



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
MILE CREEK CULVERT REPLACEMENT
HIGHWAY 599, SITE No. 48W-191/C
DISTRICT OF KENORA
ONTARIO
G.W.P. No. 6839-14-00
GEOCRES Number: 52J-18**

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Report

to

HATCH Corporation

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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 Mile Creek Culvert on Highway 599, located in the District of Kenora.

The purpose of this investigation was to explore the subsurface conditions at the culvert site 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 Corporation (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0030.

2. SITE DESCRIPTION

The site is located on Highway 599, approximately 36.5 km north of the intersection of Highway 599 and Highway 642 in Silver Dollar, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location and Soil Strata Drawings in Appendix D.

Highway 599 runs in a general east-west direction with the culvert generally perpendicular to the centreline of the highway. The culvert allows Mile Creek to flow in an southerly direction beneath the highway.

The Ontario Structural Inspection Manual (OSIM) prepared by MTO dated November 2, 2015 indicates that the existing structure is a 27 m long, two span open footing, timber structure culvert. Each span is 1.34 m wide. The timber culvert is 1.3 m high. The grade level of Highway 599 at



the existing culvert is at an approximate Elevation of 439.1 m. The height of the existing fill cover is approximately 4.0 m. The culvert invert is at approximately Elevation 434.1 m at the inlet and 433.4 m at the outlet. The upstream and downstream water levels of Mile Creek were measured at Elevation 434.22 m and 433.54 m, respectively, in April 2016, as shown on drawings provided by Hatch.

The lands surrounding the Mile Creek Culvert site predominantly consist of heavily forested areas with occasional marsh lands and lakes. Local topography is described as knobby, hummocky, and ridged and is generally of high relief. Photographs of the culvert and surrounding area are presented in Appendix C.

Based on published geological information, the subsurface soils at the site generally consist of sandy tills of ground moraines overlying shallow bedrock. Bedrock geology maps of the area show the site lies in an area consisting of mafic to intermediate metavolcanics rocks.

3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out between July 10 and July 31, 2017 and consisted of drilling and sampling six (6) boreholes, designated as Boreholes ML17-01 to ML17-06. Boreholes ML17-01 to ML17-04 were drilled along the culvert alignment. Boreholes ML17-01 and ML17-04 were drilled at the inlet and outlet, respectively, and terminated upon refusal at 0.6 m and 7.8 m depth (Elevation 433.8 and 425.8). Due to the site constraints and difficult access to the borehole locations, the drilling operations for Boreholes ML17-01 and ML17-04, were conducted using portable tripod equipment. The tripod equipment allowed us to drill at the proposed borehole location, however it encountered refusal and was not able to advance further. Multiple attempts were made in the area to advance the borehole deeper, but were unsuccessful.

Boreholes ML17-02 and ML17-03 were drilled through the highway embankment. Bedrock was proved by NQ core size diamond in Borehole ML17-02 and was advanced 3.1 m into bedrock and terminated at 10.6 m depth (Elevation 428.3). Borehole ML17-03 was advanced to 9.8 m depth (Elevation 429.4). A Dynamic Cone Penetration Test (DCPT) was carried out in Borehole ML17-03 from 9.8 m (Elevation 429.4) to cone refusal reached at 13.4 m (Elevation 425.8).



Boreholes ML17-05 and ML17-06 were drilled through the paved section of Highway 599, approximately 15.5 m and 17.5 m to the west and east and of the existing culvert, respectively. These boreholes were advanced to assess the subsurface conditions for a temporary modular bridge planned at this site for traffic staging purposes, during replacement of the culvert. Bedrock was proved by NQ size diamond in both boreholes. Boreholes ML17-05 and ML17-06 were advanced 3.4 m and 1.3 m into bedrock and terminated at 10.0 m and 13.7 m depth (Elevations 428.7 and 425.9), respectively.

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

All boreholes within the paved portion of Highway 599 were drilled using a rubber track mounted drill rig equipped with continuous flight hollow and solid stem augers. Boreholes ML17-01 and ML17-04 were drilled using the wash boring method on tripod equipment. NQ coring methods were used to advance three boreholes through bedrock. 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).

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.

All rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined. Photos of the rock cores are included in Appendix B.

Groundwater conditions were observed in the open boreholes throughout the drilling operations and upon completion of drilling. A piezometer was installed in Borehole ML17-03 and a piezometer reading was taken on July 25, 2017. The piezometer was also decommissioned on July 25, 2017. Upon completion of drilling operations, 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	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
ML17-01	0.6 / 433.8	None installed	Borehole backfilled with auger cuttings to surface.
ML17-02	10.6 / 428.3	None installed	Borehole backfilled with bentonite holeplug to 4.0 m, gravel to 0.3 m, cement to 0.2 m, then asphalt cold patch to surface.
ML17-03	13.4 / 425.8	9.1 / 430.1	Screened from 9.8 m to 7.6 m, sand backfill from 9.8 m to 7.0 m, bentonite holeplug from 7.0 m to surface.
ML17-04	7.8 / 425.8	None installed	Borehole backfilled with bentonite holeplug to surface
ML17-05	10.0 / 428.7	None installed	Borehole backfilled with bentonite holeplug and cuttings to 3.1 m, gravel to 0.3 m, cement to 0.2 m, then asphalt cold patch to surface
ML17-06	13.7 / 425.9	None installed	Borehole backfilled with bentonite holeplug to 11.9 m, auger cuttings to 1.3 m, gravel to 0.3 m, cement to 0.2 m, then asphalt cold patch to surface

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). 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.

Point load tests were carried out on selected samples of intact bedrock upon arrival at the laboratory to assist in evaluation of the compressive strength of the bedrock. Results of point load tests on the rock core samples are included in Appendix B and on the Record of Borehole sheets in Appendix A.

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 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 should be used for interpretation of site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered in the boreholes drilled through Highway 599 platform generally consists of embankment fill over layers of native loose to compact sand, sandy silt, silt, sand and silt, and cobbles/boulders underlain by bedrock. The embankment fill consisted of interlayers of silty sand, gravelly sand and rockfill. The thickness of the embankment fill ranged from 5.4 m to 6.7 m. Within the embankment fill, the total rockfill thickness ranged from 2.1 m to 5.1 m. Cobbles and boulders were encountered immediately above the bedrock in Boreholes ML17-02 and ML-06. Descriptions of the individual strata are presented below.

5.1 Topsoil

A 600-mm thick layer of topsoil, containing some sand, was encountered surficially in Borehole ML17-04.

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

5.2 Asphalt

The boreholes that were drilled through the paved portion of Highway 599 encountered approximately 25 mm to 200 mm of asphalt at the ground surface. The ground surface elevation of the boreholes drilled on the highway platform ranged from 438.7 to 439.6.



5.3 Embankment Fill

Roadbed materials consisting of 0.7 m to 0.9 m thick silty sand and gravelly sand with trace to some silt, trace clay, and occasional cobbles, was encountered below the asphalt in all boreholes drilled on Highway 599. Below the roadbed materials, the embankment consists of gravelly sand fill and coarse rock fill. The rock fill was typically 100 mm to 1200 mm in size, with thickness ranging from 0.9 m to 5.1 m. The thickness of the gravelly sand ranged from 0.6 m to 3.7 m. The embankment fill extended to depths ranging from 5.4 m to 6.7 m (Elevations 432.5 to 435.5)

SPT 'N' values in the silty sand fill and gravelly sand fill ranged from 4 to 42 blows for 0.3 m penetration, indicating a loose to dense relative density. An SPT 'N' value of 50 blows per 0.075 m of penetration, indicating a very dense state, was measured in Borehole ML17-03 at the base of the roadbed material. The high blow counts recorded were likely the result of the presence of cobbles and rock fill. Measured moisture contents in the gravelly sand fill ranged from 2 to 11 percent.

The results of grain size distribution analyses conducted on a sample of the gravelly sand fill is presented on the Record of Borehole sheets included in Appendix A and is summarized in the following table. The results are also presented on Figure B1 in Appendix B.

Soil Particle	Sand (percent)
Gravel	23
Sand	71
Silt and Clay	6

5.1 Sand and Gravel

Sand and gravel containing trace silt and occasional organics was contacted surficially in Borehole ML17-01.

Borehole ML17-01 was terminated within the sand and gravel upon auger refusal.

An SPT 'N' value recorded in the sand and gravel was 50 blows for 0.3 m penetration, indicating a very dense relative density. Measured moisture content was 17 percent.



5.2 Sand

A 600-mm thick upper layer of grey sand containing trace silt and trace clay was encountered at 0.6 m (Elevation 433.0) in Borehole ML17-04. Lower layers of grey sand were also encountered at depths of approximately 6.0 m to 10.7 m (Elevations 427.6 and 433.2) in Boreholes ML17-04 and ML17-06. The thickness of the lower layers of sand ranged from 0.6 m to 2.7m.

The depth to the base of the upper sand in Boreholes ML17-04 was at 1.2 m (Elevation 432.4). The depth to the base of the lower sand layers in Borehole ML17-06 were at 9.1 m and 11.3 m (Elevations 430.5 and 428.3).

Borehole ML17-04 was terminated within the lower sand layer at 7.8 m (Elevation 425.8).

SPT 'N' values recorded in the sand ranged from 18 to 64 blows for 0.3 m penetration, indicating a compact to very dense relative density. An SPT 'N' value of 34 blows per 0.15 m of penetration, indicating very dense state, was measured in Borehole ML17-04 near borehole termination depth. Measured moisture contents ranged 10 percent to 19 percent.

The results of grain size distribution analyses conducted on two samples of the sand are presented on the Record of Borehole sheets included in Appendix A and is summarized in the following table. The results are also presented on Figure B2 in Appendix B.

Soil Particle	Sand (percent)
Gravel	0 to 1
Sand	88 to 92
Silt	6
Clay	2
Silt and Clay	11

5.3 Sand and Silt, Sandy Silt and Silt

Layers of sand and silt, sandy silt, and silt, containing trace to some clay and trace gravel, were encountered at depths between 1.2 m and 9.1 m (Elevations 433.2 to 430.5) in Boreholes ML17-03 to ML17-06.



The thickness of the sandy silt, silt and, sand and silt layers, where fully penetrated, ranged between 1.1 m and 4.8 m and extended to depths of between 6.0 m and 10.7 m (Elevations 427.6 to 432.1).

Borehole ML17-03 was terminated within the sand and silt layer at 9.8 m (Elevation 429.4).

SPT 'N' values recorded in the sandy silt, silt and, sand and silt layers ranged from 9 to 42 blows for 0.3 m penetration, indicating a compact to dense relative density. An SPT 'N' value of 1 blow per 0.3 m of penetration, was measured in Borehole ML17-03 below Elevation 430.0, indicating a very loose state. The very loose conditions were noted within approximate Elevation 430.0, and may have been the result of hydraulic ground disturbance during drilling operations. Measured moisture contents in the sandy silt, silt and, sand and silt ranged from 13 percent to 26 percent.

