



**THURBER** ENGINEERING LTD.

**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT  
McLEAN'S CREEK CULVERT REPLACEMENT  
HIGHWAY 17, UNSURVEYED TERRITORY  
THUNDER BAY DISTRICT, ONTARIO  
LATITUDE: 48.839562°, LONGITUDE: - -87.442991°**

**G.W.P. 6809-14-00, W.P. 6809-14-01, SITE NO. 48C-178C**

**GEOCRES Number: 42D-53**

**Report**

to

**HATCH**

Date: September 11, 2018  
File: 15595



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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 McLean's Creek Culvert on Highway 17, located west of Selim, in the District of Thunder Bay, Ontario. Thurber carried out the investigation as a sub-consultant to Hatch under the Ministry of Transportation Ontario (MTO) Agreement Number 6016 -E-0008.

The purpose of this investigation was to explore the subsurface conditions at the culvert location 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.

**2. SITE DESCRIPTION**

The site is located along Highway 17, approximately 3 km west of the Selim area. The existing culvert allows McLean's Creek to flow south into Lake Superior. Highway 17 generally runs in an east-west direction at the culvert site.

Based on the Ontario Structure Inspection Manual (OSIM) prepared by MTO on November 20, 2014 the existing culvert is a cast in place concrete box culvert that is 6.1 m wide, 2.8 m high and 36.7 m long. The culvert barrel is in fair condition with severe erosion along the bottom 0.3 m of both side walls and light scaling on the bottom 0.9 m of the side walls. There are several cracks in the walls that are up to 0.9 m in length as well as a crack at the midspan of the culvert with rust stains on both the walls and soffit. Delamination has also occurred along the soffit at the outlet of the culvert.



The estimated culvert invert is at approximate Elevation 186.6 m at the inlet (north) and 186.2 m at the outlet (south). The existing road grade at the culvert location is at approximate Elev. 192.0 m, and there is approximately 2.5 m of fill above the culvert. The elevation of the water flowing through the culvert in November of 2013 was recorded at approximately 187.5 m upstream of the inlet and 185.8 m downstream of the outlet.

The area on either side of the creek near the inlet and outlet of the culvert is vegetated with grass, shrubs and small trees. Rainbow Falls provincial park is located southwest of the culvert, with the entrance to the park approximately 80 m to the west of the culvert outlet. Photographs in Appendix D show the culvert and the surrounding area.

The site lies within the physiographic region known as the Wawa Subprovince of the Superior Province of the Canadian Shield. Based on Ontario Geological Survey (OGS) Map 2518, titled "Surficial Geology of Northern Ontario", dated 1987, the site is located in an area of "bare bedrock with thin glacial sediment cover". Based on OGS Map 2545, titled "Bedrock Geology of Ontario", dated 1991, the bedrock is of the Archean age and consists of intrusive rocks, mainly massive to foliated granodiorite and granite.

### **3. INVESTIGATION PROCEDURES**

The field investigation for this project was carried out between July 24 and 26, 2017, during which time four boreholes denoted as Boreholes 17-38 to 17-41 were drilled at selected locations at the culvert site. Boreholes 17-39 and 17-41 were located within the paved section of Highway 17 on either side of the culvert. Borehole 17-38 was located near the inlet of the culvert, and 17-40 was located near the outlet. The approximate locations of the boreholes are shown on the Borehole Locations, and Soil Strata Drawing provided in Appendix C.

A track-mounted CME 55 drill rig was used to drill the boreholes. The boreholes were advanced using hollow stem augers, solid stem augers and NW casing to depths between 2.7 m and 15.8 m. In all boreholes, soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT). NQ coring was used to advance Borehole 17-40 3.5 m into bedrock. Two dynamic cone penetration tests (DCPT), numbered 17-38A and 17-39A, were conducted adjacent to Boreholes 17-38 and 17-39 to depths of 6 m and 9.4 m respectively. The results of the boreholes and DCPTs are presented on the Record of Borehole sheets included in Appendix A.

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who directed the drilling, sampling and in-situ testing operations, logged the boreholes and



processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed within the open boreholes throughout the drilling operations and in a standpipe piezometer installed in Borehole 17-38. The standpipe piezometer consisted of a 25 mm diameter PVC pipe, with a 3 m long slotted screen installed to a depth of 15.2 m. The boreholes in which no standpipe piezometers were installed, were backfilled in general accordance with Ontario Regulation 903 as amended by Regulation 128/03. The piezometer was decommissioned upon completion of the drilling investigation at the site.

Details of the piezometer installations and borehole completion are summarized as follows:

<b>Borehole Number</b>	<b>Borehole Depth / Base Elevation (m)</b>	<b>Piezometer Tip Depth / Elevation (m)</b>	<b>Completion Details</b>
17-38	15.8/174.7	15.2/175.3	Sand from 15.8 m to 11.6 m, then bentonite holeplug to surface
17-38A (DCPT)	6.0/184.5	None Installed	Bentonite holeplug to surface
17-39	15.8/176.0	None Installed	Bentonite holeplug and cuttings to 0.2 m, then asphalt to surface
17-39A (DCPT)	9.2/182.6	None Installed	Bentonite holeplug to surface
17-40	14.8/174.1	None Installed	Bentonite holeplug to surface
17-41	2.7/188.9	None Installed	Bentonite holeplug and cuttings to 0.2 m, then asphalt to surface

#### 4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (hydrometer and/or sieve) and Atterberg Limits testing, where appropriate. Point load tests were conducted on rock cores. Laboratory testing results are summarized on the Record of Borehole



sheets included in Appendix A and are presented on the figures included in Appendix B.

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

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

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In general, the subsurface conditions encountered in these boreholes consisted of asphalt and sand and gravel fill overlying varying thicknesses of sand and silt layers, which were in turn underlain by silty clay and bedrock. Descriptions of the individual strata are presented below.

### **5.1 Asphalt**

Boreholes 17-39 and 17-41 were drilled through the eastbound lane of Highway 17 and encountered a 150 mm thick layer of asphalt. Borehole 17-38 was drilled on the east side of the culvert inlet near the base of the existing highway embankment and encountered 75 mm of asphalt, that may have been part of a former road bed.

### **5.2 Sand and Gravel Fill**

Sand and gravel fill ranging to gravelly sand fill was encountered below asphalt in Boreholes 17-38, 17-39 and 17-41 and at the ground surface in Borehole 17-40. This layer had a thickness of between 2.8 m and 5.0 m and extended to depths from 2.8 m to 5.2 m (Elevation 187.4 m to 186.1 m). Borehole 17-41 was terminated within the fill at a depth of 2.7 m (Elevation 188.9 m). Based on the information obtained from the borehole investigation, the granular base/subbase material extended below the frost penetration depth estimated in this area.

SPT 'N' values within the sand and gravel fill ranged from 2 to 40 blows per 0.3 m of penetration,

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indicating a very loose to dense relative density. Moisture contents between 1 percent and 21 percent were measured in the cohesionless fill.

The results of grain size distribution analyses carried out on selected samples of the sand and gravel fill are presented on the Record of Borehole sheets included in Appendix A and on Figure B1 in Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	19 to 49
Sand	48 to 75
Silt and Clay	3 to 6

### 5.3 Silty Sand to Sand and Silt

The sand and gravel fill was underlain by a layer of silty sand to sand and silt with trace gravel and trace clay in Borehole 17-38, 17-39 and 17-40. The silty sand to sand and silt layer ranged in thickness from 4.7 m to 7.4 m, and extended to depths from 9.9 m to 10.2 m (Elevation 181.9 m to 178.7 m).

SPT 'N' values within the deposit ranged from 5 to 60 blows per 0.3 m of penetration, indicating a loose to very dense relative density. Measured moisture contents within the deposit varied between 15 percent and 22 percent.

