design**

Soil Parameter	Existing Fill	Organic Soils	Native Silty Clay
$\gamma$	20 kN/m <sup>3</sup>	18 kN/m <sup>3</sup>	20 kN/m <sup>3</sup>
$\gamma_w$	10 kN/m <sup>3</sup>	8 kN/m <sup>3</sup>	10 kN/m <sup>3</sup>
$K_a$	0.39	0.41	0.36
$K_p$	2.6	2.5	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 pressure distribution acting on the protection/shoring system is a function of the construction

sequence and the relative flexibility of the wall, and these factors have to be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

## **15. EMBANKMENT RESTORATION**

The existing Highway 602 embankment is approximately 4 m in height (1.7 m above the culvert) at the culvert 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 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 granular cover and below the roadbase granular fill, provided it is 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 or clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

## **17. CORROSION AND SULPHATE ATTACK POTENTIAL**

The results of the corrosivity and sulphate analytical tests conducted on the native silty clay 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 negligible 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.

## **18. CONSTRUCTION CONCERNS**

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

- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system. Suggested wording for an NSSP on obstructions is included in Appendix G.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

## 19. CLOSURE

Engineering analysis and preparation of this report was carried out by Ms. R. Palomeque Reyna, P.Eng. and Mr. Mark Farrant, P.Eng. The report was reviewed by Mr. Keli Shi, P.Eng., and 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 <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

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



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger Sample	GS 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<sub>pen</sub> 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 <sub>L</sub> < 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 <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 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 16-07

1 OF 3

METRIC

W.P. 6342-14-01 LOCATION Lyon Creek, Culvert No. 2 Replacement N 5 386 723.9 E 245 165.2 ORIGINATED BY OA  
 HWY 602 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.07.24 - 2016.07.24 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				GR   SA   SI   CL						
								○ UNCONFINED      + FIELD VANE	W <sub>P</sub>	W	W <sub>L</sub>									
								● QUICK TRIAXIAL      × LAB VANE	20	40	60	80		100	20	40	60			
343.1	GROUND SURFACE																			
0.0	ASPHALT: (50mm)																			
	Gravelly <b>SAND</b> , some silt and clay		1	GS								○					28	58	14	
	Brown																		(SI+CL)	
	Moist																			
342.3	(FILL)																			
0.8	Silty <b>CLAY</b> , some sand to sandy, trace gravel		1	SS	9								○							
	Firm to Stiff																			
	Grey																			
	Moist		2	SS	12							○								
	(FILL)																			
340.8																				
2.3	Silty <b>CLAY</b> , trace to some sand, trace gravel		3	SS	6								○				0	39	38	23
	Stiff to Very Stiff												○							
	Brown																			
	Moist																			
	Grey below 3.0m		4	SS	9								○							
			5	SS	5									○						
			6	SS	7									○						
			7	SS	7															

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

## METRIC

SOIL PROFILE						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
Continued From Previous Page						
331.8	Silty <b>CLAY</b> , some sand Stiff to Very Stiff Grey Moist	[Hatched Box]	9 SS 7			GR SA SI CL
11.3	End of sampling at 11.3m and start DCPT					

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

# RECORD OF BOREHOLE No 16-07

3 OF 3

METRIC

W.P. 6342-14-01 LOCATION Lyon Creek, Culvert No. 2 Replacement N 5 386 723.9 E 245 165.2 ORIGINATED BY OA  
 HWY 602 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.07.24 - 2016.07.24 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	W <sub>p</sub>	W	W <sub>L</sub>	WATER CONTENT (%)		
	Continued From Previous Page						323							
							322							
							321							
							320							
319.6														
23.5	END OF BOREHOLE AT 23.5m UPON DYNAMIC CONE REFUSAL. WATER LEVEL AT 10.1m IN OPEN BOREHOLE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.1m, THEN SURFACE PATCHED WITH ASPHALT.													

ONTMT4S 13004-MTO.GPJ 2015TEMPLATE(MTO).GDT 10/11/16

# RECORD OF BOREHOLE No 16-08

1 OF 1

METRIC

W.P. 6342-14-01 LOCATION Lyon Creek, Culvert No. 2 Replacement N 5 386 709.6 E 245 185.7 ORIGINATED BY OA  
 HWY 602 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.07.23 - 2016.07.23 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE							
343.1	GROUND SURFACE							20 40 60 80 100							
0.0	ASPHALT: (50mm)		1	GS			343								
342.3	SAND and GRAVEL, some silt and clay Brown Moist (FILL)		2	GS											35 46 19 (SI+CL)
0.8	Silty CLAY, some gravel, trace sand Grey Moist (FILL)		3	GS			342								
341.6	Silty CLAY, trace sand, trace gravel Grey Moist		4	GS			341								0 0 39 61
1.5	Firm		1	SS	4		340								
339.4	END OF BOREHOLE AT 3.7m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.1m, THEN SURFACE PATCHED WITH ASPHALT.														
3.7															

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15 10 5 0  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 16-09

1 OF 1

METRIC

W.P. 6342-14-01 LOCATION Lyon Creek, Culvert No. 2 Replacement N 5 386 703.8 E 245 193.9 ORIGINATED BY OA  
 HWY 602 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.07.23 - 2016.07.23 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				GR	SA	SI	CL
343.1	GROUND SURFACE							20   40   60   80   100		W <sub>p</sub> W                      W <sub>L</sub>							
0.0	ASPHALT: (50mm)							○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE									
0.0	Gravelly <b>SAND</b> , some silt and clay Brown Moist (FILL)		1	GS			343					○			22	66	12 (SI+CL)
342.2			2	GS								○					
0.9	Silty <b>CLAY</b> , some sand, some gravel Grey Moist (FILL)		3	GS			342					○					
341.6																	
1.5	Silty <b>CLAY</b> , some sand to sandy, trace gravel Brown Moist		4	GS			341						○				
	Firm		1	SS	5		340					┌─○─┐			0	25	40 35
339.4																	
3.7	END OF BOREHOLE AT 3.7m. WATER NOT OBSERVED UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.1m, THEN SURFACE PATCHED WITH ASPHALT.																

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

# RECORD OF BOREHOLE No 16-10

1 OF 1

METRIC

W.P. 6342-14-01 LOCATION Lyon Creek, Culvert No. 2 Replacement N 5 386 698.1 E 245 202.1 ORIGINATED BY OA  
 HWY 602 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.07.23 - 2016.07.23 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
343.1	GROUND SURFACE							20 40 60 80 100		W <sub>P</sub> W      W <sub>L</sub>				
0.0	ASPHALT: (50mm)							○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE						
	SAND and GRAVEL, some silt and clay Brown Moist		1	GS			343				○			
342.2	(FILL)		2	GS							○			32 54 14 (SI+CL)
0.9	Silty CLAY, trace sand to sandy, some gravel Grey Moist		3	GS			342				○			
341.6	(FILL)													
1.5	Silty CLAY, trace to some sand, trace gravel Brown Moist		4	SS			341							
	Firm		1	SS	5		340				○			
339.4											○			2 24 40 34
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.1m, THEN SURFACE PATCHED WITH ASPHALT.													