The results of grain size analyses conducted on samples of the silt to sand and silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B3 of Appendix B. The results are summarized as follows:

Soil Particle	Silt to Sand and Silt (Percent)
Gravel	0 to 6
Sand	19 to 35
Silt	57 to 70
Clay	8 to 11

5.4 Cobbles and Boulders

Cobbles and boulders, containing some sand and gravel, were encountered overlying the bedrock at a depth of 5.4 m and 11.3 m (Elevations 433.5 and 428.3) in Boreholes ML17-02 and ML17-06, respectively. The thickness of the cobbles and boulders was 2.1 m and 1.1 m and extended to 7.5 m and 12.4m depth (Elevations 431.4 and 427.2), in Boreholes ML17-02 and ML17-06, respectively.

5.5 Bedrock

The overburden soils described above are underlain by basalt and gabbro bedrock. The bedrock was black to grey with white cemented joints and occasional porphyritic inclusions. Occasional



mechanical breaks were noted throughout the bedrock cores. The bedrock is generally described as highly to slightly weathered. Bedrock was proved by coring in Boreholes ML17-02, ML17-05 and ML17-06. Table 5.1 summarizes depths and elevations to the top of bedrock.

Table 5.1 - Depths and Elevations of Top of Bedrock

Borehole	Top of Bedrock	
	Depth (m)	Elevation (m)
ML17-02	7.5	431.4
ML17-05	6.6	432.1
ML17-06	12.4	427.2

Total Core Recovery (TCR) in the bedrock ranged from 77% to 100% with Solid Core Recovery (SCR) ranging from 43% to 100%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 43% to 100%, indicating poor to excellent rock quality.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 1 to greater than 10.

Average unconfined compressive strengths (UCS) of the rock ranged between 79 MPa to greater than 250 MPa, indicating the rock is strong to extremely strong. The UCS was 45 MPa and 47 MPa in two rock cores, indicating the rock is medium strong. These estimated rock strength values are interpreted from point load tests that were conducted on rock cores recovered from the boreholes. A summary of the Point Load Test Results and photographs of bedrock cores are presented in Appendix B.

5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. A piezometer was also installed in Borehole ML17-03. The piezometer was decommissioned upon taking a water level measurement on July 25, 2017.

The groundwater levels measured in the open boreholes and the piezometer are summarized in Table 5.2 below.



Table 5.2 - Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
ML17-01	July 10, 2017	Dry	-	Open borehole
ML17-02	July 28, 2017	5.1	433.8	Open borehole
ML17-03	July 25, 2017	4.8	434.4	Piezometer
ML17-04	July 10, 2017	0.9	432.7	Open borehole
ML17-05	July 31, 2017	5.4	433.3	Open borehole
ML17-06	July 29, 2017	5.4	434.2	Open borehole

The upstream and downstream water levels of Mile Creek were measured at Elevation 434.22 m and 433.54 m, respectively, in April 2016, as shown on drawings provided by Hatch. The groundwater level should be assumed to reflect the local creek water level.

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

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the gravelly sand from Borehole ML17-03, and a sample of the creek water, taken from the inlet area, were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1 below. The laboratory certificates of analysis are presented in Appendix B.



Table 6.1 - Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results	
			ML17-03 SS 3 Depth 2.4 m	Mile Creek
			(Soil Sample)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	2.4	2.7
Sulphate	µg/g	mg/L	10	0.8
pH	No unit	No unit	8.27	7.62
Electrical Conductivity	µS/cm	µS/cm	35	63
Resistivity	Ohms.cm	Ohms.cm	28700	15800
Redox Potential	mV	mV	303	352

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 either Mr. Ryan McCourt or Stephen Hillier of Thurber. Overall supervision of the field program was provided by Mr. Cory Zanatta, EIT 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, The report was reviewed by Mr. Jason Lee, 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 design of the proposed Mile Creek Culvert replacement located on Highway 599, approximately 36.5 km north of the intersection of Highway 599 and Highway 642 in Silver Dollar, 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 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 information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference and the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO dated November 2, 2015. The existing structure is a two-span open footing timber culvert. The culvert is approximately 2.6 m wide and 27 m long. The estimated culvert invert is at approximately Elevations 434.1 and 433.4, at the inlet and outlet, respectively. The existing road grade at the culvert location is at about Elevation 439.1 m, which indicates approximately 4.0 m of fill above the top of the culvert. The height of the highway embankment is up to 6.4 m.



General Arrangement Drawings and discussions with Hatch/MTO, indicate that two replacement options are being considered:

1. Single CSP Culvert

A circular CSP is being considered to provide increased hydraulic opening. The CSP is approximately 4.3-m in diameter. The proposed founding level (base of culvert bedding) of the new pipe is approximately at Elevations 432.5 and 431.8. The CSP culvert is approximately 29.0 m long.

2. Single Span Precast Concrete Box Culvert

A single cell precast concrete box culvert is an option for this site. Information provided by Hatch indicates that a 4.0 m x 1.8 m box culvert is being considered. Proposed inlet and outlet founding levels (base of culvert bedding) of the culvert are at Elevations 432.8 at the inlet and 432.1 at the outlet, respectively. The length of the proposed culvert is 28.9 m.

The alignment of the replacement culvert will remain largely the same as for the existing culvert. Grade raise or embankment widening is not anticipated at the culvert location.

The culvert replacement is proposed to be constructed utilizing a traffic staging, which would require installation of a temporary modular bridge.

For CSP culvert and box culvert options, a temporary stream diversion pipe (CSP) is planned during construction, approximately 6.6 m south of the existing culvert centreline with an invert level at approximate elevations 433.0 to 433.5.

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.

9. CULVERT DESIGN

9.1 Culvert Replacement Options

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 Pipe, Structural Plate Corrugated Steel Pipe (SPCSP), or Helical Corrugated Structural Pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete open frame culvert on spread footings
- Precast Concrete Slabs Supported on Sheet Pile Abutments (Sheet pile culvert)

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

- Precast 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;

A sheet pile system culvert is not recommended at this site due to the presence of rock fill in the embankment, which will impede the installation of sheet piles. Recommendations for sheet piles as a culvert replacement are not presented in the report.

An open footing culvert is not recommended at this site since it would require deeper excavation and more dewatering effort. Hence, recommendations for this option have not been developed.

Recommendations for the design and installation of concrete pipe or SPCSP and concrete box culverts are presented below.

9.2 Foundation Design for Culverts

In general, the subsurface conditions encountered in the boreholes drilled through Highway 599 platform generally consists of embankment fill over layers of native loose to compact sand, sandy silt, silt, sand and silt, and cobbles/boulders underlain by bedrock. The embankment fill consisted



of layers of silty sand, gravelly sand and rockfill. The thickness of the embankment fill ranged from 5.4 m to 6.7 m. Within the embankment fill, the rockfill thickness ranged from 0.9 m to 5.1 m thick. Cobbles and boulders were encountered immediately above the bedrock in one borehole.

The founding soils encountered at the proposed founding elevations 432.8 to 431.8 (base of bedding), generally consist of cobbles and boulders and compact sand and silt to sandy silt. Auger refusal was encountered at the inlet area at Elevation 433.8, therefore founding strata consists of either rockfill or bedrock.

Foundation design aspects for the replacement culvert include 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 a CSP on the same alignment as the existing culvert may be considered for this site. Since there is no grade raise or embankment widening, settlement of the underlying soils is expected to be negligible.

If this alternative is selected, 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. The underside of the bedding layer should be placed at or below Elevations 432.5 to 431.8. At this level, it is anticipated that subgrade condition varies along the culvert alignment, from probable bedrock or rockfill (at the inlet zone) to cobbles and boulders, compact sand and silt, and sandy silt.

Placement of a CSP culvert at the anticipated level is considered feasible, however it is recommended that the subgrade be prepared to reduce the potential for non-uniform and abrupt settlement (i.e. hard point effect) between possible bedrock and soils. It is recommended that a transition zone (wedge) be constructed between these variable founding materials at this site:

- The transition zone (wedge) must be constructed between the bedrock/rockfill and native cohesionless soils beneath the north half of culvert.
- Based on available information, sub-excavation into possible rockfill/bedrock should be expected between Borehole ML17-01 and ML17-02, from Elevation 432.5 to Elevation 431.4 (top of bedrock).



- The excavation within the transition zone between the bedrock/rock fill and native soils, should be conducted with a downward 11H:1V slope over approximately 11.0 m from the inlet end towards south along the culvert alignment until bedrock is encountered, then proceed with an upward 5H:1V slope over approximately 6.0 m to reach the bedding base elevation.
- This zone (wedge) should be backfilled with rock fill to within 300 mm below the culvert base (Elevations 432.8 to 432.5, which correspond to the base of the culvert bedding). The rockfill should be placed in accordance with OPSS.PROV 206 and the NSSP for rock fill provided in Appendix F.
- The surface of the rockfill should be chinked with rock fragments and spall. The chinked surface should then be covered with a 300-mm thick layer of granular bedding material in order to provide a uniform foundation subgrade.

Any organics, topsoil, soft, loose or deleterious material encountered at and below the culvert subgrade, must be removed and replaced by compacted granular fill up to the underside of the bedding material, as described in Section 11.1. Culvert subgrade preparation and placement and compaction of the granular fill must be carried out in the dry. Geotextile should be placed between the founding soils and the granular layer of bedding material. Adequate preparation of the subgrade will be essential for performance of the culvert.

Bedrock or rockfill excavation will be required to achieve the design invert level. At the inlet area, refusal was encountered at 0.6 m (Elevation 433.8), therefore subexcavation of approximately 1.0 m or more into rock fill or possible bedrock will be required to reach the founding elevations. The contract must contain a line item for rock excavation. The rock removal/excavation procedures should be the responsibility of the Contractor. However, it is important that his procedures incorporate methods of reducing damage to the founding surfaces. Blasting methods must be avoided at this site. Suggesting wording for an NSSP in this regard is included in Appendix F.

Depending on final design culvert invert grades there may be a need to excavate bedrock at the culvert inlet. It is recommended that additional investigation, including rock coring, be conducted during detailed design in order to confirm the bedrock, particularly at the inlet. This additional investigation will be required to situate the culvert in a location which minimizes the chance of encountering bedrock.



9.2.2 Precast Concrete Box Culvert

Replacement of the culvert with precast concrete box culvert on the same alignment is considered a viable alternative for this site. Since there is no grade raise or embankment widening, settlement of the underlying soils is expected to be negligible.

Based on available information, it is anticipated that the proposed inlet and outlet founding levels (base of the culvert bedding) of the culvert are at Elevations 432.8 and 432.1, respectively. At this level, it is anticipated that subgrade condition varies along the culvert alignment, from probable bedrock or rockfill (at the inlet zone) to cobbles and boulders, compact sand and silt, and sandy silt.