The DCPTs 17-38A and 17-39A were terminated within this deposit at depths of 6.0 m and 9.2 m (Elevation 184.5 m and 182.6 m) respectively upon refusal of 100 blows per 0.3 m of penetration.

The results of grain size distribution analyses carried out on selected samples of the silty sand and sand and silt are presented on the Record of Borehole sheets included in Appendix A and on Figure B2 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 4
Sand	47 to 72
Silt	25 to 43
Clay	3 to 10





#### 5.4 Sand

A 4.9 m thick layer of sand with trace gravel and trace to some silt was encountered below the sand and silt in Borehole 17-39. The sand layer extended to a depth of 14.8 m (Elevation 177.0 m)

The sand was very loose to dense, based on SPT 'N' values ranging from 2 to 41 blows per 0.3 m of penetration. A moisture content of 28 percent was recorded in the sand.

The results of grain size distribution analysis carried out on a sample of the sand are presented on the Record of Borehole sheets included in Appendix A and on Figure B3 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	96
Silt and Clay	4

#### 5.5 Silt

Below the silty sand layer in Borehole 17-38, a 4.5 m thick silt layer was encountered. The silt contained some sand, some clay and trace gravel, and extended to a depth of 14.6 m (Elevation 175.9 m).

SPT 'N' values within the silt deposit ranged from 19 to 28 blows per 0.3 m of penetration, indicating a compact relative density. Measured moisture contents within the silt deposit varied between 19 percent and 23 percent.

The results of grain size distribution analyses carried out on a selected sample of the silt are presented on the Record of Borehole sheets included in Appendix A and on Figure B4 of Appendix B. The results of the grain size distribution analyses are summarized below:



Soil Particle	Percentage (%)
Gravel	0
Sand	11
Silt	75
Clay	14

## 5.6 Silty Clay

A layer of silty clay with trace sand and gravel was encountered below the sand and silt layers in Boreholes 17-38, 17-39 and 17-40. The silty clay layer was 1.1 m thick at Borehole 17-40. At Boreholes 17-38 and 17-39 the silty clay layer extended to the borehole termination depth of 15.8 m (Elevation 176.0 m to 174.7 m).

SPT 'N' values of 9 to 19 blows per 0.3 m penetration indicated that the silty clay had a stiff to very stiff consistency. The silty clay had a measured moisture content ranging from 20 to 28 percent.

The results of grain size distribution analyses and Atterberg Limits testing carried out on selected samples of the silty clay are presented on the Record of Borehole sheets included in Appendix A and on Figures B5 and B6 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	0 to 6
Silt	66 to 69
Clay	28 to 31

The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Plastic Limit	14 to 15
Liquid Limit	24 to 28

The results of the Atterberg Limits testing indicate the layer to be of low plasticity with group symbol CL.



## 5.7 Bedrock

Bedrock was encountered below the silty clay at a depth of 11.3 m (Elevation 177.6 m) in Borehole 17-40. The bedrock was proven by coring 3.5 m to a depth of 14.8 m (Elevation 174.1 m). The bedrock consisted of moderately weathered grey basalt underlain by slightly weathered reddish brown granite. The total core recovery, solid core recovery and rock quality index values recorded for the three runs of rock that were sampled are shown below.

Run Number	Total Core Recovery (%)	Solid Core Recovery (%)	Rock Quality Index (%)
1	100	100	89
2	77	37	20
3	97	70	40

The RQD results indicate very poor to good rock quality. Average unconfined compressive strengths (UCS) of the rock ranged between 70 MPa and 187 MPa based on correlations with the point load tests, indicating the rock was strong to very strong. The point load test results are included in Appendix B.

## 5.8 Groundwater Conditions

Groundwater conditions were observed during drilling operations, and groundwater levels were measured in the open boreholes upon completion of drilling. A standpipe piezometer was installed in Borehole 17-38 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the standpipe piezometer are summarized below.

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
17-38	July 26, 2017	2.6	187.9	Standpipe piezometer
17-39	July 24, 2017	2.1	189.7	Open borehole
17-40	July 26, 2017	1.0	187.9	Open borehole
17-41	July 24, 2017	Dry	Dry	Open borehole

The creek water level in November 2013 was reported to be Elev. 187.5 m upstream of the inlet and 185.8 m downstream of the outlet, and was measured at Elevation 187.5 m and 187.2 m (at the inlet and outlet respectively) during the current investigation.



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

## 6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the sand and gravel fill from Borehole 17-39 and a sample of the creek water were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Units (Water)	Test Results	
			17-39, 3.0 m – 3.7 m	McLean's Creek
			(Sand and Gravel Fill)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	mg/L	mg/L	1500	0.39
Sulphate	mg/L	mg/L	37	2
pH	No unit	No unit	6.17	7.17
Electrical Conductivity	µS/cm	µS/cm	1520	33
Resistivity	Ohms.cm	Ohms.cm	656	30300
Redox Potential	mV	mV	276	198

## 7. MISCELLANEOUS

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

RPM Drilling Ltd. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Mr. John Zoldy of Thurber. Overall supervision of the field program was provided by Mr. Cory Zanatta, EIT of Thurber.

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. The



coordinate system MTM NAD83 Zone 14 was used for these boreholes.

Routine laboratory testing was carried out at Thurber's geotechnical laboratory. Interpretation of the field data and preparation of this report was carried out by Dr. Nancy Berg, EIT and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

*Nancy Berg*  
Sept 11/18

Nancy Berg, Ph.D.  
Geotechnical EIT



Mark Farrant, P.Eng.  
Geotechnical Engineer



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



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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This report provides an interpretation of the geotechnical data in the factual report and presents foundation design recommendations for the preliminary design of the proposed McLean's Creek Culvert replacement on Highway 17, located in the Unsurveyed District of Thunder Bay, Ontario.

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

Information on the existing culvert site was obtained from the MTO Terms of Reference, and the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on November 20, 2014. The existing structure is a cast in place concrete box culvert. The culvert measures 6.1 m wide, 2.8 m high and is 36.7 m long. The estimated culvert invert is at approximate Elevation 186.6 m at the inlet (north) and 186.2 m at the outlet (south). The existing road grade at the culvert location is at approximate Elev. 192 m, and there is approximately 2.5 m of fill above the culvert.

A Preliminary General Arrangement Drawing and discussions with Hatch indicate that the replacement option being considered at this site consist of either a twin cell precast concrete box culvert or two corrugated steel pipe culverts. The twin precast concrete box culvert consists of two 4.5 m wide, 3.75 m high and 36.9 m long cells, with a proposed underside of box at an

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approximate Elevation of 185.1 m at the inlet and 185.0 m at the outlet. The corrugated steel pipe (CSP) option would consist of two parallel 36.9 m long CSP culverts with a diameter of 4.6 m and a proposed invert level at an approximate Elevation of 185.4 m at the inlet and 185.3 m at the outlet. The new culvert will be installed along the same alignment as the existing culvert. A temporary creek diversion pipe is to be located approximately 12 m west of the culvert centreline while the culvert is being installed. The invert level of the diversion pipe is approximately at Elevation 186.5 m. No grade raise or embankment widening are proposed.

Temporary roadway protection or an offline diversion route using a temporary modular bridge are being considered during installation of the culvert.

## **9. CULVERT DESIGN**

### **9.1 Culvert Alternatives**

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

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

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

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

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



The open footing culvert is not recommended at this site due the greater potential for differential settlement, and the need for deeper excavation and additional dewatering effort in cohesionless soils below the water table to provide adequate frost protection.