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

## **Appendix B**

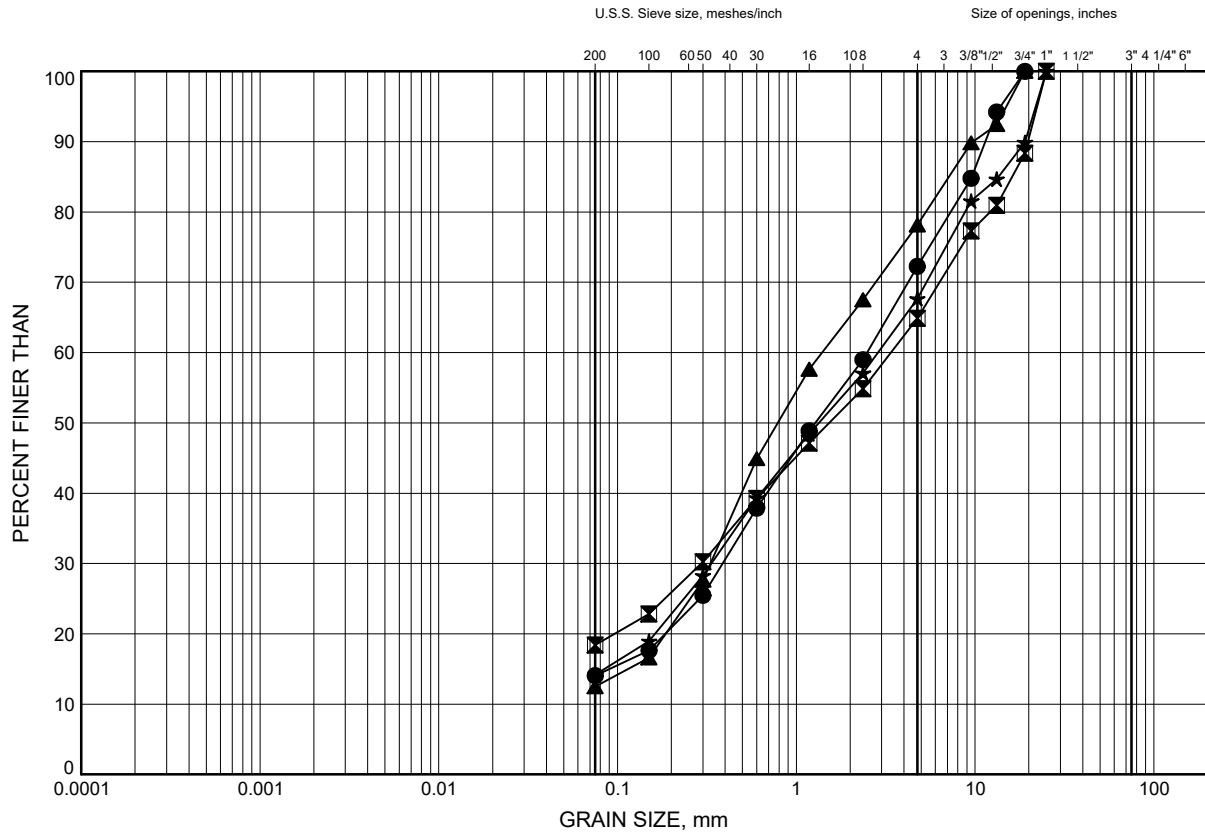
### **Geotechnical and Analytical Laboratory Test Results**



Lyon Creek, Culvert No. 2 Replacement  
**GRAIN SIZE DISTRIBUTION**

FIGURE B1

**Gravelly SAND FILL/SAND and GRAVEL FILL**



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-07	0.30	342.80
⊠	16-08	0.76	342.34
▲	16-09	0.30	342.80
★	16-10	0.76	342.34

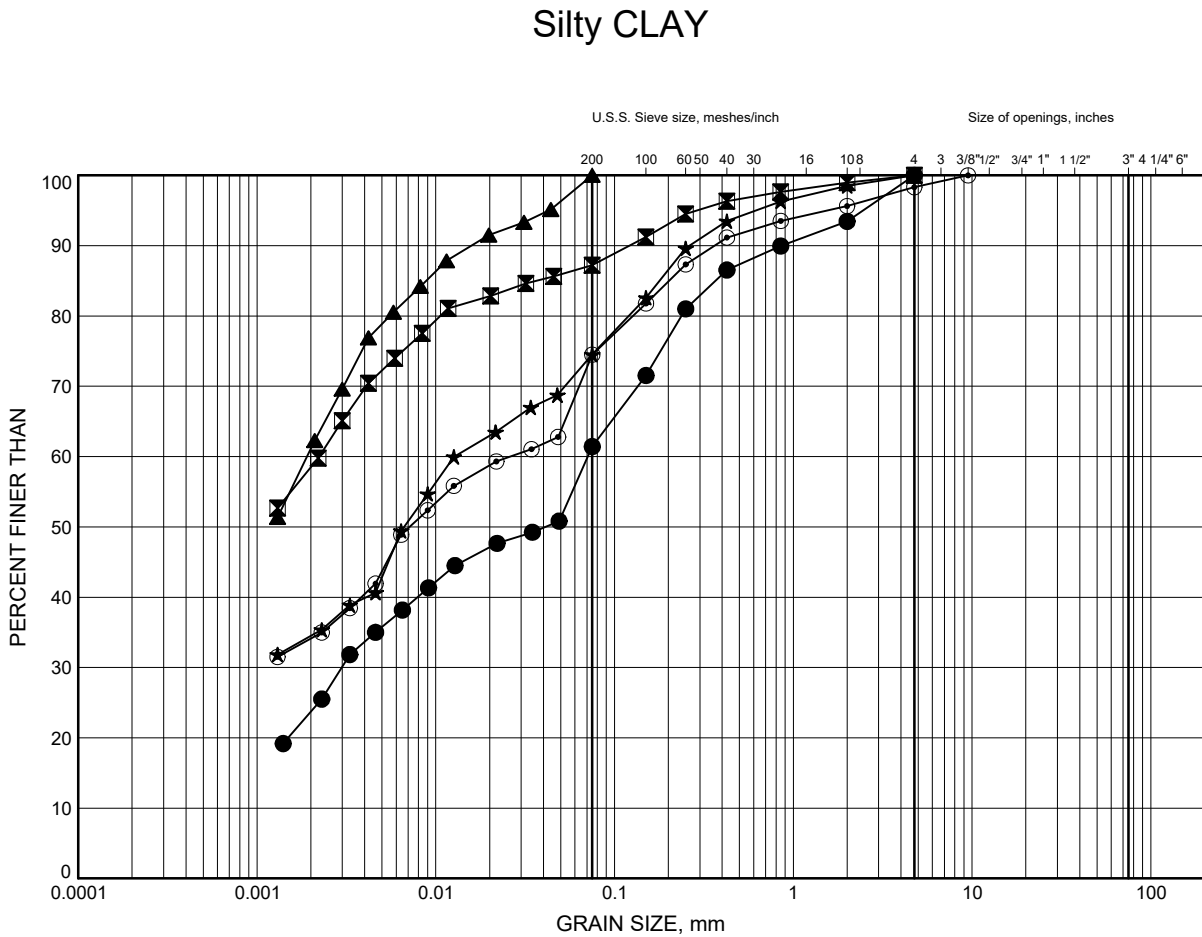
Date ..October 2016.....  
W.P. ..6342-14-01.....



Prep'd .....AN.....  
Chkd. ....RPR.....

Lyon Creek, Culvert No. 2 Replacement  
GRAIN SIZE DISTRIBUTION

FIGURE B2



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

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-07	2.44	340.66
⊠	16-07	7.92	335.18
▲	16-08	2.29	340.81
★	16-09	3.35	339.75
⊙	16-10	3.35	339.75

Date ..October 2016.....  
W.P. ..6342-14-01.....