Placement of a box culvert at the anticipated level is considered feasible, however it is recommended that the subgrade be prepared to reduce the potential for non-uniform and abrupt settlement (i.e. hard point effect) between possible bedrock and soils. It is recommended that a transition zone (wedge) be constructed between these variable founding materials at this site:

- The transition zone (wedge) must be constructed between the bedrock/rockfill and native cohesionless soils beneath the north half of culvert.
- Based on available information, sub-excavation into possible rockfill/bedrock should be expected between Borehole ML17-01 (inlet) and ML17-02, from Elevation 432.8 to Elevation 431.4 (top of bedrock).
- The excavation within the transition zone between the bedrock/rock fill and native soils, should be conducted with a downward 11H:1V slope over approximately 11.0 m from the inlet end towards south along the culvert alignment until bedrock is encountered, then proceed with an upward 5H:1V slope over approximately 6.0 m to reach the bedding base elevation.
- This zone (wedge) should be backfilled with rock fill to within 300 mm below the culvert base (Elevations 432.8 to 432.1, which correspond to the base of the culvert bedding). The rockfill should be placed in accordance with OPSS.PROV 206 and the NSSP for rock fill provided in Appendix F.
- The surface of the rockfill should be chinked with rock fragments and spall. The chinked surface should then be covered with a 300-mm thick layer of granular bedding material in order to provide a uniform foundation subgrade.



The bedding material should conform to OPSS PROV 1010 Granular A or Granular B Type II requirements. It 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. Geotextile should be placed between the founding soils and the granular layer of bedding material. Subgrade preparation should also be conducted as indicated in Section 11.1.

The following geotechnical capacities could be used for design of a box culvert founded at or below Elevations 432.8 to 432.1 m on the native cobbles and boulders, compact sand and silt, and sandy silt:

- Factored Geotechnical Resistance at ULS of 225 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 165 kPa.

The above values of the geotechnical resistance and reaction were based on a box culvert width of 4.0 m.

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 Canadian Highway and Bridge Design Code (CHBDC) 2014, Sec. 6.9.

The ULS resistance and settlement are dependent on the 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 should be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

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



Bedrock or rock fill excavation will be required to achieve the design invert level. Consideration should be given to raise the invert level to minimize bedrock/rock fill excavation. At the inlet area, refusal was encountered at 0.6 m (Elevation 433.8), therefore subexcavation of approximately 1.0 m or more into rock fill or possible bedrock will be required to reach the founding elevations. The contract must contain a line item for rock excavation. The rock removal/excavation procedures should be the responsibility of the Contractor. However, it is important that his procedures incorporate methods of reducing damage to the founding surfaces. Blasting methods must be avoided at this site. Suggesting wording for an NSSP in this regard is included in Appendix F.

Depending on final design culvert invert grades there may be a need to excavate bedrock at the culvert inlet. It is recommended that additional investigation, including rock coring, be conducted during detailed design in order to confirm the bedrock, particularly at the inlet. This additional investigation will be required to situate the culvert in a location which minimizes the chance of encountering bedrock.

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 Culvert Headwall / Wingwalls

If headwalls or wingwalls are required, consideration may be given to the use of Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are relatively somewhat tolerant to limited differential settlement.

The borehole information indicates that the founding soils generally consist of compact sandy silt at the outlet area and below the southern half of the embankment, and possible rock fill or bedrock at the inlet area and below the northern half of the embankment.

9.2.3.1 RSS Walls

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

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



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

If topsoil/organics are encountered along the alignment of the RSS wall, they must be removed down to native sand/silt. The RSS mass should then be founded on a 0.5 m thick engineered fill pad resting on the native compact sandy silt, possible rockfill or bedrock at or below approximate Elevation 432.5. An RSS wall founded on this subgrade material may be designed using a factored geotechnical resistance at ULS of 250 kPa and a geotechnical reaction at SLS of 175 kPa (up to 25 mm of settlement). The engineered fill pad placed under the RSS mass must consist of OPSS.PROV 1010 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.

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 granular material behind the wall subject to fluctuating water level. Since the RSS wall will be constructed adjacent to a lake/water course, the wall may be subjected to flooding. The RSS supplier should be made aware that for submerged conditions the RSS strips may need to be longer than the usual 70% of fill height and the strips must be corrosion resistant.

Adequate scour and erosion protection must be provided for the bases of the RSS walls so that they are not undermined by water course flow.



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

Lateral earth pressures acting on the wingwalls should be computed as described in Section 10. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

Global stability of the RSS walls should be assessed once the detailed configurations of the walls are known.

9.2.3.2 Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on native compact sandy silt and possible rockfill or bedrock subgrade. All topsoil, organics or soft soils encountered along the alignment of the walls must be removed. The walls should be provided with a sufficient frost cover (minimum 2.5 m at this site) and founded at or below approximate Elevation 432.5. A factored geotechnical resistance at ULS of 250 kPa and a geotechnical reaction at SLS of 175 kPa (up to 25 mm of settlement) may be used for design. A minimum 300 mm thick granular levelling pad should be provided below the wall footing. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to sliding between precast concrete and the underlying sand, and sand and gravel should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.45.

Lateral earth pressures acting on the wingwalls should be computed as described in Section 10. If the wall is retaining sloping backfill, appropriate earth pressure parameters for sloping backfill should be used.

Adequate erosion protection must be provided for the bases of the retaining walls so that they are not undermined by water course flow.



9.3 Settlement

Grade raise or embankment widening is not planned for the culvert replacement at this site. Therefore, settlement is expected to be negligible.

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 of the loose cohesionless soils at this site.

9.4 Frost Cover

The depth of frost penetration at this site is approximately 2.5 m, as per OPSD 3090.100. The base of any retaining wall footings, if employed, should be provided with a minimum of 2.5 m of earth cover as protection against frost action. The pipe and box culvert foundations do not require frost cover/protection.

10. MODULAR BRIDGE

A temporary modular bridge is proposed at this site during replacement of the culvert for traffic staging purpose.

The modular bridge can be supported on spread footings founded on the rock fill. Frost action within the rock fill is not expected to be an issue and the footings can be founded within the rock fill at a level which is convenient to the design, typically 1.0 m to 1.5 m below ground surface (i.e. top of pavement).

The recommended geotechnical resistances at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS) for spread footings founded on the rock fill, are given below:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 200 kPa

Resistance to lateral forces / sliding resistance between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an ultimate coefficient of friction of 0.55.



Rock fill excavation will be required to achieve the design founding level of the modular bridge. Suggesting wording for an NSSP in this regard is included in Appendix F.

To provide a competent founding surface for the modular bridge footings, it is recommended that the excavation be extended to 1.0 m below the founding level, then the rock fill be chinked and the excavation be backfilled with compacted Granular A or Granular B Type II material to the founding level.

The set-back distance from the crest of the excavation to the footing, should not be less than 2.0 m. Forward slope of the excavation for the culvert construction should not be steeper than 2H : 1V.

11. LATERAL EARTH PRESSURES

A triangular distribution of lateral earth pressures acting on the culvert walls may be assumed for design. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally given by the expression:

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

where	p_h	=	horizontal pressure on the wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	γ	=	unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 11.1 below.



Table 11.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ; \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ; \gamma = 21.2 \text{ kN/m}^3$		Rock Fill (Limited to 300 mm size) $\phi = 42^\circ, \gamma = 19 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.2	0.28
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.33	0.55
Passive	3.7	-	3.3	-	5.0	-

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

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

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

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added.

12. CULVERT CONSTRUCTION CONSIDERATIONS

It is understood that construction staging will be required to replace the existing culvert at this site.

Staged construction sequencing will likely require the following:

- Construction of temporary modular bridge for staging.
- Embankment excavation for diversion of the creek (i.e. installation of temporary diversion pipe). In addition, a suitable dewatering plan will be required to construct the culvert in the dry.
- Excavation and removal of the existing culvert, installation of the new culverts and backfilling.
- All culvert and headwall subgrade preparation and foundation preparation must be carried out in the dry.



12.1 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. Any fill, topsoil, creek bed 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.

The subgrade must be prepared to reduce the potential for non-uniform and abrupt settlement between possible bedrock and soils. A transition zone must be constructed between these variable founding materials as indicated in Sections 9.2.1 and 9.2.2. of this report.

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.

If the culvert will be constructed in wet condition, the bedding material may consist of a minimum 300 mm thick 19 mm clear stone conforming to OPSS.PROV. 1004. Geotextile should be placed between the founding soils and the granular layer of bedding material for separation purpose.

Construction equipment should not be allowed to travel on the prepared subgrade, which has to be protected from disturbance during construction.

12.2 Culvert Bedding and Backfill

A minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the CSP or box culvert and compacted in accordance with OPSS 501 in the dry. The culvert subgrade preparation, placement and compaction of granular bedding should be carried out in the dry. However, if the dewatering efforts are not fully effective and if the culvert is to be constructed in the remaining wet condition, coarse 53 mm clear stone wrapped in geotextile should be used as backfill in the



wet below the culvert. Once the clear stone backfill is above the water level, granular bedding for the culvert may then be placed and compacted in the dry. The clear stone backfill may be fully enclosed in geotextile. Geotextile should be placed between the founding soils and the granular layer of bedding material for separation purpose.

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 802.014, and as per the requirements of the CHBDC.

Backfilling for the culvert should be in accordance with OPSS 501, OPSS 902, and as per the CHBDC requirements. 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.

12.3 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 (silty sand, gravelly sand and rock fill) and native sand and silt, sandy silt, silt and cobbles and boulders at this site are classified as Type 3. Surficial alluvial deposits and alluvium/muskeg/organics encountered, should be classified as Type 4 soils.

Excavation 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 native sand and silt, sandy silt, silt and cobbles and boulders. It is anticipated that at the inlet area, the excavation will encounter rock fill or bedrock. Due to the relatively shallow depth of rock fill/bedrock, it is recommended that rock fill or bedrock excavation be carried out using pneumatic breakers, or other methods that will avoid shattering and disturbing the bedrock. Blasting must be avoided at this site. The rock fill or bedrock removal procedures should be the responsibility of the Contractor. However, it is important that his procedures incorporate methods of reducing damage to the founding surfaces.

Excavation for culvert replacement will be carried out below water level indicated at Elevations 433.5 and 434.2 shown in a drawing provided by Hatch. Groundwater level was measured at



Elevation 434.4 in the piezometer installed in Borehole ML17-03. In order to construct a pipe or a box culvert in the dry, diversion of the lake/creek flow will be required. Given the relatively high permeability of the embankment fill materials, water inflow/seepage into the excavation should be anticipated from the embankment fill. A combination of cofferdam enclosures and lake/creek/water course diversion along with the use of sumps/pumps within an enclosure will be required to maintain dry excavations during the course of staged construction. Use of a sheet pile cofferdam at the outlet and use of sand bags are feasible options for this site. It may not be possible to drive sheet piles at the inlet, where refusal was encountered at shallow depth, 0.6 m, in Borehole ML17-01. The dewatering scheme must be effective to lower the groundwater level to at least 0.5 m below the final subgrade level to avoid base boiling in the native soils.