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

## **9.2 Summary of Subsurface Conditions**

In general, the subsurface conditions encountered in the boreholes consisted of 150 mm of asphalt underlain by 2.8 to 5.0 m of embankment fill overlying a native loose to very dense silty sand to sand and silt deposit, followed by sand, silt and silty clay layers. Bedrock was encountered in Borehole 17-40, below the silty clay deposit.

Water levels in the piezometer and open boreholes ranged from 187.9 to 189.7 m. The creek water level is reported to range from 185.8 to 187.5 m.

## **9.3 Foundation Design for Culverts**

The invert level / bottom of box of the proposed culvert is at approximate Elevation 185.1 m to 185.4 m. The founding soils encountered at this level consist of loose to very dense silty sand to sand and silt.

Foundation design aspects for the replacement culvert include subgrade conditions and preparation, geotechnical capacities, settlement of foundation soils, lateral earth pressures, roadway protection system design, temporary modular bridge foundation design, groundwater control, staged construction, and restoration of the roadway embankment.

### **9.3.1 Concrete Pipe or Corrugated Steel Pipe Culvert**

Replacement of the culvert with one or multiple concrete pipes or CSPs on the same alignment may be considered for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

If this alternative is selected, the concrete pipes or CSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.034 or 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. Construction equipment should not be allowed to





travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212  $\mu\text{m}$ .

The underside of the bedding layer should be placed at or below Elevation 185.1 m, which corresponds to compact silts and sands subgrade. Any loose soil, large cobbles and boulders, and any organic or other detritus material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.

### **9.3.2 Concrete Box Culvert**

Replacement of the culvert with a concrete box culvert or multiple boxes on the same alignment is considered a viable alternative for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement.

In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, similar to as shown on OPSS 803.010. The bedding material should 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 should be carried out in the dry. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212  $\mu\text{m}$ . The subgrade surface prepared to support the box units should have a 75 mm minimum thick top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 184.7 m, which corresponds to compact silts and sands subgrade. Any excessively loose soil, large cobbles and boulders, and any organic or other detritus material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.



The following geotechnical resistances are recommended for the preliminary design of a 9 m to 11 m wide twin box culvert founded at or below Elevation 184.7 m on the native sand and silt deposit:

<b>Geotechnical Resistance</b>	<b>9 m to 10 m wide Twin Culvert</b>
Factored Geotechnical Resistance at ULS	300 kPa
Geotechnical Resistance at SLS (for up to 25 mm settlement)	200 kPa

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

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

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

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

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

### **9.3.3 Culvert Headwall / Wingwalls**

If headwalls or wingwalls are proposed for the replacement culvert, consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are more tolerant to a limited amount of differential settlement.

The borehole information indicates that the founding conditions at the inlet and outlet generally consist of loose to dense sand and silt.



### 9.3.3.1 RSS Walls

RSS walls, if used, would be constructed in a watercourse at this site. It should be noted that RSS wall types listed on the MTO DSM are not pre-approved for use within or adjacent to watercourses or floodplains. If consideration is given to the use of an RSS wall at this site then the Contractor will be required to submit a project/site-specific design submission to the MTO RSS Committee for approval. Suggested wording for an NSSP in regard to this has been included in Appendix E.

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 of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

The RSS mass should be founded on a minimum 0.5 m thick engineered fill layer resting on the native sand and silt subgrade at or below an approximate elevation of 185.0. A RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 300 kPa and a geotechnical reaction at SLS of 200 kPa (for up to 25 mm of settlement). The engineered fill layer placed under the RSS mass should consist of OPSS.PROV Granular A or Granular B Type II compacted to 100 percent of its Standard Proctor Maximum Dry Density (SPMDD) at a moisture content within 2 percent of optimum. The engineered layer should extend at least 300 mm beyond the limits of the RSS mass and levelling strip.

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

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

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



preparation for the RSS wall and placement and compaction of the granular fill must be carried out in the dry.

A geotextile filter fabric should be incorporated in the RSS design to prevent loss of fines from the granular material behind the RSS wall subject to fluctuating water levels. Since the RSS wall will be constructed adjacent to a creek, the wall may be subjected to flooding. The RSS supplier should be made aware that the RSS strips may need to be longer in flooding conditions and the strips must be corrosion resistant.

The RSS walls may be founded on native sand and silt soil which is erodible. Adequate scour and erosion protection must be provided in front of the base of the RSS walls to prevent any foundation soil erosion undermining the walls.

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

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

### **9.3.3.2 Foundation for Concrete Retaining Walls**

Any concrete retaining walls, if required, may be supported on spread footings founded on the compact native sands and silts subgrade. Any organic or soft soil should be removed from the wall subgrade and replaced with granular fill compacted as per OPSS.PROV 501. The walls should be provided with sufficient frost cover and founded at Elevation 184.1 m or lower. A factored geotechnical resistance at ULS of 300 kPa and a geotechnical reaction at SLS of 200 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 footing. Load inclination and eccentricity should also be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The concrete retaining wall should be designed against various modes of failure including translation and overturning. Resistance to sliding between the granular pad (below the precast



concrete footing) and the underlying native soil should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for compact to dense sand and silt.

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

#### **9.3.4 Frost Cover**

The depth of frost penetration at this site is approximately 2.2 m based on OPSD 3090.100. The base of retaining wall footings, if employed, should be provided with a minimum of 2.2 m of earth cover as protection against frost action. The frost cover requirement does not apply to the pipe and box culvert options.

Based on the results of the field investigation, the existing embankment fill at the culvert location comprises sand and gravel material to below the frost penetration depth; therefore, construction of new frost tapers does not appear warranted as part of the culvert replacement.

#### **9.3.5 Subgrade Preparation**

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

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

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



### **9.3.6 Settlement**

It is anticipated that the replacement culvert will be constructed approximately on the same alignment and with similar opening size as the existing culvert with no grade raise on the overlying embankment or embankment widening. Therefore, changes in the loading conditions on the foundation soils consisting of loose to very dense sand and silt are not expected to be significant. The post-construction settlements after culvert construction and embankment reconstruction at this site are estimated to be less than 25 mm. The post-construction settlements will essentially be complete at the end of construction.

If the final design involves embankment widening or grade raise, foundation soil settlement due to this addition of fill must be assessed to determine the impact of such settlement on the performance of the replacement culvert.

### **9.4 Construction Considerations**

Construction staging will be required to maintain one lane of traffic.

Staged construction sequencing will likely require the following:

- Diversion of the creek will be required for construction. In addition, an effective dewatering plan will be required to construct the culvert in the dry.
- Temporary roadway protection or an offline diversion using a temporary modular bridge may be required during all stages of construction, including excavation and removal of the existing culvert, installation of the new culvert and backfilling.
- All culvert subgrade preparation and foundation preparation must be carried out in the dry.

## **10. EXCAVATION AND GROUNDWATER CONTROL**

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

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

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

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

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 which amends OPSS 902.

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01. A preconstruction survey is not required, thus Designer Fill-In \*\*\*\*\* in SP FOUN0003 should be "N/A". Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing systems of similar nature and scope to the required work is not required, and thus Designer Fill-In \*\*\*\*\* in SP517F01 should be "No".

The groundwater level should be maintained at a depth of at least 0.5 m below the final subgrade level. 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 E.

## **11. STREAM DIVERSION PIPE**

A temporary CSP stream diversion pipe is proposed to accommodate creek water flow during culvert replacement. Based on the preliminary general arrangement drawings, the invert of the diversion pipe is at approximate Elevation 186.5 m, which corresponds to native sand and silt.