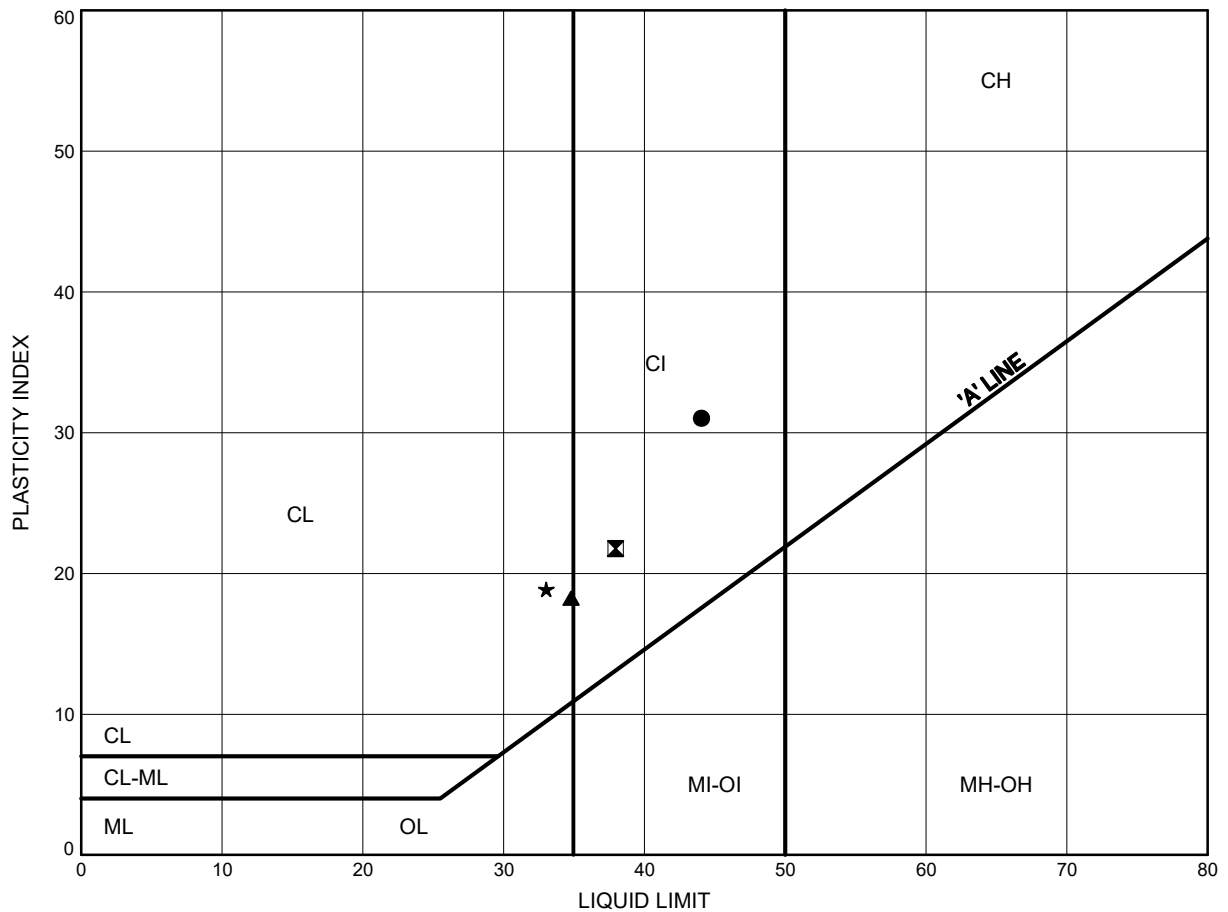


Prep'd .....AN.....  
Chkd. ....RPR.....

Lyon Creek, Culvert No. 2 Replacement  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B3

Silty CLAY



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-07	7.92	335.18
⊠	16-08	2.29	340.81
▲	16-09	3.35	339.75
★	16-10	3.35	339.75

Date ..October 2016.....  
W.P. ..6342-14-01.....



Prep'd .....AN.....  
Chkd. ....RPR.....

**SGS Canada Inc.**

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

**Project : 13004****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive, Oakville  
, L6H 5R7  
Phone: 905-829-8666 x 228, Fax:

**09-August-2016**

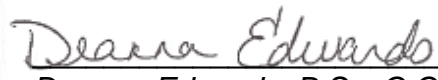
**Date Rec. :** 03 August 2016  
**LR Report:** CA14113-AUG16  
**Reference:** 13004

**Copy: #1**

## CERTIFICATE OF ANALYSIS

### Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	7: BH-16-07 SS3B, 8'4"-9'6"
Sample Date & Time					24-Jul-16
Temperature Upon Receipt [°C]	---	---	---	---	24.2
Corrosivity Index [none]	09-Aug-16	13:32	09-Aug-16	14:29	1
pH [no unit]	08-Aug-16	11:40	09-Aug-16	09:32	7.83
Soil Redox Potential [mV]	08-Aug-16	18:47	09-Aug-16	08:27	246
Sulphide [%]	08-Aug-16	10:07	09-Aug-16	09:35	< 0.02
% Moisture (wet wt) [%]	05-Aug-16	07:02	05-Aug-16	09:08	14.2
pH [no unit]	04-Aug-16	09:56	04-Aug-16	15:49	8.72
Chloride [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	33
Sulphate [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	17
Conductivity [µS/cm]	04-Aug-16	09:56	04-Aug-16	15:49	98
Resistivity (calculated) [Ohms.cm]	09-Aug-16	13:31	09-Aug-16	14:29	10200

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



**SGS Canada Inc.**

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

**Project : 13004**

**LR Report : CA14113-AUG16**

Temperature of Samples upon receipt 24 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.

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

**Project :** 13004**LR Report :** CA14113-AUG16

## Method Descriptions

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



**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

**Project :** 13004

**LR Report :** CA14113-AUG16

## 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 (%)
					%	Low				High	Low	
Anions by IC - QCBatchID: DIO0053-AUG16												
Chloride	0.4	µg/g	<0.4		0	20	109	80	120	111	75	125
Sulphate	0.4	µg/g	<0.4		3	20	101	80	120	101	75	125
Carbon/Sulphur - QCBatchID: ECS0007-AUG16												
Sulphide	0.02	%	<0.02		NV	20	113	80	120			
Conductivity - QCBatchID: EWL0045-AUG16												
Conductivity	2	uS/cm	2		1	10	99	90	110	NA		
pH - QCBatchID: EWL0045-AUG16												
pH	0.05	no unit	NA		0		100			NA		

**SGS Canada Inc.**

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

**Project : 13004****02-August-2016****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive, Oakville  
, L6H 5R7  
Phone: 905-829-8666 x 228, Fax:

**Date Rec. :** 27 July 2016  
**LR Report:** CA15442-JUL16  
**Reference:** 13004

**Copy: #1**

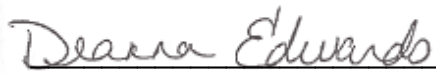
## CERTIFICATE OF ANALYSIS

### Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	6: Lyon Creek Culvert
Sample Date & Time					N/A
Temperature Upon Receipt [°C]	---	---	---	---	21.0
Corrosivity Index [none]	02-Aug-16	13:33	02-Aug-16	13:33	16
pH [no unit]	27-Jul-16	06:49	28-Jul-16	15:17	7.71
Redox Potential [mV]	27-Jul-16	13:39	02-Aug-16	10:54	290
Sulphide [mg/L]	29-Jul-16	13:00	29-Jul-16	12:19	< 0.02
Chloride [mg/L]	27-Jul-16	11:45	28-Jul-16	10:10	30
Sulphate [mg/L]	27-Jul-16	12:42	29-Jul-16	14:35	< 10
Conductivity [uS/cm]	27-Jul-16	06:49	28-Jul-16	15:17	195
Resistivity (calculated) [MOhms.cm]	02-Aug-16	13:27	02-Aug-16	13:27	513

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.