Installation of a temporary cofferdam is planned at the inlet and outlet of the culvert. Boreholes were not drilled at the proposed cofferdam location, and the closest boreholes to the cofferdam locations are Boreholes ML17-01 and ML17-04. Record of Boreholes Sheets of these boreholes are included in Appendix B.

Dewatering of all excavations should be carried out in accordance with OPSS. PROV 517, SP 517F01 Amendment to OPSS 517, November 216 (issued July 2017), and OPSS. PROV 902.

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

13. STREAM DIVERSION PIPE

A stream diversion pipe consisting of a CSP may be used to facilitate construction of the CSP culvert or concrete box culvert replacement options, as indicated on the Preliminary General Arrangement drawings provided by Hatch. The diversion pipe is shown to be located approximately 6.6 m to the west of the centreline of the existing culvert with the invert at approximate Elevations 433.0 to 433.5 m. Below the invert level, the subgrade consists of cobbles and boulders, rock fill and silt, as documented in Boreholes ML17-02 and ML17-05. The base of the diversion pipe should be kept above the bedrock surface noted at Elevation 431.4 in Borehole ML17-02.

Any organics, loose, soft or deleterious material should be excavated and then be replaced with a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A



or Granular B Type II, or clear stone if wet. 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.

The stream diversion pipe could be installed within the temporary open cut excavations, or alternatively within a shored trench.

14. TEMPORARY PROTECTION SYSTEM

It is our understanding that a temporary modular bridge is proposed at this site during replacement of the culvert for traffic staging purpose.

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

The soil parameters in Table 14.1 may be used for design of the temporary roadway protection system with horizontal backfill. The embankment contains rockfill. Accordingly, driving sheet piles for roadway protection will likely not be possible. Soldier piles drilled in through the rockfill may be required for roadway protection.

Full hydrostatic pressure should be considered assuming a water level equal to the design high water level in the river.

Table 14.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Rockfill	Existing Silty Sand Fill	Native Silt to Sand
Angle of Internal Friction (ϕ)	42°	30°	30°
Bulk Unit Weight (γ)	21 kN/m ³	20 kN/m ³	20 kN/m ³
Submerged Unit Weight (γ_w)	11 kN/m ³	10 kN/m ³	10 kN/m ³
Coefficient of Active Earth Pressure (K_a)	0.2	0.33	0.33
Coefficient of Passive Earth Pressure (K_p)	5.0	3.0	3.0



Given the presence of the sensitive sand/silt deposits vibratory methods must not be used at this site to install or extract the sheet piles and H-piles (if used). A NSSP to this effect is provided in Appendix F.

The design of the 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

It is anticipated that there will not be grade raise or embankment widening at this site for the culvert replacement.

Settlement of the embankment is expected to be negligible under the existing culvert footprint of the culvert embankment.

Provided that the embankment is reconstructed with side slopes inclined at not steeper than 2H:1V, the restored embankment slopes should remain stable.

Embankment widening and 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. Where new embankment fill is placed against existing embankment slopes or on sloping ground surface steeper than 3H : 1V, the existing fill slope must be benched in accordance with OPSD 208.010.

In general, surface vegetation, alluvium/muskeg/organics, 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 must be conducted at this site.

16. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the average soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site include very loose to compact granular fill underlain by layers of native cohesionless soils



consisting compact to loose sand, sandy silt, gravelly sand and, sand and gravel. This would correspond 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% in 50 year probability of exceedance at this site is 0.054 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 16.1 may be used:

Table 16.1 – 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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 30^\circ, \gamma = 20 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33	0.36
At Rest (K_{OE})**	0.50	0.54	0.57

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

** After Woods

The site is underlain by layers of loose to compact sandy silt, sand and gravel, sand, sandy silt, cobbles and boulders, and bedrock. In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

However, localized liquefaction during a seismic event may result in local toe failure or minor embankment settlement, but this is expected to be readily repairable.

17. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures considering hydrologic and hydraulic factors should be carried out by specialists experienced in this field and in accordance with OPSD 810.010, OPSS 511 and OPSS PROV 1004.

Typically, rock protection will be required 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.

RSS walls and concrete headwalls must be protected for scour and erosion.



A concrete cut-off wall or a clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should be provided at the inlet and should extend 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.

18. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The potential for 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 selection of class of concrete should consider the effects of the road de-icing salts.
- The potential for soil or surface water corrosion on metal is considered to be very mild to mild.
- Appropriate protection measures commensurate with the above are recommended if metal structural elements are used. The effects of road de-icing salts should be also considered.

19. CONSTRUCTION CONCERNS

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

- Rock fill and possible bedrock excavation is required at this site. The Contractor's selection of rock excavation equipment should include assessment of the bedrock strength.
- An effective 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.
- 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 (e.g., 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.



- Boreholes ML17-01 (adjacent to the culvert inlet) was terminated at 0.6 m depth. Placement of the replacement structure and/or diversion pipe below Elevation 433.8 m may encounter probable bedrock or rock fill. Bedrock or rock fill excavation will be required. Additional investigation is recommended during the detailed design stage to confirm the bedrock surface profile along the culvert, retaining wall and diversion pipe alignments to situate them in locations which minimize the chance of encountering bedrock.
- Rock fill was encountered in the embankment fill; therefore, rock pieces or cobbles and boulders should be anticipated and dealt with during construction. These materials may interfere with the excavation. The Contractor must be prepared to remove or otherwise penetrate these obstructions. Suggested wording for an NSSP on obstructions is included in Appendix F.

20. DETAILED DESIGN INVESTIGATION

For detailed design of the culvert, the following additional investigation is recommended:

- An additional deeper borehole is recommended near the inlet of the proposed culvert. Borehole ML17-01, which was advanced with a tri-pod, encountered refusal on probable bedrock or rockfill at a depth of 0.6 m below the ground surface. It is recommended that a borehole be drilled using equipment that is capable of coring rock in order to confirm the depth to the bedrock surface at this location.

21. CLOSURE

Engineering analysis and preparation of this report was carried out by Ms. R. Palomeque Reyna, P.Eng., and Mr. Jason Lee, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Thurber Engineering Ltd.



Rocío Palomeque Reyna, P.Eng.
Geotechnical Engineer



Jason Lee, P.Eng.
Principal/Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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


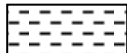



 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS


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

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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

RECORD OF BOREHOLE No ML17-01 1 OF 1 METRIC

GWP# 6839-14-00 LOCATION Mile Creek Culvert, MTM NAD 83 Zone 15 N 5 546 410.5 E 237 267.6 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2017.07.10 - 2017.07.10 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
434.4	GROUND SURFACE							20	40	60	80	100						
0.0	SAND and GRAVEL , trace silt, occasional organics		1	SS	50		434											
433.8	Very Dense																	
0.6	Brown Moist																	
	END OF BOREHOLE AT 0.6m UPON AUGER REFUSAL. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.																	

METRIC

+³, ×³: Numbers refer to Sensitivity

METRIC

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa						WATER CONTENT (%)					
						○ UNCONFINED + FIELD VANE											
						● QUICK TRIAXIAL × LAB VANE											
						20	40	60	80	100	20	40	60	kN/m³			
	Continued From Previous Page																
428.3	BEDROCK (BASALT) slightly weathered, grey to black and white bands, occasional mechanical breaks														2		
10.6	END OF BOREHOLE AT 10.6m. WATER LEVEL AT 5.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 4.0m, GRAVEL TO 0.3m, CEMENT TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.														3		

RECORD OF BOREHOLE No ML17-03

1 OF 2

METRIC

GWP# 6839-14-00 LOCATION Mile Creek Culvert, MTM NAD 83 Zone 15 N 5 546 401.1 E 237 283.1 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Wash Boring/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2017.07.25 - 2017.07.25 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
439.2	GROUND SURFACE							20	40	60	80	100		
0.8	ASPHALT: (30mm)													
	Gravelly SAND , trace silt Very Dense Brown (FILL)		1	GS			439						○	
438.3			2	SS	50/ 0.075									
0.9	ROCKFILL: (size ranging from 100mm to 1200mm) Advanced by coring						438						○	
437.1														
2.1	Gravelly SAND , with cobbles, trace silt and clay Loose to Compact Brown Moist (FILL)		3	SS	4		437						○	
			4	SS	11		436							
							435							
			5	SS	14		434						○	
433.4														
5.8	ROCKFILL: (size ranging from 100mm to 1200mm) Advanced by coring		1	RUN			433						○	
432.5														
6.7	SAND and SILT , trace clay, occasional organics Compact to Very Loose Grey Wet		6	SS	23		432						○	
							431							
							430						○	
429.4	Low SPT "N" values due to hydraulic ground disturbance at approx. elevation 430.0m		7	SS	1									
9.8	End of sampling and start DCPT													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No ML17-03

2 OF 2

METRIC

GWP# 6839-14-00 LOCATION Mile Creek Culvert, MTM NAD 83 Zone 15 N 5 546 401.1 E 237 283.1 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Wash Boring/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2017.07.25 - 2017.07.25 CHECKED BY RPR

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)	W _p	W	W _L		
	Continued From Previous Page						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60						
425.8														
13.4	END OF BOREHOLE AT 13.4m UPON DCPT REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.07.25 4.8 434.4													

RECORD OF BOREHOLE No ML17-04

1 OF 1

METRIC

GWP# 6839-14-00 LOCATION Mile Creek Culvert, MTM NAD 83 Zone 15 N 5 546 385.1 E 237 289.1 ORIGINATED BY STH
 HWY 599 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.10 - 2017.07.10 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
433.6	GROUND SURFACE							20 40 60 80 100							
0.0	TOPSOIL , some sand, occasional organics Very Loose Brown Moist		1	SS	1		433								
433.0															
0.6	SAND , trace silt and clay Compact Grey Wet		2	SS	22										0 92 6 2
432.4															
1.2	Sandy SILT , trace clay Compact to Loose Grey Wet		3	SS	21										
			4	SS	22										0 21 70 9
			5	SS	9										
							430								
			6	SS	10		429								
							428								
427.6															
6.0	SAND , trace to some silt Dense to Very Dense Grey Wet		7	SS	30		427								
425.8			8	SS	34/		426								
7.8	END OF BOREHOLE AT 7.8m UPON AUGER REFUSAL. WATER LEVEL AT 0.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.				0.150										

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RECORD OF BOREHOLE No ML17-05

1 OF 2

METRIC

GWP# 6839-14-00 LOCATION Mile Creek Culvert, MTM NAD 83 Zone 15 N 5 546 384.9 E 237 270.1 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.31 - 2017.07.31 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
438.7	GROUND SURFACE													
0.0	ASPHALT: (200mm)													
0.1	Gravelly SAND, trace silt Dense Brown Moist (FILL)		1	GS										
437.8			2	SS	41									
0.9	ROCKFILL:(size ranging from 100mm to 1200mm) Advanced by coring													
433.2														
5.5	SILT, some sand and clay, trace gravel Dense Grey Wet		3	SS	42									6 19 64 11
	Coring bedrock started at 6.6m													
432.1														
6.6	BEDROCK (BASALT) slightly weathered, grey, occasional mechanical breaks		1	RUN										RUN #1 TCR=100% SCR=83% RQD=78% UCS=220MPa (Average)
			2	RUN										RUN #2 TCR=100% SCR=93% RQD=75% UCS=173MPa (Average)
			3	RUN										RUN #3 TCR=100% SCR=100% RQD=88% UCS=79MPa (Average)
428.7														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