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

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



## 12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

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

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

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

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

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

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

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ ; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70





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 or Type III $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Passive	3.7	-	3.3	-

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

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

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

### 13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the harmonic mean of the  $N_{60}$  values for the site the area corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.033 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active ( $K_{AE}$ ) and passive ( $K_{PE}$ ) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 13.1 may be used:

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

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ , $\gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or Type III $\phi = 32^\circ$ , $\gamma = 21.2 \text{ kN/m}^3$
Active ( $K_{AE}$ )*	0.29	0.32
Passive ( $K_{PE}$ )	3.6	3.2
At Rest ( $K_{OE}$ )**	0.48	0.53

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

\*\* After Woods



The site is underlain by typically compact to dense sand and silt. In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

#### 14. TEMPORARY PROTECTION SYSTEM

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

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

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

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

Soil Parameter	Existing Fill	Native Sand and Silt
$\phi$ (angle of internal friction)	32°	30°
$\gamma$ (total unit weight)	20 kN/m <sup>3</sup>	20 kN/m <sup>3</sup>
$\gamma_w$ (Submerged unit weight)	10 kN/m <sup>3</sup>	10 kN/m <sup>3</sup>
$K_a$	0.31	0.33
$K_p$	3.3	3.0

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

The temporary protection system may be removed or partially removed upon completion of the work. Care must be taken when removing the sheet piles or soldier piles as to not incur damage to the subgrade of the newly installed culvert.

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



## 15. TEMPORARY MODULAR BRIDGE

A temporary modular bridge on an offline diversion route may be considered at this site during replacement of the culvert for traffic staging purposes. The modular bridge can be supported on precast concrete bearing pads founded on engineered granular fill pads at an approximate Elevation of 190.8 m. The granular fill pads should be a minimum of 1 m thick and consist of OPSS Granular A or Granular B Type II, placed in 150 mm thick lifts and compacted to 100% of the SPMDD at  $\pm 2\%$  of Optimum Moisture Content (OMC). The granular fill pads should be 1.0 m wider than the concrete bearing pads at the level of the concrete pad base and projected outward and downward at no steeper than 1H:1V. If the engineered granular fill pads are located close to the creek channel, the forward slope of the granular fill pads should be located at least 2 m behind the edge of the head slope of the creek bank.

The recommended geotechnical resistance at the ULS and SLS for a minimum 1.5 m wide concrete pad founded on the engineered granular 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 pad and the underlying Granular A or B Type II engineered fill should be calculated assuming an ultimate coefficient of friction of 0.5.

## 16. EMBANKMENT RESTORATION

Provided that the embankment is reconstructed with side slopes inclined not steeper than 2H:1V, the restored embankment slope should remain stable. As discussed in Section 9.3, and if there is no grade raise or embankment widening, settlement of the embankment under the existing culvert footprint should be less than 25 mm.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206. The embankment reconstruction material may consist of imported Granular A, Granular B Type II, or Granular B Type III material.

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



## 17. PAVEMENT REINSTATEMENT RECOMMENDATIONS

Pavement reinstatement designs were developed using the MTO Northwestern Region Pavement Design Chart. It is understood that the 20-year Design ESALs are estimated at 4.5 million, with culvert backfill materials assumed to be granular material meeting OPSS Granular B (Type II or III) subbase requirements. The required pavement reinstatement that is to support these conditions should comprise:

50 mm	Superpave 12.5 Surface Course
40 mm	Superpave 12.5 Upper Binder Course
40 mm	Superpave 12.5 Lower Binder Course
150 mm	Granular A Base
300 mm	Granular B, Type II or III Subbase

The asphalt mix shall be designed in accordance with OPSS.PROV 313 and OPSS.PROV 1151. It is understood that pavement reinstatement should be designed to support 20-year ESALs of 4.5 million ESALs, designating a Traffic Category C for the Superpave 12.5 asphalt mix.

The performance grade (PG) asphalt cement for the asphalt mix shall be PG 58-34, in accordance with OPSS.PROV 1101.

All granular base material shall consist of new OPSS Granular A, while the new granular subbase material shall consist of new OPSS Granular B, Type II or III. All granular material shall meet the requirements of OPSS 1010. All granular material should be compacted in accordance with the requirements of OPSS 501, and should be carried the entire width of the roadway platform. During reinstatement of the pavement, drainage must be maintained within the existing and new granular base and subbase layers.

## 18. SCOUR AND EROSION PROTECTION

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

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



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

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

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

- The potential for corrosion on concrete foundations from the surrounding surface water is considered to be negligible. However, the high chloride content of the soil indicates that the surrounding soil may be corrosive to concrete elements. The risk of sulphate attack on concrete from the native soil or surface water is negligible. The effect of road deicing salt should also be considered while selecting the class of concrete.
- The potential for surface water corrosion on metal is considered to be mild. However, due to the low resistivity of the soil, the potential for corrosion on steel, cast iron and other metals is considered to be very severe.
- Appropriate protection measures are recommended for concrete and metal structural elements. The effect of road deicing salt should be considered while selecting the corrosion protection measures.

## **20. CONSTRUCTION CONCERNS**

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

- A suitable dewatering / unwatering system must be employed to enable culvert and wingwall construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The creek level may fluctuate and be at a 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 (i.e., as a pad for crane support). Site conditions



may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

## 21. CLOSURE

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

Thurber Engineering Ltd.

*Nancy Berg*  
Sept 11/18

Nancy Berg, Ph.D.  
Geotechnical EIT



Mark Farrant, P.Eng.  
Geotechnical Engineer



P.K. Chatterji, P.Eng., Ph.D.  
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 <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

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


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

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (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


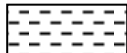



- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT      Dynamic Cone Penetration Test – Continuous 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 <sub>L</sub> < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

## EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
<b>Fresh (FR)</b>	No visible signs of weathering.		
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.		CLAYSTONE
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
<b>Completely Weathered (CW)</b>	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	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				



<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
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.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
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 17-38

1 OF 2

METRIC

W.P. 6809-14-01 LOCATION McLean's Creek Culvert, MTM NAD 83 Zone 14 N 5 411 354.2 E 272 288.6 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Solid Stem Augers/NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2017.07.25 - 2017.07.25 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>P</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE								WATER CONTENT (%)				GR
190.5	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (75mm)  Gravelly <b>SAND</b> to <b>SAND</b> and <b>GRAVEL</b> , trace silt, occasional cobbles  Very Loose to Loose Dark Brown Moist to Wet (FILL)		1	AS													19	75	6 (SI+CL)	
0.1			1	SS	2															
			2	SS	7															
			3	SS	5															
187.4	Silty <b>SAND</b> , trace gravel, trace clay Loose to Very Dense Grey Wet		4	SS	9															
3.1																				
			5	SS	35															
			6	SS	53															
			7	SS	26															

Continued Next Page

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

# RECORD OF BOREHOLE No 17-38

2 OF 2

METRIC

W.P. 6809-14-01 LOCATION McLean's Creek Culvert, MTM NAD 83 Zone 14 N 5 411 354.2 E 272 288.6 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Solid Stem Augers/NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2017.07.25 - 2017.07.25 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
Continued From Previous Page							<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><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ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 1/26/18

# RECORD OF BOREHOLE No 17-38A

1 OF 1

METRIC

W.P. 6809-14-01 LOCATION McLean's Creek Culvert, MTM NAD 83 Zone 14 N 5 411 354.2 E 272 288.6 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2017.07.25 - 2017.07.25 CHECKED BY NLB

SOIL PROFILE				SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE			WATER CONTENT (%) PLASTIC LIMIT    NATURAL MOISTURE CONTENT    LIQUID LIMIT w <sub>p</sub> w    w <sub>L</sub>				
190.5 0.0	GROUND SURFACE Start DCPT from surface												