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



**SGS Canada Inc.**

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

**Project :** 13004**LR Report :** CA15442-JUL16

### Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by discrete analyzer	ME-CA-[ENV]EWL-LAK-AN-026	US EPA 325.2
Anions by discrete analyzer	ME-CA-[ENV]EWL-LAK-AN-026	US EPA 375.4
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential		SM 2580
Sulphide by SFA	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500



**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

**Project :** 13004

**LR Report :** CA15442-JUL16

## 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 discrete analyzer - QCBatchID: DIO0458-JUL16												
Chloride	1	mg/L	<1		1	20	96	80	120	91	75	125
Sulphate	1	mg/L	1		1	20	93	80	120	109	75	125
Conductivity - QCBatchID: EWL0410-JUL16												
Conductivity	2	uS/cm	< 2		0	10	98	90	110	NA		
pH - QCBatchID: EWL0385-JUL16												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0394-JUL16												
Redox Potential	no	mV	NA		1	20	107	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0211-JUL16												
Sulphide	0.02	mg/L	<0.02		0	20	92	80	120	NV	75	125

## **Appendix C**

### **Site Photographs**



**Photo 1: Lyon Creek Culvert No. 2, looking northwest**





**Photo 2: Lyon Creek Culvert No. 2, looking southeast**





**Photo 3: Lyon Creek Culvert No. 2, south embankment, looking north**





**Photo 4: Lyon Creek Culvert No. 2 outlet, looking north**





**Photo 5: Lyon Creek Culvert No. 2, north embankment, looking south**



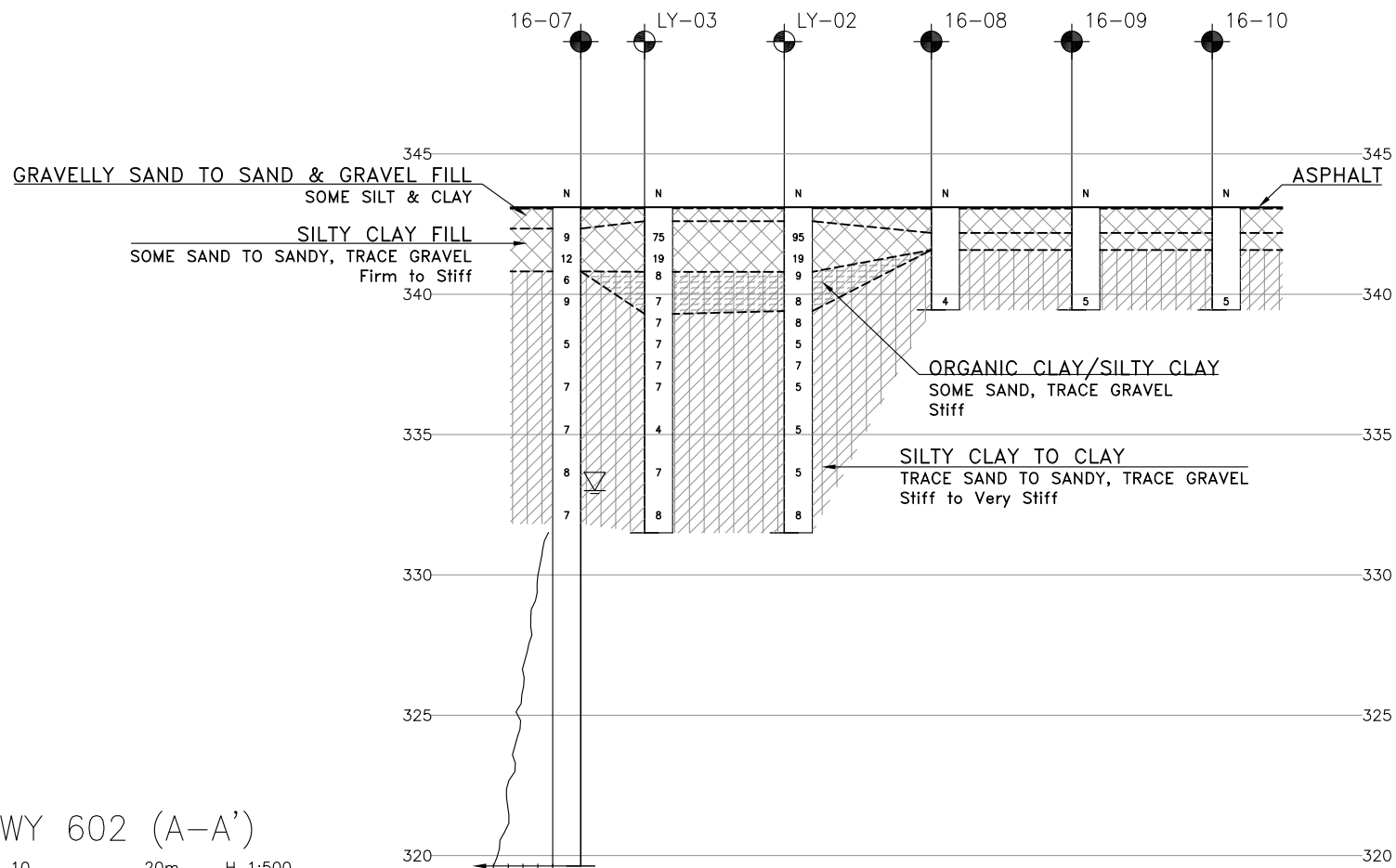
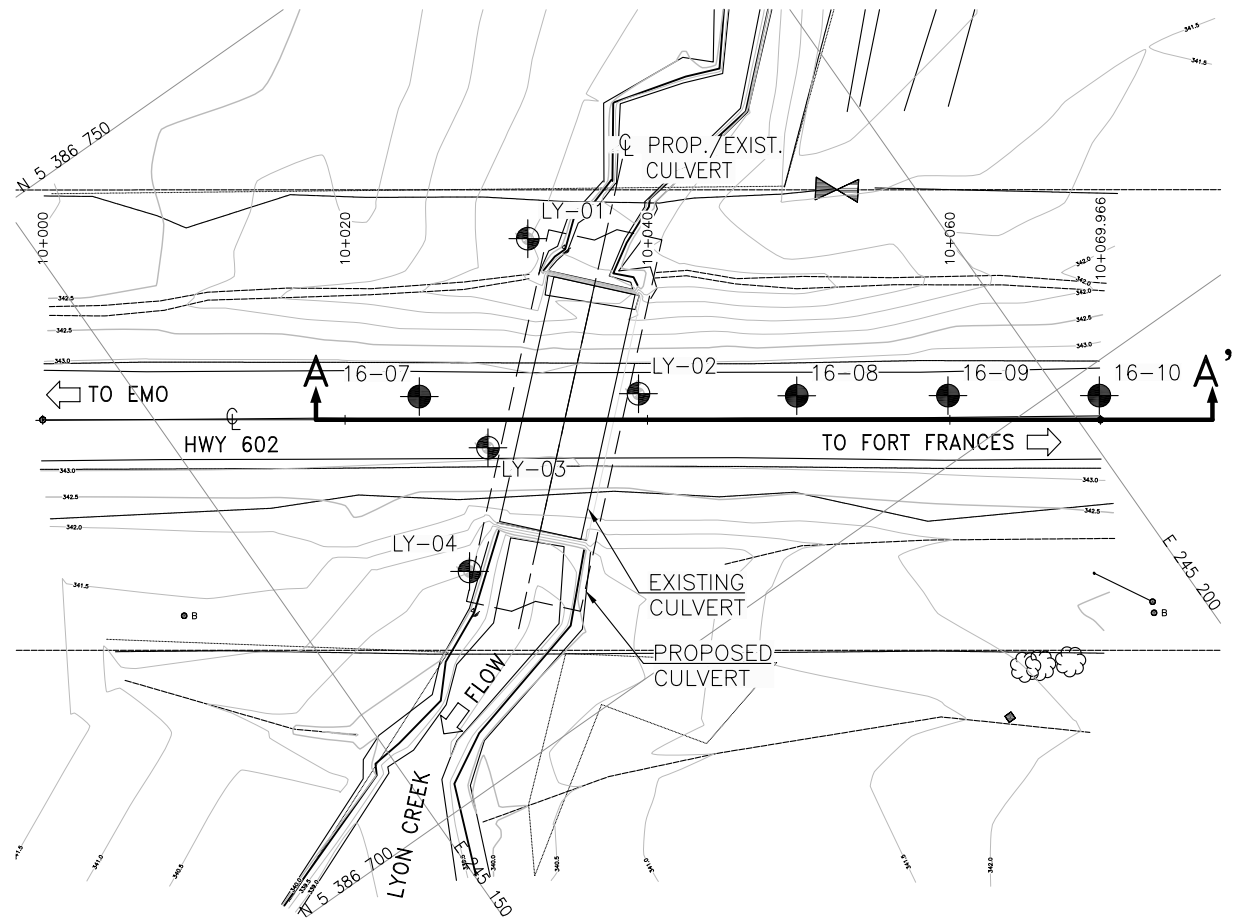