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METRIC

[illegible]

RECORD OF BOREHOLE No ML17-06

1 OF 2

METRIC

GWP# 6839-14-00 LOCATION Mile Creek Culvert, MTM NAD 83 Zone 15 N 5 546 413.7 E 237 287.1 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.29 - 2017.07.29 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL
439.6	GROUND SURFACE							20	40	60	80	100							
0.8	ASPHALT: (25mm)		1	GS			439												
438.9	Gravelly SAND, trace silt Brown Moist (FILL)																		
0.7	ROCKFILL: (size ranging from 100mm to 1200mm)						438												
							437												
435.9							436												
3.7	Gravelly SAND, trace silt and clay Dense Brown to Grey Moist (FILL)		2	SS	42		435												
435.3							434												
4.3	ROCKFILL: (size ranging from 100mm to 1200mm)						433												
							432												
433.2							431												
6.4	SAND, some silt and clay, trace gravel Compact Grey Wet		3	SS	18		430												
			4	SS	19														
430.5																			
9.1	Sandy SILT, some clay Compact Grey Wet		5	SS	12														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No ML17-06 2 OF 2 METRIC

GWP# 6839-14-00 LOCATION Mile Creek Culvert, MTM NAD 83 Zone 15 N 5 546 413.7 E 237 287.1 ORIGINATED BY BRM
 HWY 599 BOREHOLE TYPE Hollow Stem Augers/Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.29 - 2017.07.29 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
	Continued From Previous Page																
428.9	Sandy SILT , some clay Compact to Very Dense Grey Wet						429										
10.7	SAND , some silt and gravel, trace clay Very Dense Grey		6	SS	64												
428.3	Moist																
11.3	BOULDERS Advanced by coring						428										
	Coring bedrock started at 12.4m																
427.2																	
12.4	BEDROCK (GABBRO and BASALT) highly to moderately weathered, blue to grey and white bands		1	RUN			427										
	Mechanical breaks, broken zones																
425.9							426										
13.7	END OF BOREHOLE AT 13.7m. WATER LEVEL AT 5.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 11.9m, SLOUGH TO 1.3m, GRAVEL TO 0.3m, CEMENT TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																

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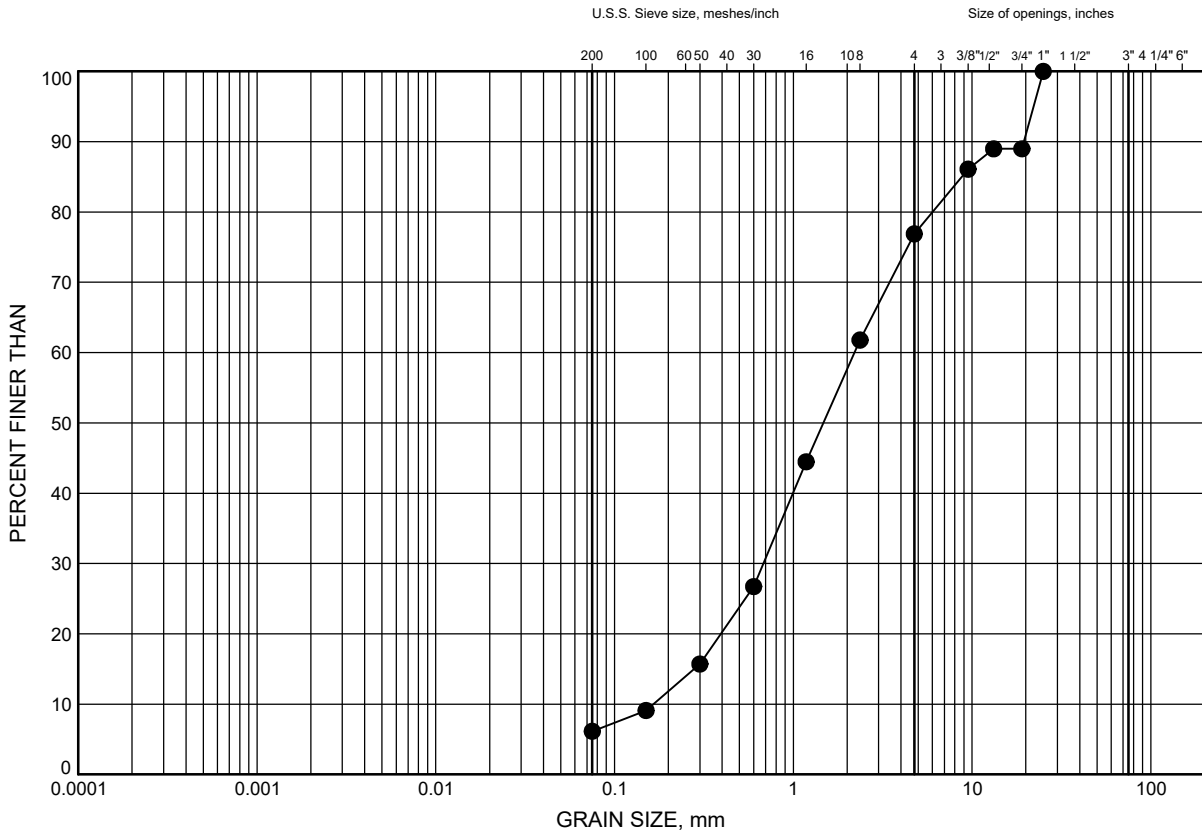
Appendix B

Geotechnical and Analytical Laboratory Test Results And Bedrock Core Photos

Mile Creek Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ML17-02	3.8	435.1

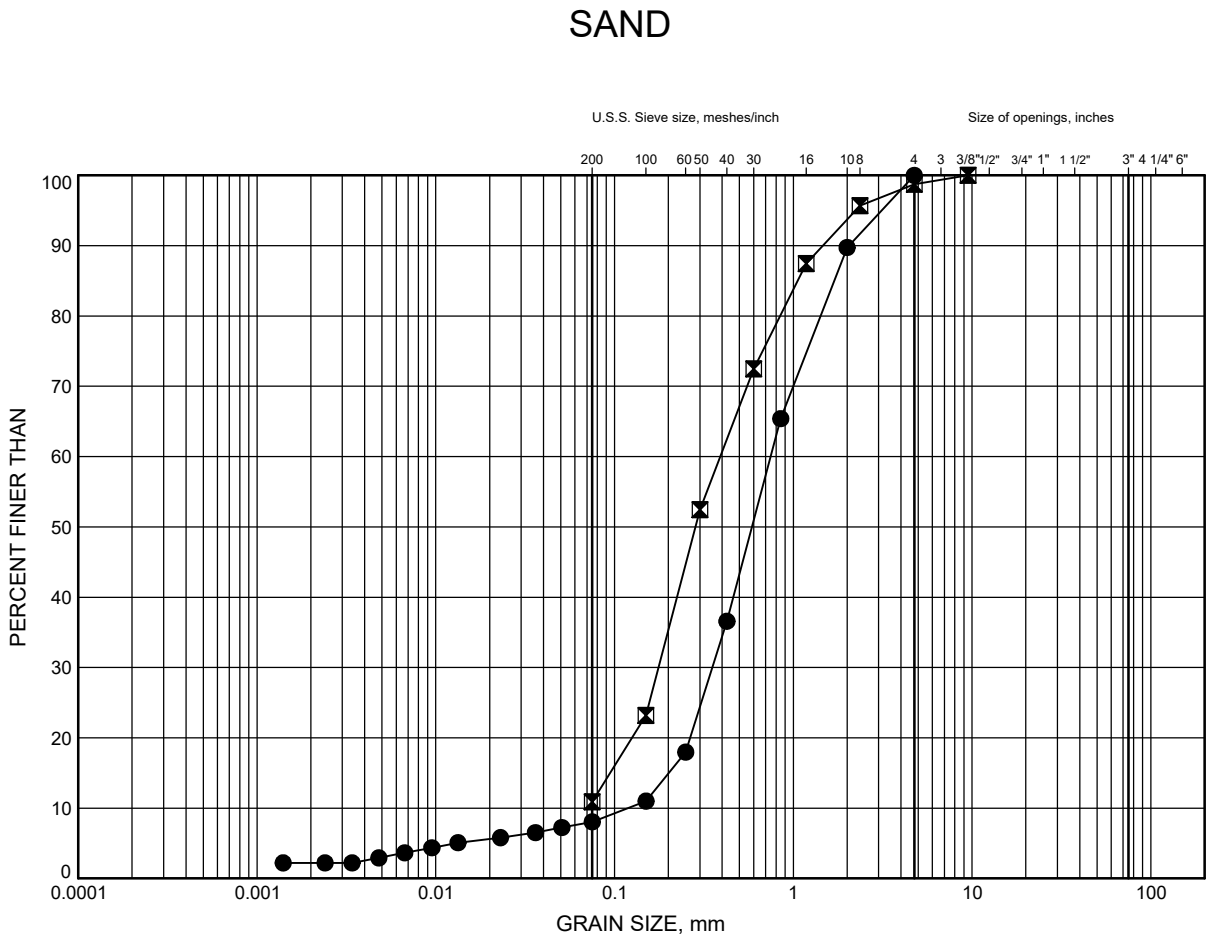
Date October 2017
 GWP# 6839-14-00



Prep'd AN
 Chkd. RPR

Mile Creek Culvert 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)
●	ML17-04	0.9	432.7
⊠	ML17-06	6.7	432.9