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 1/26/18

# RECORD OF BOREHOLE No 17-39

1 OF 2

METRIC

W.P. 6809-14-01 LOCATION McLean's Creek Culvert, MTM NAD 83 Zone 14 N 5 411 336.2 E 272 274.3 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Solid & Hollow Stem Augers/NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2017.07.24 - 2017.07.24 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W <sub>P</sub> W   W <sub>L</sub>				GR   SA   SI   CL			
								20   40   60   80   100	WATER CONTENT (%)										
191.8	GROUND SURFACE																		
0.0	ASPHALT: (150mm)																		
0.2	SAND and GRAVEL, trace silt Compact Brown Moist (FILL)		1	AS			191												
			1	SS	23														
			2	SS	29		190												
			3	SS	22														
			4	SS	25														
	Dark Brown Wet		5	SS	26		187												
186.6	SAND and SILT, trace clay, trace gravel Compact Grey Wet						186												
5.2			6	SS	28														
			7	SS	14		184												
			8	SS	14		183												
181.9							182												

Continued Next Page

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

# RECORD OF BOREHOLE No 17-39

2 OF 2

METRIC

W.P. 6809-14-01 LOCATION McLean's Creek Culvert, MTM NAD 83 Zone 14 N 5 411 336.2 E 272 274.3 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Solid & Hollow Stem Augers/NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2017.07.24 - 2017.07.24 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa																		
								20	40	60	80	100						WATER CONTENT (%)								
Continued From Previous Page							○ UNCONFINED      + FIELD VANE																			
							● QUICK TRIAXIAL      × LAB VANE																			
							20					40					60									
9.9	<b>SAND</b> , trace to some silt, trace gravel Very Loose to Dense Grey Saturated  <																									

ONTMT4S MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 1/26/18

## METRIC

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



## METRIC

SOIL PROFILE						SAMPLES					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
188.9 0.0	GROUND SURFACE							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	W <sub>P</sub> W W <sub>L</sub>	kN/m <sup>3</sup>	GR SA SI C
	<b>SAND</b> and <b>GRAVEL</b> , trace silt, occasional cobbles, trace organics Dense to Compact Brown Moist (FILL)		1	AS			188				49 48 3 (SI+C)
	No recovery		1	SS	40		187				
			2	SS	17						
	Grey Wet		3	SS	16						
186.1 2.8	<b>SAND</b> and <b>SILT</b> , trace clay, trace gravel Loose to Very Dense Grey Wet		4	SS	5		186				4 47 43 6
							185				
			5	SS	8		184				
							183				
			6	SS	54		182				
							181				
			7	SS	52		180				0 52 38 1
			8	SS	60		179				

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

# RECORD OF BOREHOLE No 17-40

2 OF 2

METRIC

W.P. 6809-14-01 LOCATION McLean's Creek Culvert, MTM NAD 83 Zone 14 N 5 411 323.6 E 272 294.2 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Solid Stem Augers/NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2017.07.26 - 2017.07.26 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								20 40 60 80 100						

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

# RECORD OF BOREHOLE No 17-41

1 OF 1

METRIC

W.P. 6809-14-01 LOCATION McLean's Creek Culvert, MTM NAD 83 Zone 14 N 5 411 335.2 E 272 289.9 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.07.24 - 2017.07.24 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
191.6	GROUND SURFACE																
0.0	ASPHALT: (150mm)																
0.2	SAND and GRAVEL, trace silt Brown Moist (FILL)		1	AS													
188.9	Loose		1	SS	5											42 54 4 (SI+CL)	
2.7	END OF BOREHOLE AT 2.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																

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



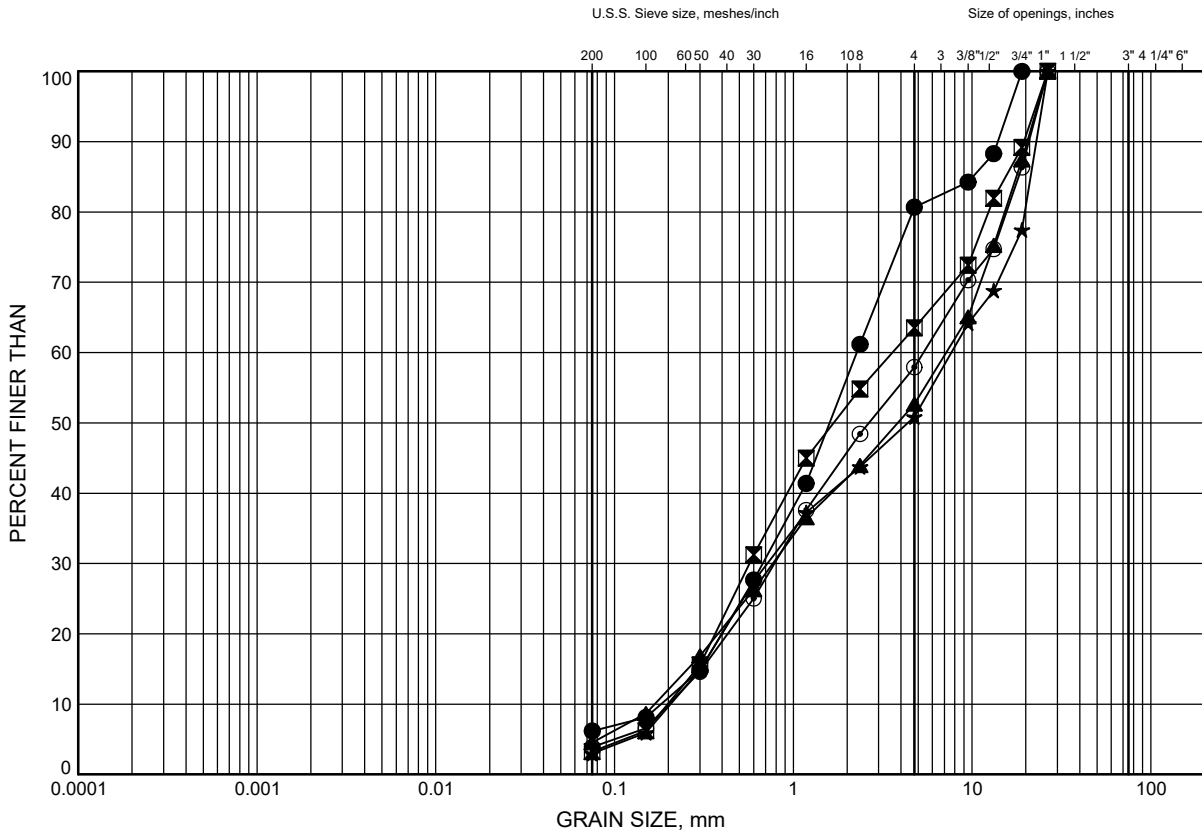
## **Appendix B**

### **Laboratory Test Results**

# McLean's Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

## SAND and GRAVEL FILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-38	0.3	190.2
⊠	17-38	2.6	187.9
▲	17-39	1.8	190.0
★	17-40	1.1	187.8
⊙	17-41	2.4	189.2