**Photo 6: Lyon Creek Culvert No. 2 inlet, looking south**

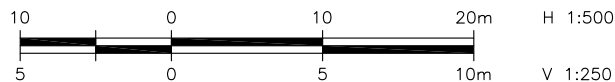
## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**

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



PROFILE ALONG  $\text{CL}$  HWY 602 (A-A')



CONT No 2016-6035  
WP No 6342-14-01

LYON CREEK  
CULVERT NO. 2  
STRUCTURAL REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

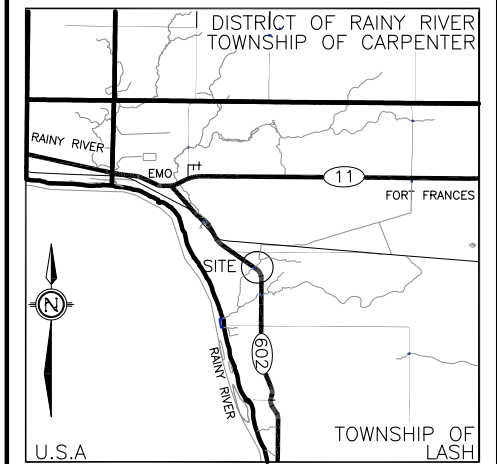


SHEET  
32

**HATCH**



THURBER ENGINEERING LTD.



KEYPLAN

### LEGEND

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

NO	ELEVATION	NORTHING	EASTING
16-07	343.1	5 386 723.9	245 165.2
16-08	343.1	5 386 709.6	245 185.7
16-09	343.1	5 386 703.8	245 193.9
16-10	343.1	5 386 698.1	245 202.1
LY-01	340.9	5 386 728.3	245 177.1
LY-02	343.1	5 386 715.7	245 177.2
LY-03	343.1	5 386 718.5	245 167.0
LY-04	340.5	5 386 712.5	245 161.3

### NOTES

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

GEOCRES No. 52C-52

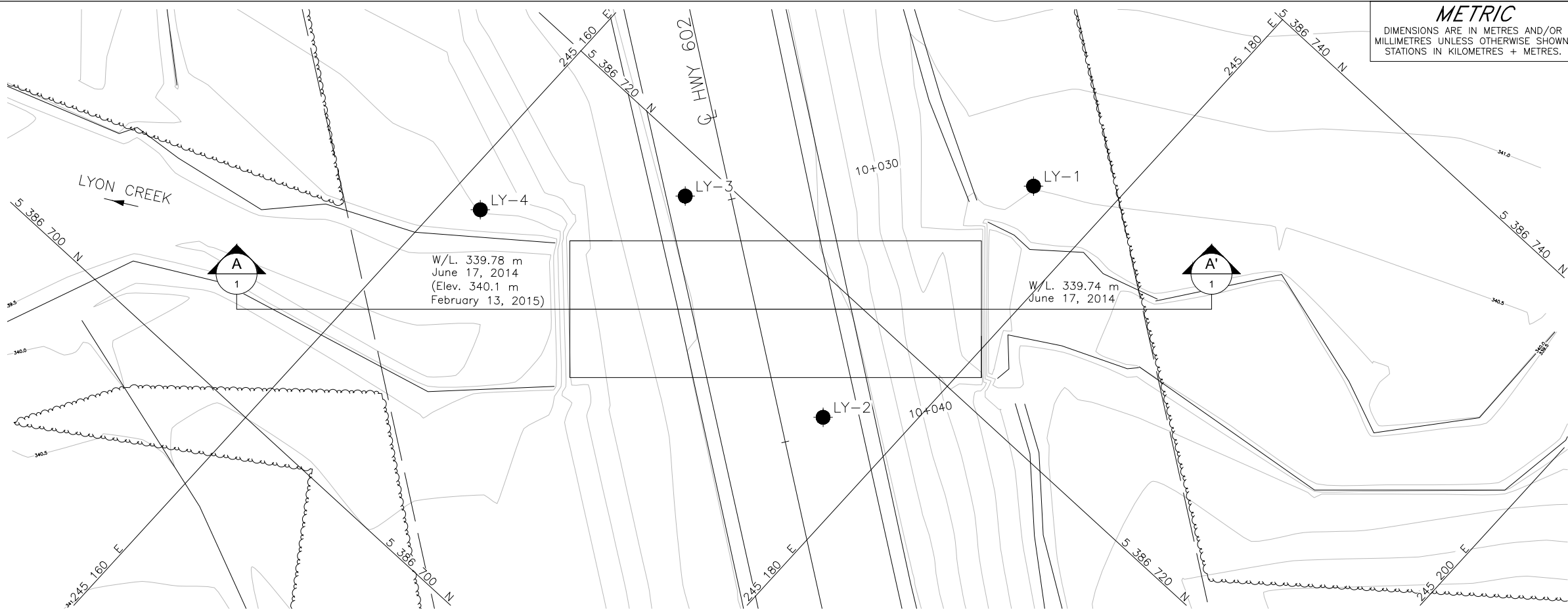


REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MEF	CHK	MEF
DRAWN	AN	CHK	SITE
			LOAD
			STRUCT
			DWG 2
			DATE JAN 2017