Date October 2017
GWP# 6839-14-00

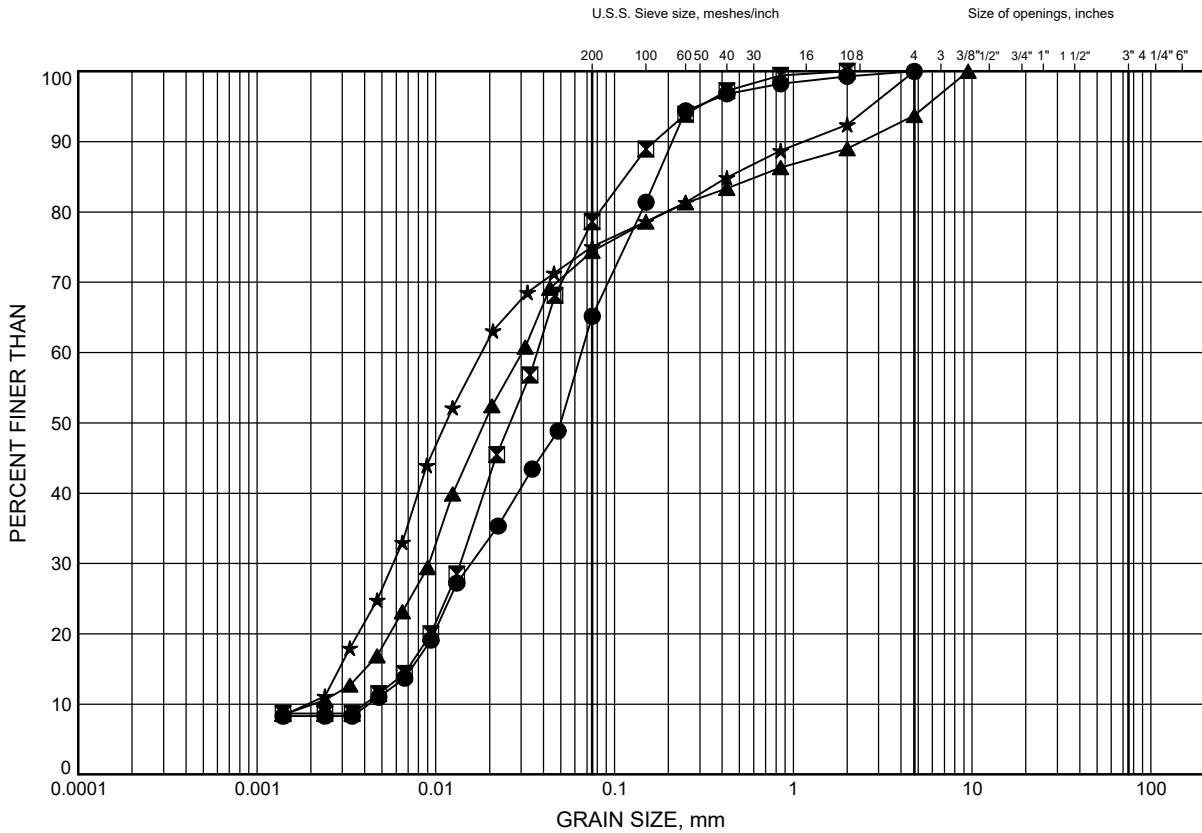


Prep'd AN
Chkd. RPR

Mile Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

Sandy SILT to SAND, some silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ML17-03	7.6	431.6
⊠	ML17-04	2.1	431.5
▲	ML17-05	5.8	432.9
★	ML17-06	9.4	430.2

Date ..October 2017.....
GWP# ..6839-14-00.....



Prep'dAN.....
Chkd.RPR.....



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17077
Client: Hatch
Project Name: Mile Creek Culvert
Core Size: NQ BH No : MI17-06

Date Drilled: 31-Jul-17
Date Tested: 10-Aug-17
Tester: KK
Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	11.5	D	30.4	46.0	93.8	13.1	314.8	Basalt	Extremely Strong
2	1	11.6	A	17.9	46.0	53.5	5.7	136.6	Basalt	Very Strong
3										
4										
5										
6										
7										
8										
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10										
11										
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31										
32										
33										
34										
35										

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24.



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17077
Client: Hatch
Project Name: Mile Creek Culvert
Core Size: NQ BH No : MI17-05

Date Drilled: 31-Jul-17
Date Tested: 10-Aug-17
Tester: KK
Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_s(50)$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	6.7	A	20.0	47.0	54.8	6.1	147.3	Argillite	Very Strong
2	1	7.1	D	21.1	47.0	70.6	8.8	211.5	Argillite	Very Strong
3	1	7.5	D	30.0	47.0	101.9	12.5	300.2	Argillite	Extremely Strong
4	2	7.7	D	14.5	47.0	149.5	6.0	144.8	Argillite	Very Strong
5	2	8.0	A	15.0	47.0	59.4	4.3	103.8	Argillite	Very Strong
6	2	8.5	D	26.6	47.0	108.0	11.1	266.8	Argillite	Extremely Strong
7	2	8.6	A	9.5	47.0	55.1	2.9	69.8	Argillite	Strong
8	2	9.0	D	28.1	47.0	109.9	11.7	281.5	Argillite	Extremely Strong
9	3	9.2	A	15.0	47.0	54.8	4.6	110.6	Argillite	Very Strong
10	3	9.8	D	4.7	47.0	124.8	1.9	46.7	Argillite	Medium Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24.

Last Modified: September 14, 2016



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 17077
Client: Hatch
Project Name: Mile Creek Culvert
Core Size: NQ BH No : MI17-02

Date Drilled: 29-Jul-17
Date Tested: 14-Aug-17
Tester: KK
Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	3	9.1	A	35.0	47.0	47.8	12.0	287.0	Basalt	Extremely Strong
2	3	9.3	D	4.5	47.0	120.8	1.9	44.9	Basalt	Medium Strong
3	3	9.8	A	35.0	47.0	53.9	10.9	261.5	Basalt	Extremely Strong
4	3	10.2	A	35.0	47.0	53.7	10.9	262.2	Basalt	Extremely Strong
5	3	10.3	D	19.8	47.0	122.4	8.3	198.7	Basalt	Very Strong
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35										

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24.

Last Modified: September 14, 2016



0 m

50 m

100 m

150 m

Core Photo 1: Borehole ML17-02 Run 2 to Run 3 (9.0 m to 10.6 m)



0 m

50 m

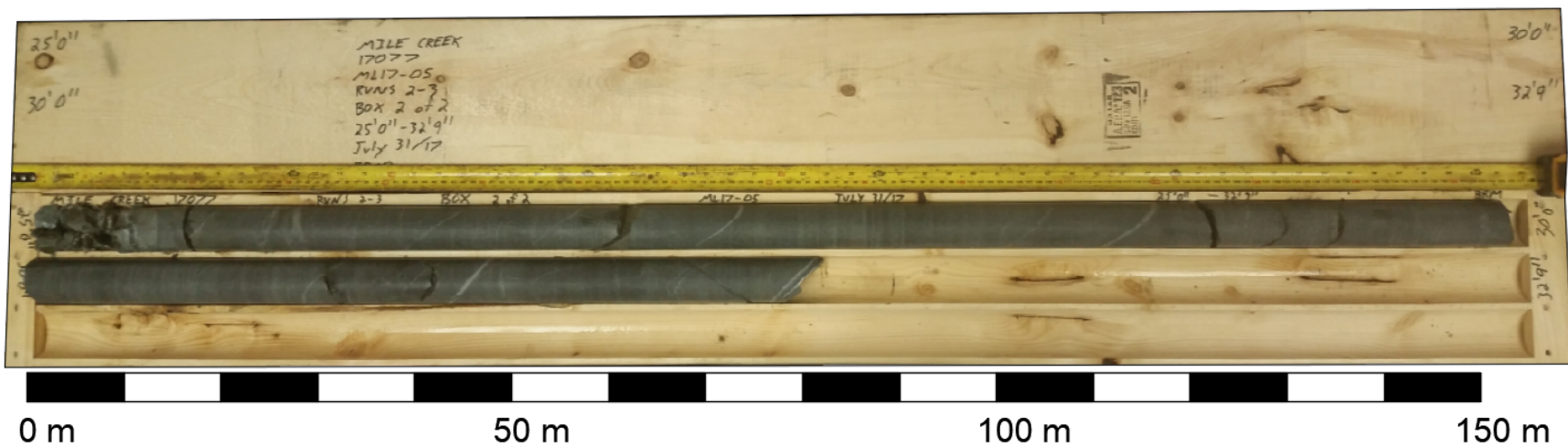
100 m

150 m

Core Photo 2: Borehole ML17-02 Rockfill (1.2 m to 2.0 m)



Core Photo 3: Borehole ML17-05 Rockfill and Run 1 (0.9 m to 5.5 m and 6.6 m to 7.6 m)



Core Photo 4: Borehole ML17-05 Run 2 to Run 3 (7.6 m to 10.0 m)



Core Photo 5: Borehole ML17-06 Rockfill and Boulders (0.7 m to 6.4 m and 11.3 m to 12.0 m)



Core Photo 6: Borehole ML17-06 Run 1 (12.0 m to 13.7 m)



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 17077
Thurber Engineering Ltd.
CA15302-AUG17
Corrosivity (Soil)

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada,
K0L 2H0

Sample ID	Unit	PR17-02 SS7	KE 17-03 SS5	ME 17-03 SS3	TU 17-02 SPT5	CO 17-03 SS4	AG 147-02 SS4
Sample Date/Time		30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17	30-Jul-17
Moisture	%	15.6	7.0	7.7	22.2	15.6	21.0
pH	no unit	8.25	6.40	8.27	8.14	8.65	8.33
Corrosivity Index	none	4.5	1.0	1.0	1.0	4.0	1.0
Soil Redox Potential	mV	325	338	303	301	295	290
Sulphide	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Chloride	mg/L	6.9	240	2.4	25	1.2	150
Sulphate	mg/L	26	10	10	1.2	46	6.1
Conductivity	uS/cm	49	269	35	81	83	213
Resistivity (calculated)	ohms.cm	20300	3720	28700	12400	12000	4690

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
Environment, Health and Safety

Certificate of Analysis

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada, K0L 2H0



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 17077 Hwy 599
Thurber Engineering Ltd.
CA15314-JUN17
Corrosivity (Solution)

Sample ID	Unit	RL	Tug Creek	Pratt Creek	Mile Creek	Cobb Bay	Kekwanzik Lake	Agimak River
			10-Jun-17 12:10	10-Jun-17 12:30	10-Jun-17 10:40	10-Jun-17 11:20	10-Jun-17 12:45	10-Jun-17 13:10
Sample Date/Time								
Temperature Upon Receipt	°C		10.0	10.0	10.0	10.0	10.0	10.0
Soil Redox Potential	mV		334	272	352	301	312	345
Sulphide	mg/L	0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
pH	no unit	0.05	7.78	7.81	7.62	7.70	7.38	7.26
Chloride	mg/L	0.04	2.1	2.9	2.7	1.7	8.8	7.8
Sulphate	mg/L	0.04	0.3	1.2	0.8	0.6	2.0	1.9
Conductivity	µS/cm	2	100	78	63	78	67	56
Resistivity (calculated)	ohms.cm		9990	12700	15800	12800	15000	17700

Corrosivity Index is based on the AWWA
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
Environment, Health and Safety

Data reported represents the sample submitted to SGS. Reproduction of this analytical report in full or in part is prohibited without prior written approval. Please refer to SGS General Conditions of Services located at http://www.sgs.com/terms_and_conditions_service.htm. (Printed copies are available upon request.). Test Method information available upon request. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.