Date January 2018  
W.P. 6809-14-01

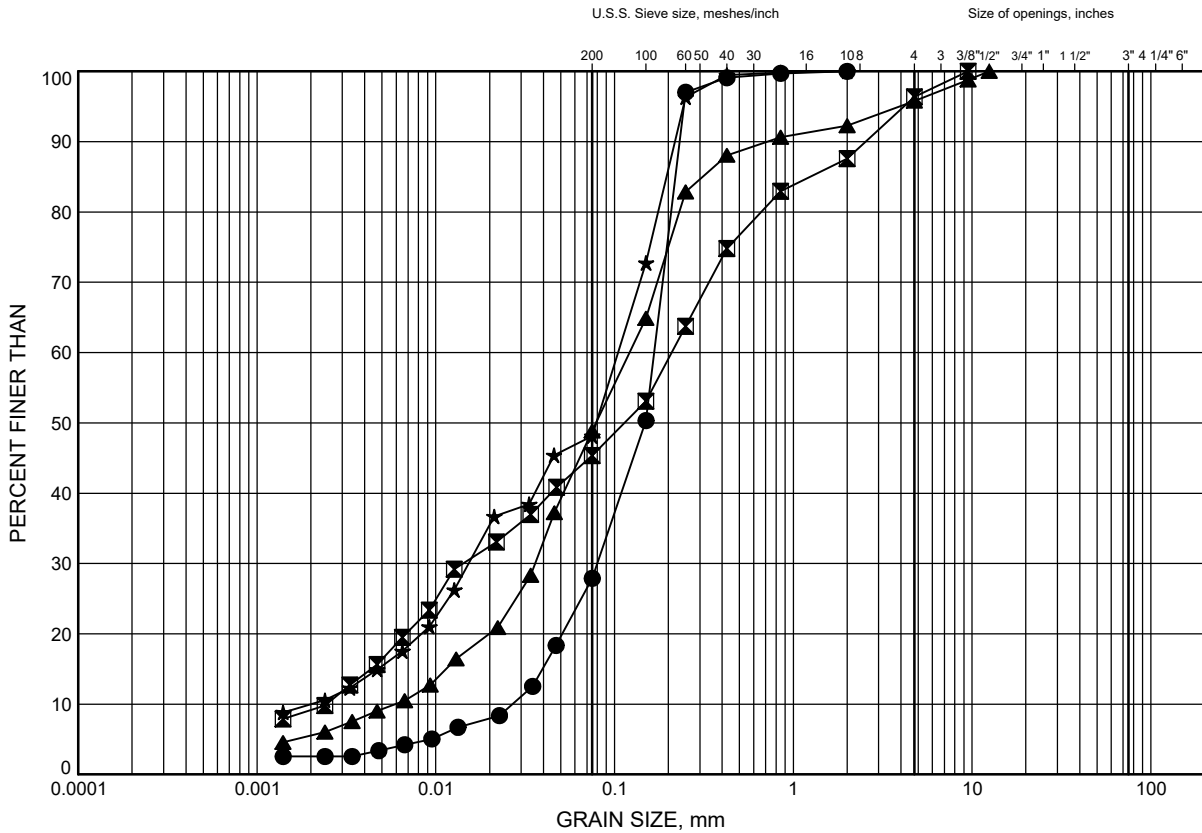


Prep'd AN  
Chkd. MEF

# McLean's Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

## Silty SAND to SAND and SILT



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-38	4.9	185.6
⊠	17-39	6.4	185.4
▲	17-40	4.7	184.2
★	17-40	9.3	179.6