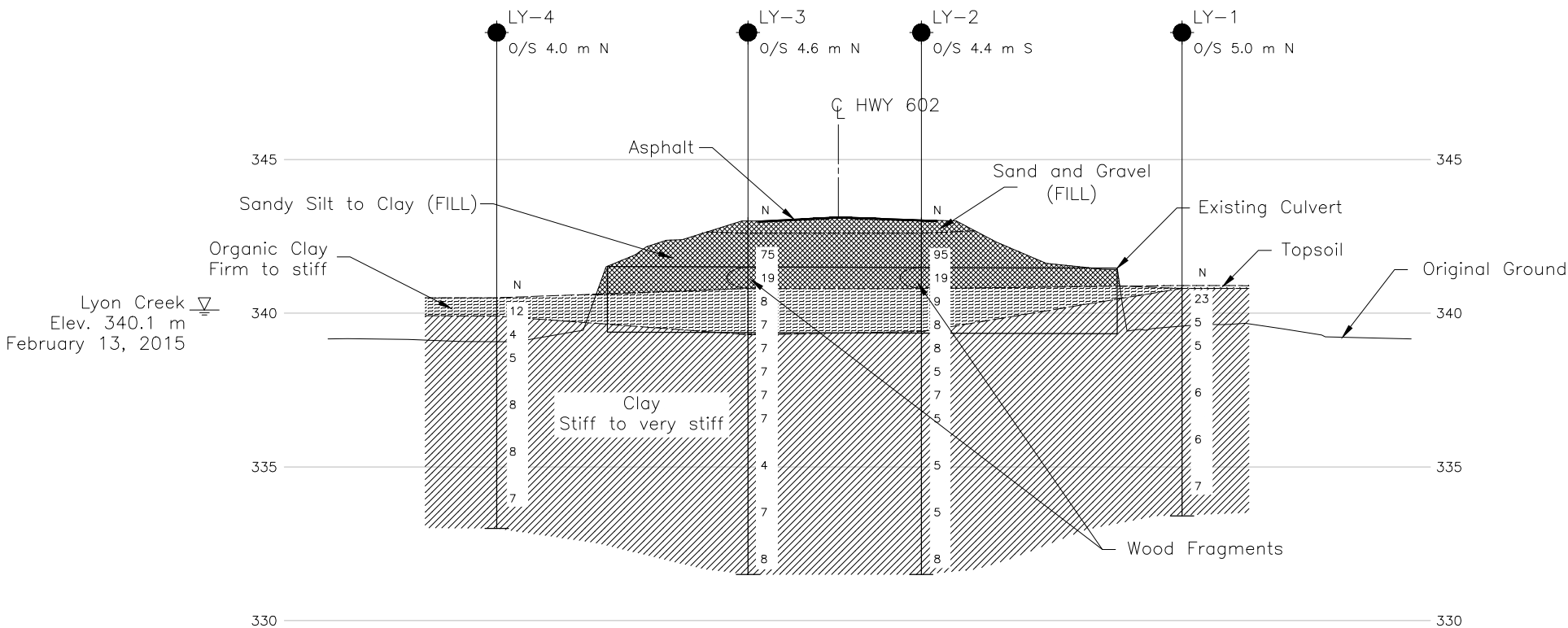
## **Appendix E**

### **Factual Data from 2015 Golder Foundation Investigation Report**





PLAN  
SCALE



PROFILE

HORIZONTAL SCALE



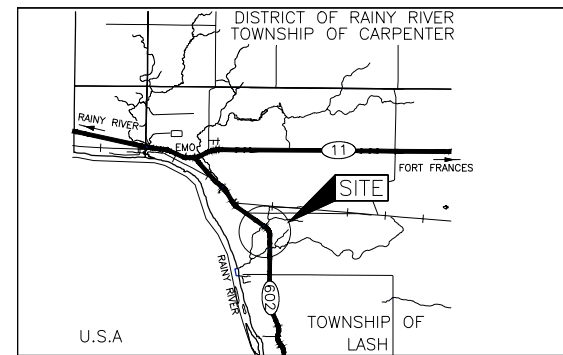
VERTICAL SCALE

A-A'  
1

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

CONT No. .  
GWP No. 6342-14-00

HIGHWAY 602  
LYON CREEK CULVERT NO. 2 STA 10+035  
BOREHOLE LOCATION PLAN AND  
SOIL STRATA



KEY PLAN  
1:50,000 m

LEGEND

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

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
LY-1	340.9	5386728.3	245177.1
LY-2	343.1	5386715.7	245177.2
LY-3	343.1	5386718.5	245167.0
LY-4	340.5	5386712.5	245161.3

NOTES

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

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MTO, drawing file no. E7256022, dated JUN 2014, received JAN 27, 2015.

NO.	DATE	BY	REVISION
Geocres No. 52C-44			
HWY. 602	PROJECT No. 1411523		DIST. .
SUBM'D. AC	CHKD. .	DATE: 10/26/2015	SITE: 45-264/C
DRAWN: TB	CHKD. DAM	APPD. JMAC	DWG. 1



PROJECT 1411523			RECORD OF BOREHOLE No LY-1			1 OF 1 METRIC											
G.W.P. 6342-14-00			LOCATION N 5386728.3; E 245177.1			ORIGINATED BY MR											
DIST _____ HWY 602			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY TB											
DATUM GEODETIC			DATE March 15, 2015			CHECKED BY DAM											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) W <sub>p</sub> W W <sub>L</sub>			γ	GR SA SI CL
340.9	GROUND SURFACE							20 40 60 80 100									
0.0	TOPSOIL (75 mm)																
0.1	CLAY, trace to some sand, trace gravel Stiff to very stiff Brown to grey Frozen* to wet  Trace organics in the upper 1.5 m.		1	SS	23*		340										
			2	SS	5												
			3	SS	5		339										
							338										
			4	SS	6												
							337										
			5	SS	6		336										
							335										
			6	SS	7		334										
333.4	END OF BOREHOLE																
7.5	Note: 1. Borehole dry upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/10/15 DATA INPUT:

PROJECT 1411523			RECORD OF BOREHOLE No LY-2			1 OF 1 METRIC															
G.W.P. 6342-14-00			LOCATION N 5386715.7; E 245177.2			ORIGINATED BY DM															
DIST _____ HWY 602			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY TB															
DATUM GEODETIC			DATE February 13, 2015			CHECKED BY DAM															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
343.1	GROUND SURFACE							20 40 60 80 100	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60
0.0	ASPHALT (40 mm)						343														
342.6	Sand and gravel, trace silt (FILL)																				
0.5	Brown Frozen																				
	Sandy silt, trace clay, wood fragments (FILL)		1	SS	95		342														
	Grey Frozen		2	SS	19		341														
340.8	ORGANIC CLAY, some sand																				
2.3	Stiff Black Moist		3	SS	9		340														
			4	SS	8																
339.4	CLAY, some sand, trace gravel																				
3.7	Very stiff Grey Moist		5	SS	8		339														
			6	SS	5		338														
			7	SS	7		337														
			8	SS	5		336														
			9	SS	5		335														
			10	SS	5		334														
			11	SS	8		333														
331.5	END OF BOREHOLE						332														
11.6	Note: 1. Borehole dry upon completion of drilling.																				

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/10/15 DATA INPUT:

[illegible]

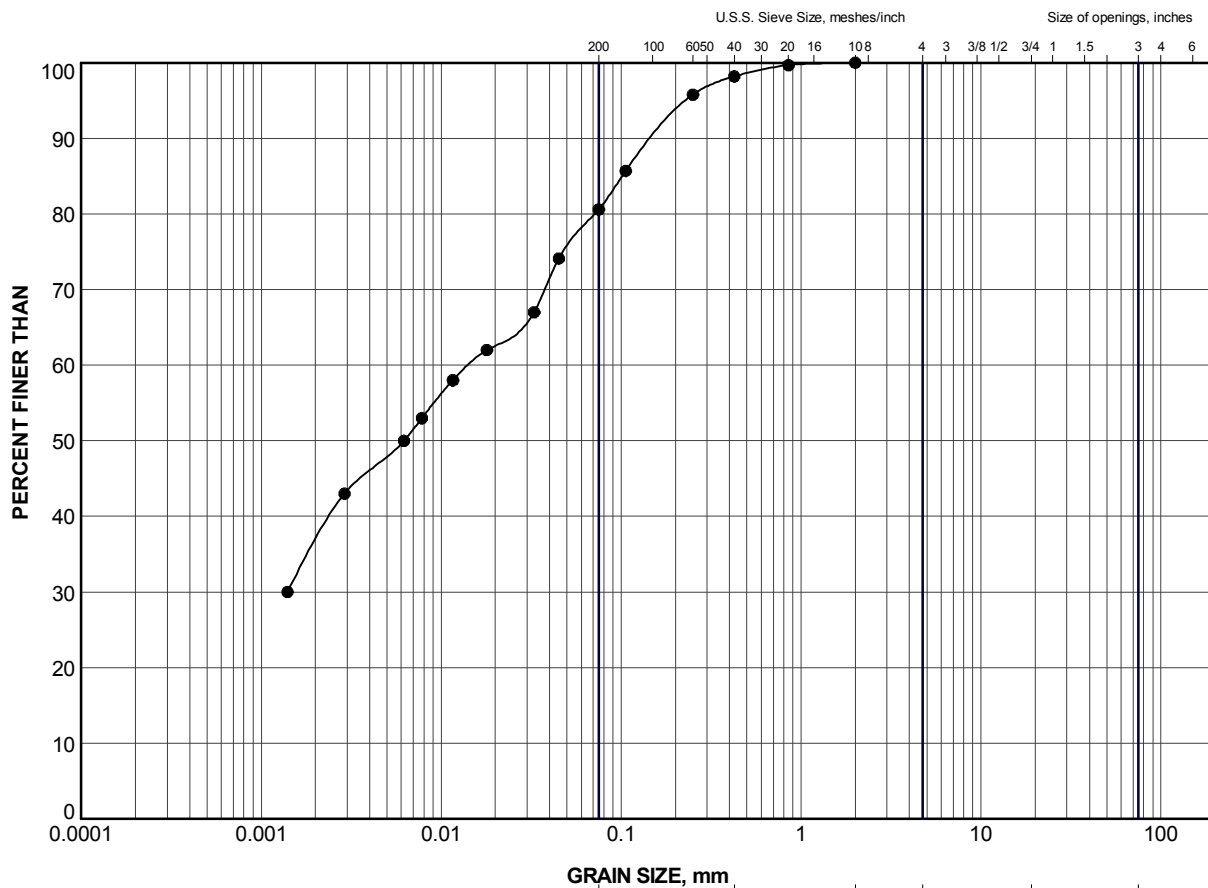
+ 3, × 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE



[illegible]

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






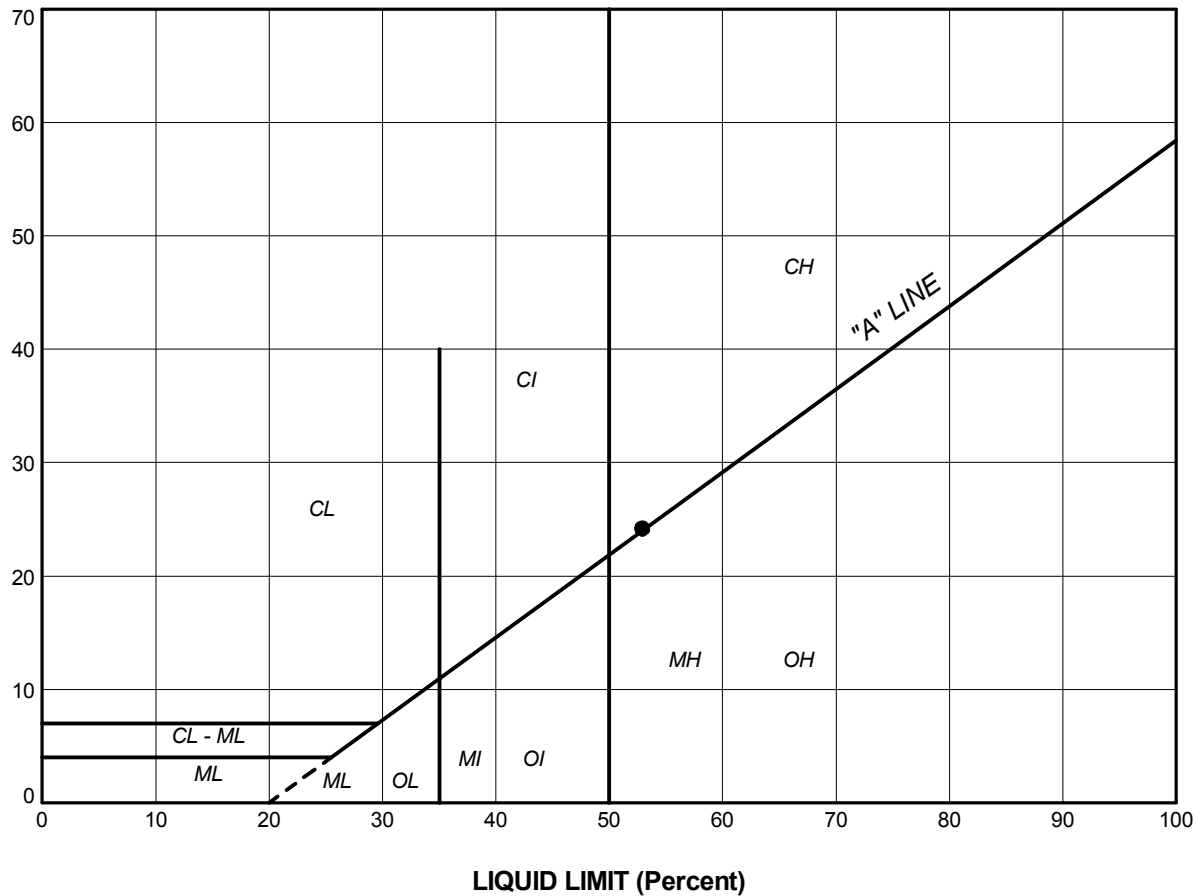
GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	LY-2	3	340.5

PROJECT					HIGHWAY 602 LYON CREEK CULVERT NO. 2 STA 10+035				
TITLE					GRAIN SIZE DISTRIBUTION ORGANIC CLAY				
PROJECT No. 1411523			FILE No. 1411523.GPJ						
DRAWN	TB	May 2015	SCALE	N/A	REV.				
CHECK	DAM	May 2015							
APPR	JMAC	May 2015							
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B2</b>						

PLASTICITY INDEX (Percent)




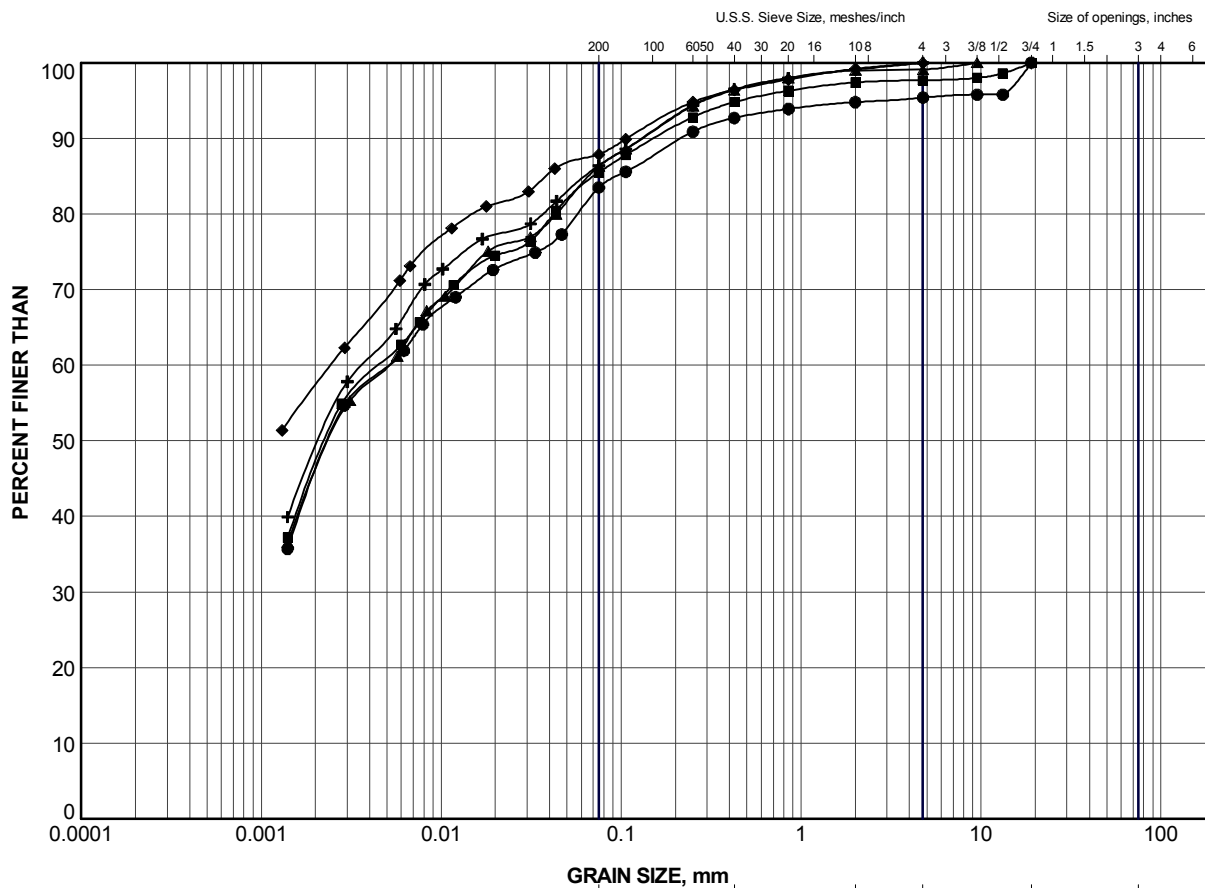
**SOIL TYPE**  
C = Clay  
M = Silt  
O = Organic