Appendix C

Selected Site Photographs



Photo 1: East bank of Highway 599 at Mile Creek Culvert looking south



Photo 2: West bank of Highway 599 at Mile Creek Culvert looking south



Photo 3: Mile Creek Culvert outlet

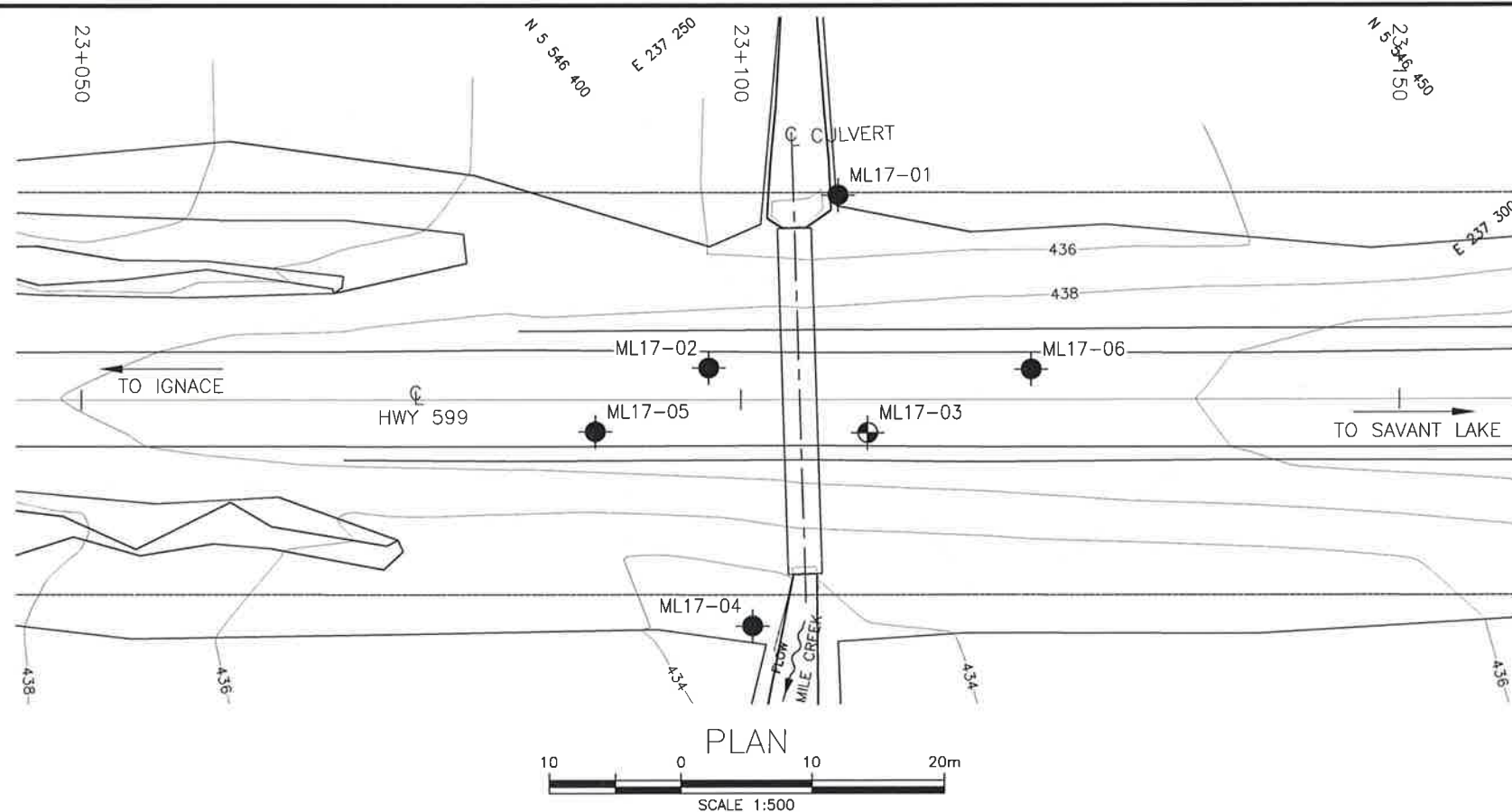


Photo 4: Mile Creek Culvert inlet



Appendix D

Borehole Locations and Soil Strata Drawing



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



CONT No 2018-6002
WP No 6841-14-01

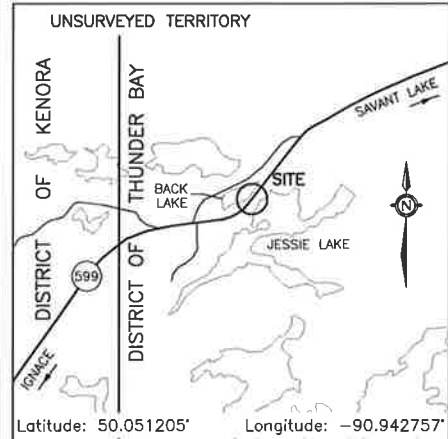
HIGHWAY 599
MILE CREEK CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
38

HATCH



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

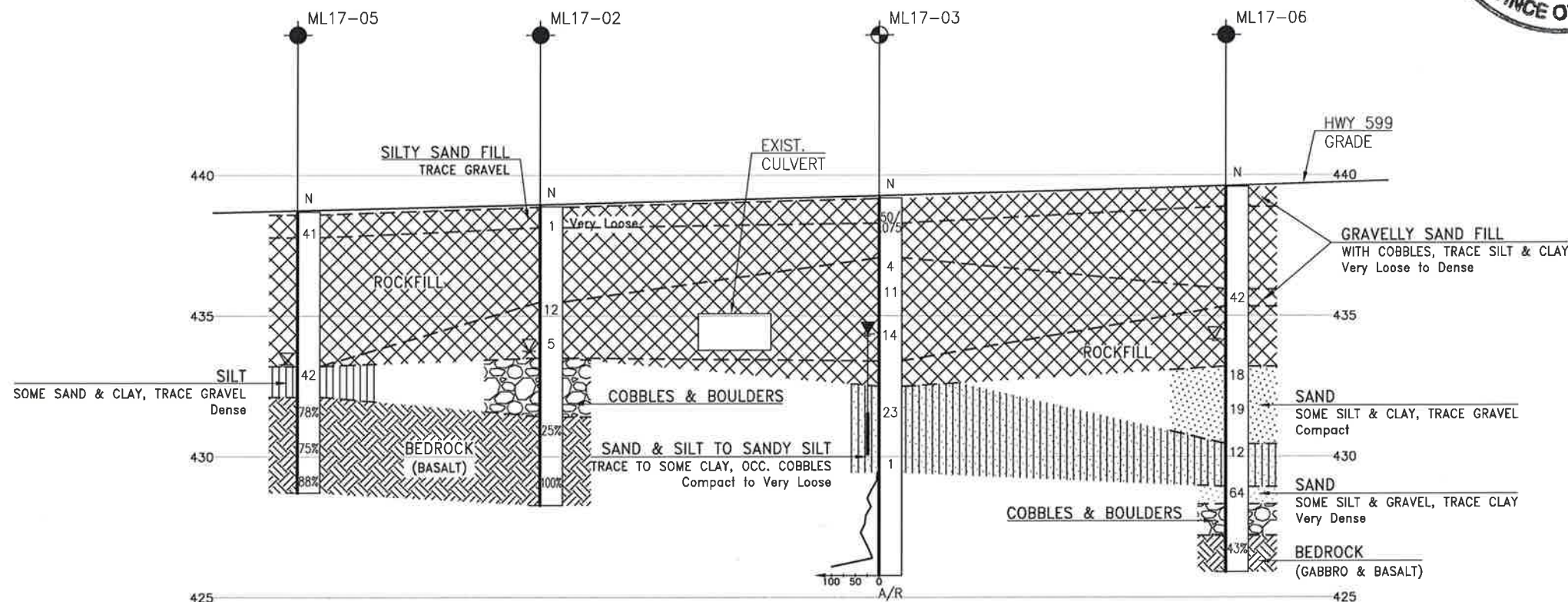
- ◆ Borehole
- ◆ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level
- ↑ Head Artesian Water
- ⊥ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
ML17-01	434.4	5 546 410.5	237 267.6
ML17-02	438.9	5 546 394.7	237 271.7
ML17-03	439.2	5 546 401.1	237 283.1
ML17-04	433.6	5 546 385.1	237 289.1
ML17-05	438.7	5 546 384.9	237 270.1
ML17-06	439.6	5 546 413.7	237 287.1

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.
- Coordinate system is MTM NAD 83 Zone 15.

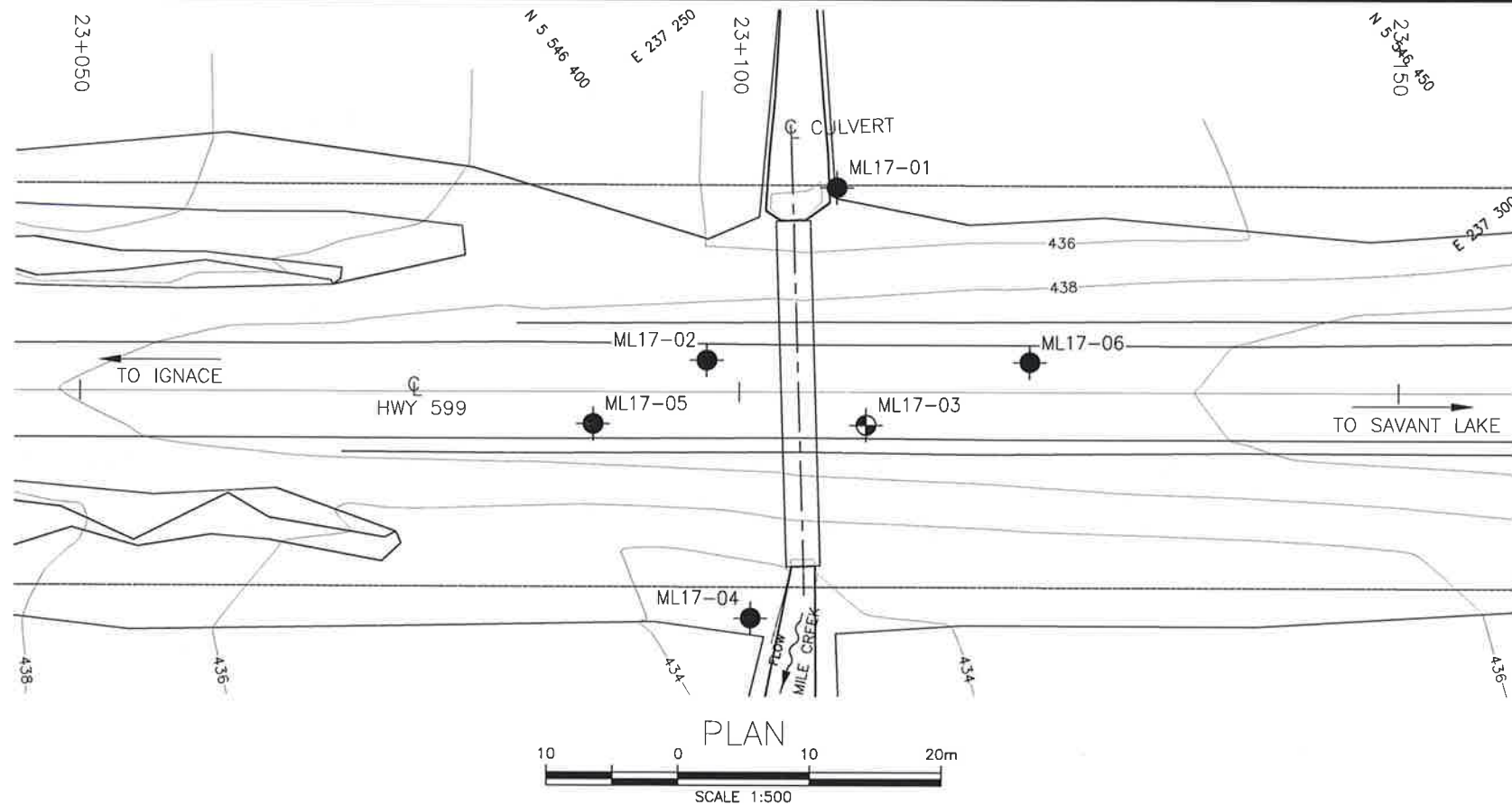
GEOCRES No. 52J-18



PROFILE ALONG C HWY 599



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK JPL	CODE LOAD DATE JAN 2018
DRAWN	AN	CHK RPR	SITE 48W-191C STRUCT DWG 2