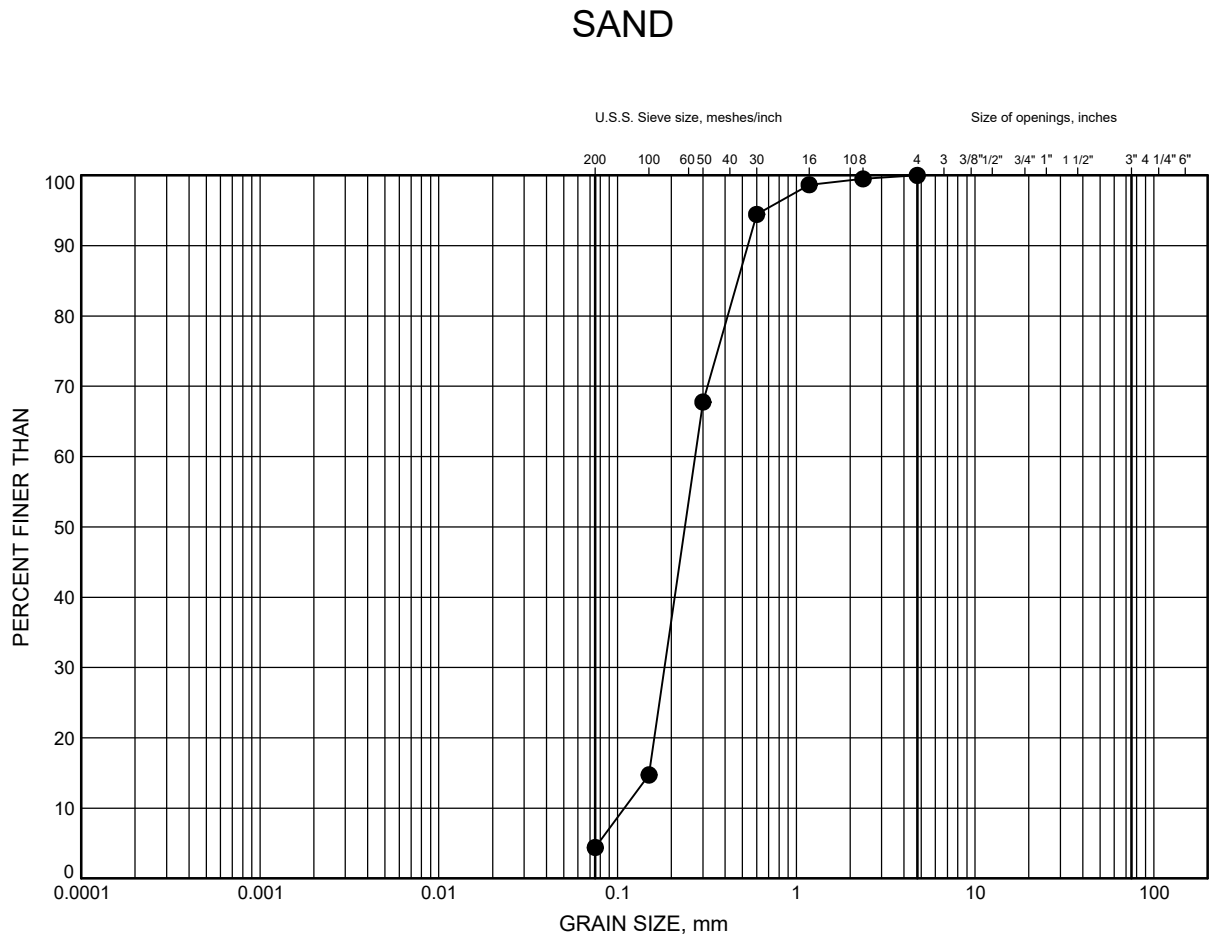
Date January 2018  
W.P. 6809-14-01



Prep'd AN  
Chkd. MEF

# McLean's Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-39	11.0	180.8

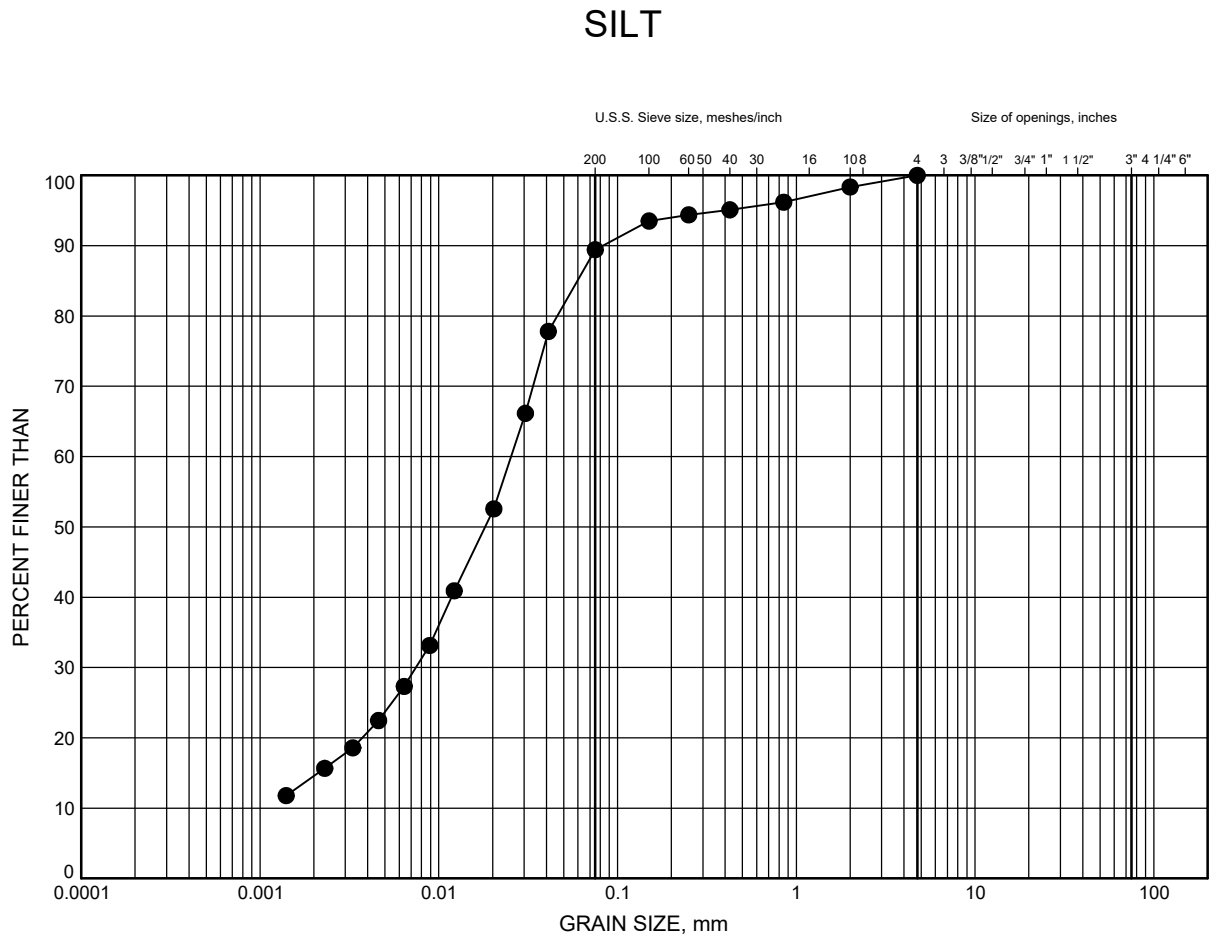
Date March 2018  
W.P. 6809-14-01



Prep'd AN  
Chkd. MEF

# McLean's Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B4



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-38	11.0	179.5

Date January 2018  
W.P. 6809-14-01



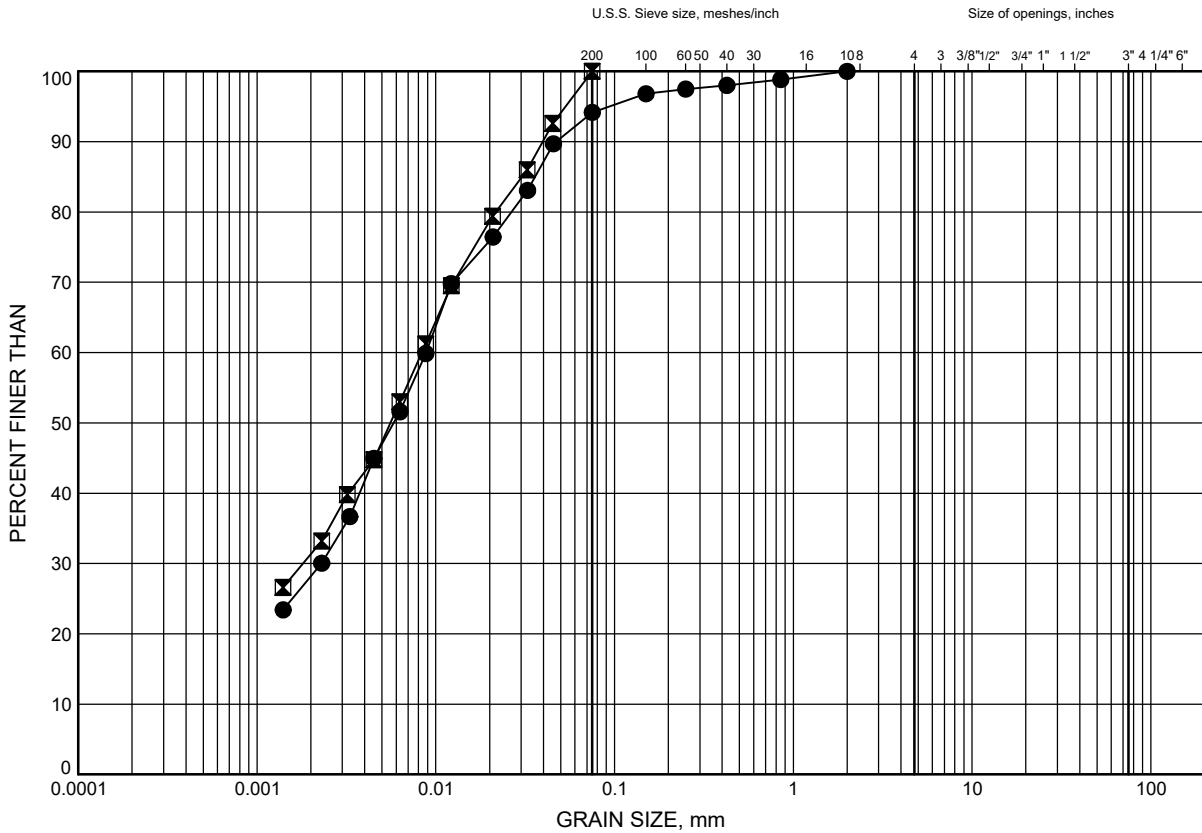
Prep'd AN  
Chkd. MEF



# McLean's Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B5

Silty CLAY



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-38	15.5	175.0
⊠	17-39	15.5	176.3