**PLASTICITY**  
L = Low  
I = Intermediate  
H = High

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	LY-2	3	52.9	28.7	24.2

PROJECT					
HIGHWAY 602 LYON CREEK CULVERT NO. 2 STA 10+035					
TITLE					
PLASTICITY CHART ORGANIC CLAY					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	TB	May 2015	SCALE	N/A	REV.
CHECK	DAM	May 2015			
APPR	JMAC	May 2015			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B3</b>		



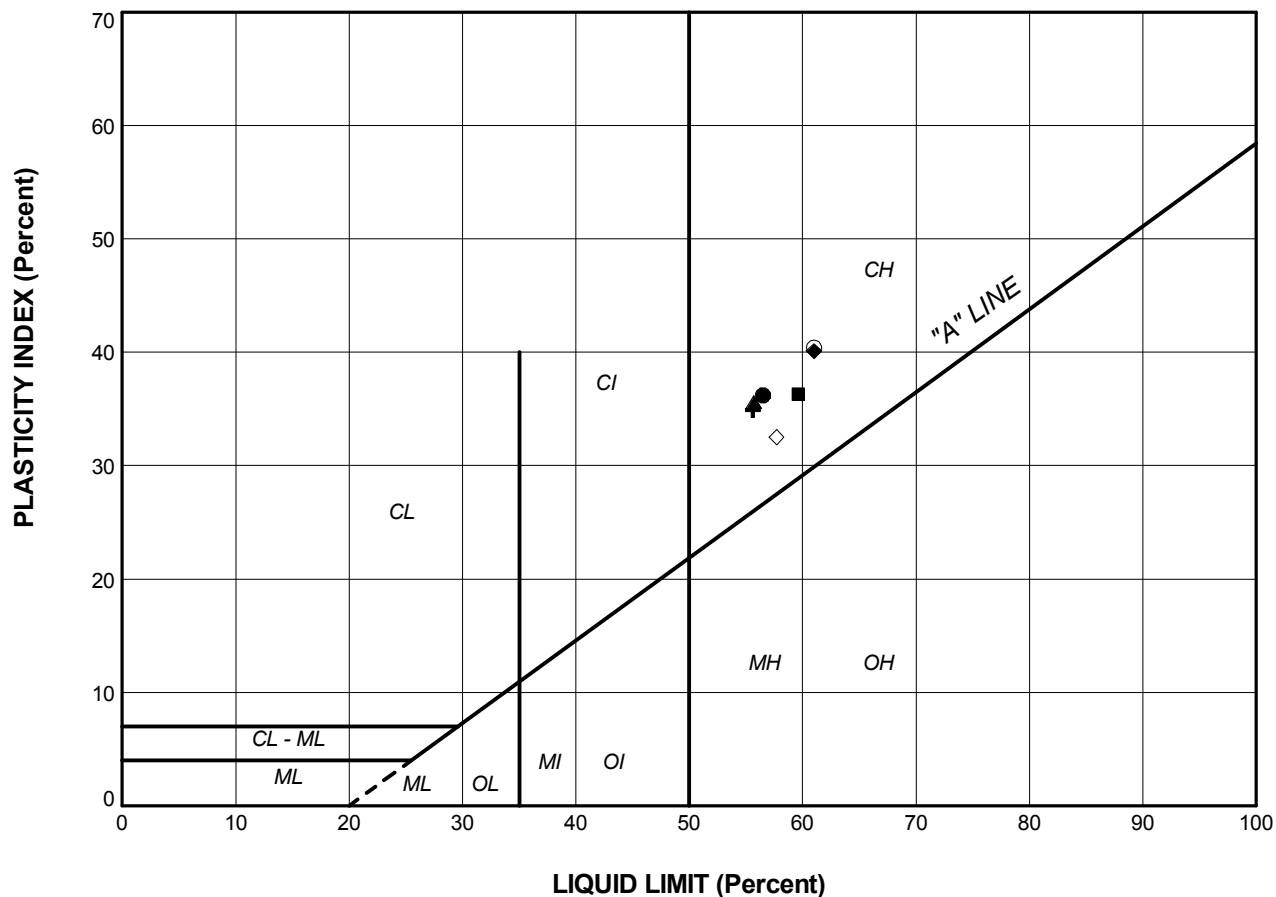
CLAY AND SILT		SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
		fine	medium	coarse	fine	coarse	
		SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	LY-2	5	339.0
■	LY-2	8	336.7
▲	LY-3	6	338.2
+	LY-3	9	335.2
◆	LY-4	5	335.6

PROJECT					
HIGHWAY 602 LYON CREEK CULVERT NO. 2 STA 10+035					
TITLE					
GRAIN SIZE DISTRIBUTION CLAY					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	TB	May 2015	SCALE	N/A	REV.
CHECK	DAM	May 2015			
APPR	JMAC	May 2015			
			<b>FIGURE B4</b>		





PROJECT					
HIGHWAY 602 LYON CREEK CULVERT NO. 2 STA 10+035					
TITLE					
PLASTICITY CHART CLAY					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	TB	May 2015	SCALE	N/A	REV.
CHECK	DAM	May 2015	FIGURE B5		
APPR	JMAC	May 2015			



## **Appendix F**

### **Foundation Comparison**

## COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Ease of construction.</li> <li>ii. Less stringent requirement for soil geotechnical resistances.</li> <li>iii. Segmented pipes can accommodate potential differential settlement along culvert axis</li> <li>iv. Concrete or steel pipes may be more cost effective than concrete box or open footing culverts.</li> </ul>	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used.</li> <li>ii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area.</li> <li>iii. Segmental option can accommodate potential differential settlement along culvert axis.</li> </ul>	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Conventional construction.</li> <li>ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.</li> </ul>
<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Steel pipes may have shorter design life than concrete culverts.</li> <li>ii. Multiple pipes needed to meet hydraulic requirements.</li> <li>iii. Large excavation through approx. 4 m of fill required to install pipe.</li> <li>iv. Relatively high roadway protection system required.</li> </ul>	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. More expensive than a concrete pipe or CSP culvert.</li> <li>ii. Large excavation through approx. 7 m of fill required to install culvert.</li> <li>iii. Relatively high roadway protection system required.</li> </ul>	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Requires deeper excavation and potentially longer dewatering requirements.</li> <li>ii. Cannot tolerate differential settlement.</li> </ul>
<b>FEASIBLE</b>	<b>FEASIBLE</b>	<b>NOT RECOMMENDED</b>



## **Appendix G**

### **List of OPSSs and OPSDs and Suggested Wording for NSSP**

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

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

**2. Suggested Wording for NSSP on Dewatering**

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

**3. Suggested Wording for NSSP on Obstructions**

Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the native till soils, and possibly in the fill. 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.