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



CONT No 2018-6002
WP No 6841-14-01

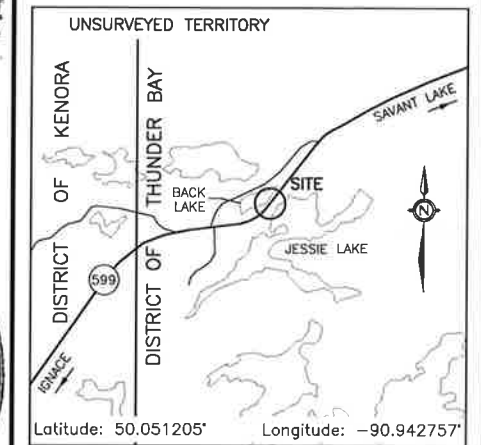
HIGHWAY 599
MILE CREEK CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
39

HATCH



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

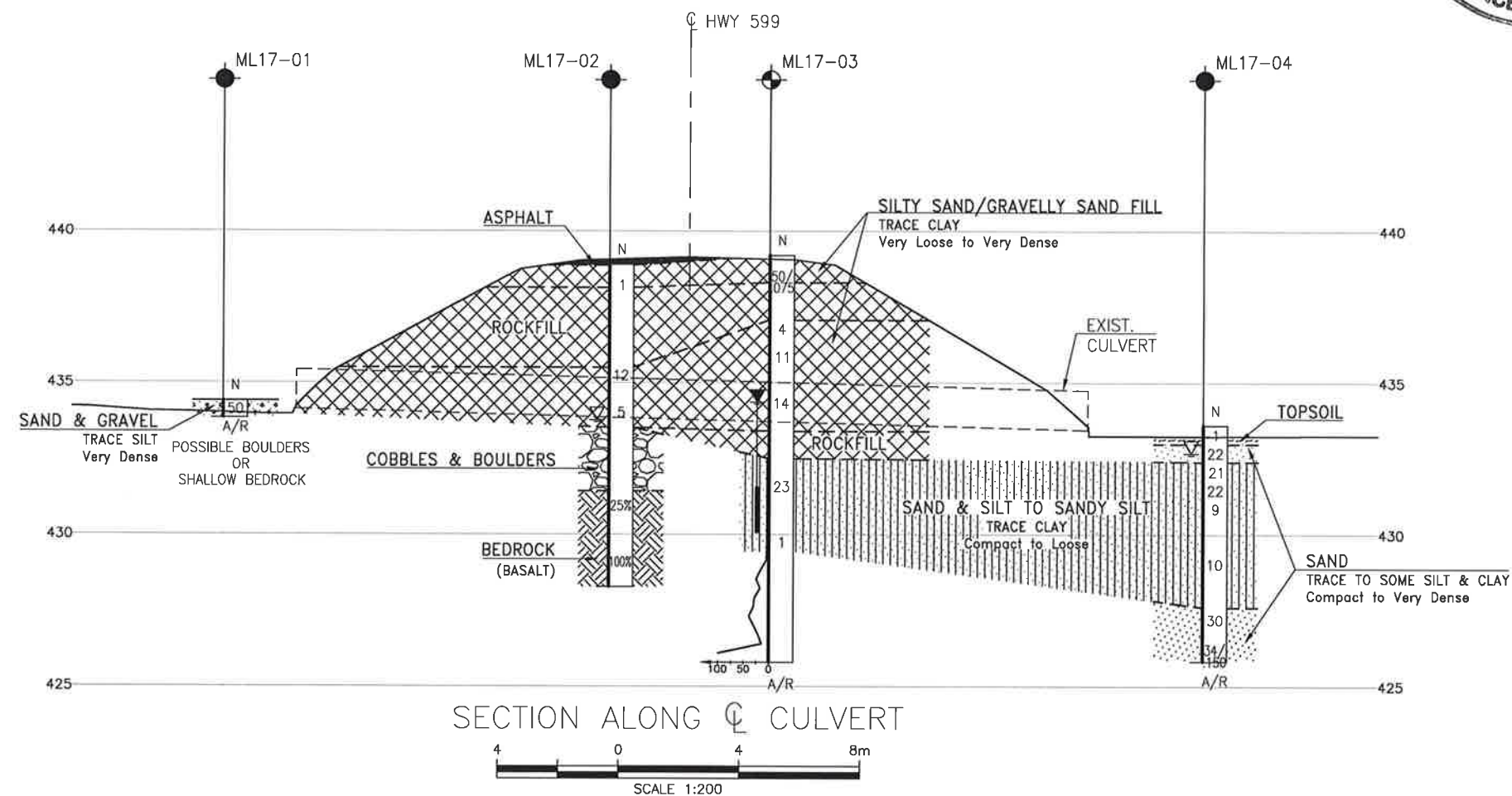
●	Borehole
⊙	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▽	Head Artesian Water
↑	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
ML17-01	434.4	5 546 410.5	237 267.6
ML17-02	438.9	5 546 394.7	237 271.7
ML17-03	439.2	5 546 401.1	237 283.1
ML17-04	433.6	5 546 385.1	237 289.1
ML17-05	438.7	5 546 384.9	237 270.1
ML17-06	439.6	5 546 413.7	237 287.1

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) Coordinate system is MTM NAD 83 Zone 15.

GEOCRES No. 52J-18



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK JPL	CODE
DRAWN	AN	CHK RPR	SITE 48W-191C
LOAD	DATE	JAN 2018	DWG 3



Appendix E

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert	Driven Sheet Piles Driven to Refusal or to Bedrock
<u>Advantages:</u> i. Ease of construction. ii. CSP's can accommodate small differential settlement along culvert axis iii. Steel pipes are likely to be more cost effective than concrete box or open footing culverts.	<u>Advantages:</u> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Segmental option can accommodate limited amount of potential differential settlement along culvert axis. iii. Less requirement for soil geotechnical resistances as loading is spread over a larger width. iv. Can accommodate differential settlement.	<u>Advantages:</u> i. Conventional construction. ii. Generally less costly than deep foundation elements. iii. Eliminates bedding requirement. iv. May have less environmental issues such as those involving spawning fish species.	<u>Advantages:</u> i. Minimizes potential for disturbance of streambed. ii. Ease of construction. iii. Provides shoring and foundation elements in one operation. iv. Installation of sheet piles could continue in freezing weather. v. Potentially minimizes volume of excavation.
<u>Disadvantages:</u> i. Multiple pipes may be needed to meet hydraulic requirements. ii. CSP cannot be rehabilitated as concrete culverts. iii. Culvert subgrade preparation and bedding placement must be carried out in the dry. iv. Dewatering is required. v. Requires subexcavation of soft or organic material from streambed if encountered.	<u>Disadvantages:</u> i. More expensive than a CSP culvert and sheet pile system. ii. Culvert subgrade preparation and bedding placement must be carried out in the dry. iii. Dewatering is required. iv. Requires subexcavation of soft or organic material from streambed if encountered. v. Requires complete excavation of river bed.	<u>Disadvantages:</u> i. Presence of rockfill in the highway embankment. ii. Requires deeper excavation below the groundwater level. Excavation to base of existing roadway embankment is required for footing construction. iii. High groundwater levels. Dewatering will be required. Potential longer dewatering requirements. iv. Potential disturbance of creek during excavation. v. Cannot tolerate differential settlement. vi. Shallow foundations close to water would be at risk due to scour, erosion and undermining problems.	<u>Disadvantages:</u> i. Less conventional construction. ii. Presence of rockfill within the embankment.
RECOMMENDED	RECOMMENDED	NOT RECOMMENDED	NOT RECOMMENDED



Appendix F

List of Specifications and Suggested Wording for NSSP



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

- OPSS PROV 206 Construction specification for grading
- OPSS PROV 209 Construction specification for embankments over swamps and compressible soils
- OPSS PROV 501 Construction specification for compacting
- OPSS.PROV 511 Construction specification for rip-rap, rock protection, and granular sheeting
- OPSS.PROV 517 Construction specification for dewatering
- SP 517F01 Amendment to OPSS 517
- OPSS PROV 539 Construction specification for temporary protection systems
- OPSS PROV 804 Construction specification for seed and cover
- OPSS PROV 902 Construction specification for excavating and backfilling - Structures
- OPSS PROV 1004 Material specification for aggregates - miscellaneous
- OPSS PROV 1010 Material specification for aggregates - base, subbase, select subgrade, and backfill material
- OPSS PROV 1205 Material specification for clay seal
- OPSD 802.014 Flexible pipe embedment in embankment. original ground: earth or rock
- OPSD 803.031 Frost treatment – pipe culverts, frost penetration line between top of pipe and bedding grade
- OPSD 810.010 General rip-rap layout for sewer and culvert outlets
- OPSD 3090.100 Foundation frost penetration depths for Northern Ontario



2. Suggested Wording for NSSP on Dewatering

Effective dewatering shall be designed and provided by the Contractor during culvert 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 may encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths. Vibrating equipment is not permitted for installation of sheet piles.

4. Suggested Text for NSSP on “Rock Excavation”

The strength of the bedrock increases with depth. As such, rock coring equipment, pneumatic rock splitting/breaking equipment and ripping machinery should be available on site to assist in excavation and drilling. Blasting is not recommended at this site.

The possibility exists that concentrated seepage may be experienced from localized seams or fractures in the rock. Means to handle this seepage, such as additional pumps, should be made available.



5. Suggested text for a NSSP on Rock Fill

Rock fill shall be as specified in OPSS.PROV 206, and the following:

- Rock fill shall not contain shale or shale fragments.
- Rock fill shall be placed as per clause 206.07.06 Rock Backfill to Structure