Date January 2018  
W.P. 6809-14-01

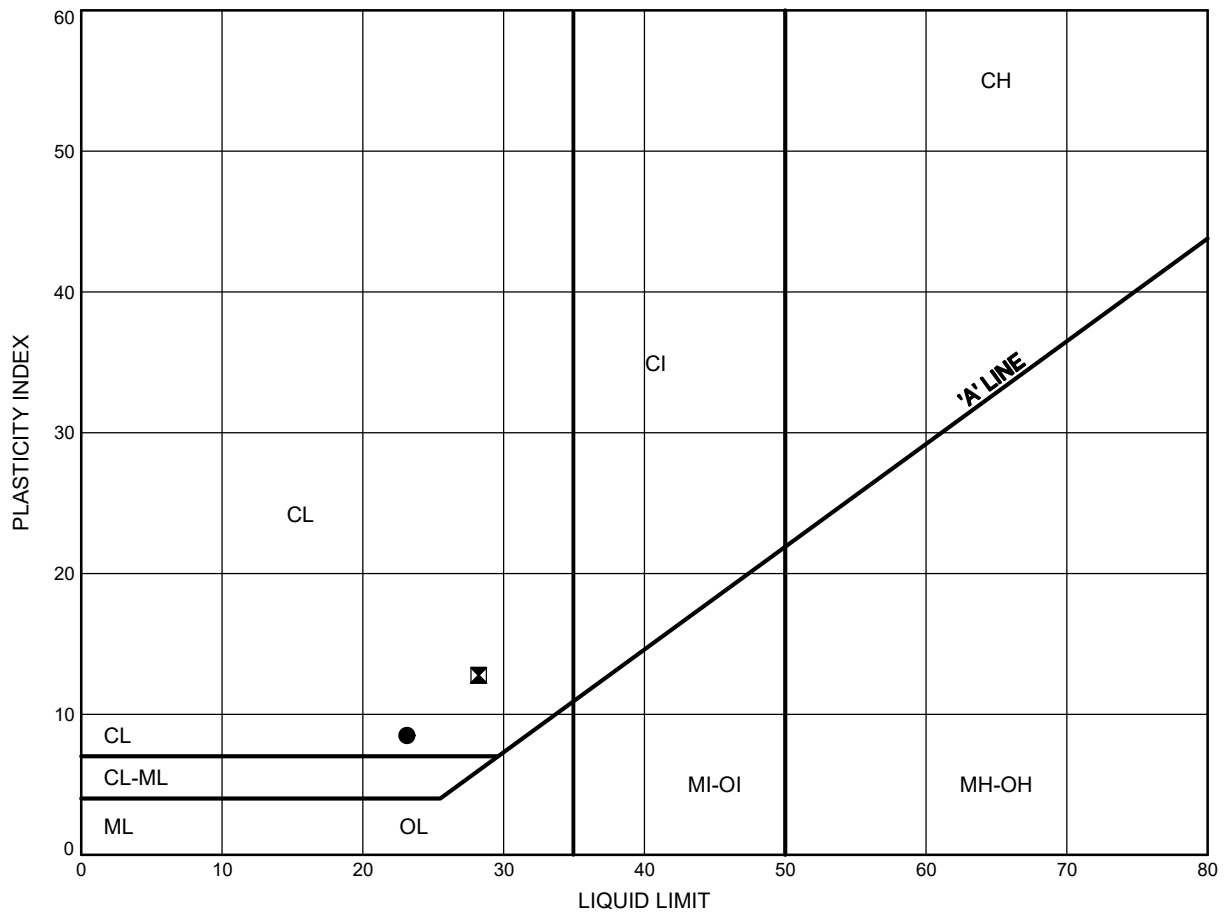


Prep'd AN  
Chkd. MEF

McLean's Creek Culvert  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B6

Silty CLAY



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-38	15.5	175.0
⊠	17-39	15.5	176.3

Date January 2018  
 W.P. 6809-14-01



Prep'd AN  
 Chkd. MEF



**ASTM D5731-08**

Date Drilled:	July 26/17
Date Tested:	Aug 23/17
Tester:	ISP
Reviewed by:	MEF

[illegible]

## Certificate of Analysis

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



Client  
SGS LIMS Number  
Analysis Package:

Attention: Mark Farrant  
Project#: 15595  
Thurber Engineering Ltd.  
CA14253-SEP17  
Corrosivity (Soil)

Sample ID	Unit	BH-39, SS#5, 10'-12'
Sample Date/Time		24-Jul-17
Moisture	%	9.9
pH	no unit	6.17
Corrosivity Index	none	11.0
Soil Redox Potential	mV	276
Sulphide	mg/L	<0.02
Chloride	mg/L	1500
Sulphate	mg/L	37
Conductivity	uS/cm	1520
Resistivity (calculated)	ohms.cm	656

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

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(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.



## FINAL REPORT

CA12892-JUL17 R

Prepared for

**Thurber Engineering Ltd.**

## First Page

## CLIENT DETAILS

Client                   Thurber Engineering Ltd.

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

Contact                Mark Farrant

Telephone             905-829-8666 x 228

Facsimile

Email                   mfarrant@thurber.ca

Project

Order Number

Samples               Water (2)

## LABORATORY DETAILS

Project Specialist     Deanna Edwards, B.Sc, C.Chem

Laboratory            SGS Canada Inc.

Address                185 Concession St., Lakefield ON, K0L 2H0

Telephone             705-652-2000

Facsimile             705-652-6365

Email                   deanna.edwards@sgs.com

SGS Reference         CA12892-JUL17

Received               07/28/2017

Approved              01/23/2018

Report Number        CA12892-JUL17 R

Date Reported         01/23/2018

## COMMENTS

Temperature of Sample upon Receipt: 23 degrees C

Cooling Agent Present: Yes

Custody Seal Present: Yes

## SIGNATORIES

Deanna Edwards, B.Sc, C.Chem





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Legend..... 8

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# FINAL REPORT

CA12892-JUL17 R

**Client:** Thurber Engineering Ltd.

**Project:**

**Project Manager:** Mark Farrant

**Samplers:** John Zoldy

## PACKAGE: REG153 - 1.3 Other (ORP) (WATER)

**Sample Number** 6  
**Sample Name** 15595 McLeans  
Creek  
**Sample Matrix** Water  
**Sample Date** 26/07/2017

Parameter	Units	RL	Result
<b>1.3 Other (ORP)</b>			
pH	units	0.05	7.17

## PACKAGE: REG153 - Corrosivity Index (WATER)

**Sample Number** 6  
**Sample Name** 15595 McLeans  
Creek  
**Sample Matrix** Water  
**Sample Date** 26/07/2017

Parameter	Units	RL	Result
<b>Corrosivity Index</b>			
Resistivity (calculated)	ohms.cm	-9999	30300

## PACKAGE: REG153 - Metals and Inorganics (WATER)

**Sample Number** 6  
**Sample Name** 15595 McLeans  
Creek  
**Sample Matrix** Water  
**Sample Date** 26/07/2017

Parameter	Units	RL	Result
<b>Metals and Inorganics</b>			
Conductivity	µS/cm	2	33
Chloride	mg/L	0.04	0.39
Sulphate	mg/L	0.04	2.0





FINAL REPORT

CA12892-JUL17 R

Client: Thurber Engineering Ltd.

Project:

Project Manager: Mark Farrant

Samplers: John Zoldy

PACKAGE: REG153 - UNDEFINED (WATER)

Sample Number 6  
Sample Name 15595 McLeans  
Creek  
Sample Matrix Water  
Sample Date 26/07/2017

Parameter	Units	RL	Result
UNDEFINED			
Redox Potential	mV	-	198
Sulphide	mg/L	0.006	< 0.006



FINAL REPORT

CA12892-JUL17 R

QC SUMMARY

Anions by IC  
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0425-JUL17	mg/L	0.04	<0.04	11	20	97	80	120	99	75	125
Sulphate	DIO0425-JUL17	mg/L	0.04	<0.04	0	20	99	80	120	98	75	125
Chloride	DIO0438-JUL17	mg/L	0.04	<0.04	1	20	99	80	120	111	75	125
Sulphate	DIO0438-JUL17	mg/L	0.04	<0.04	1	20	94	80	120	103	75	125

Conductivity  
Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0430-JUL17	µS/cm	2	< 2	0	10	100	90	110	NA		



FINAL REPORT

CA12892-JUL17 R

QC SUMMARY

pH  
Method: SM 4500 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0431-JUL17	no unit	0.05	NA	0		100			NA		

Redox Potential  
Method: SM 2580 |

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Redox Potential	EWL0428-JUL17	mV	no	NA	5	20	109	80	120	NA		

Sulphide by SFA  
Method: SM 4500 | Internal ref.: ME-CA-IENVISFA-LAK-AN-008

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	SKA0007-AUG17	mg/L	0.006	<0.006	ND	20	98	80	120	102	75	125

## QC SUMMARY

---

**Method Blank:** a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

**Duplicate:** Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

**LCS/Spike Blank:** Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

**Matrix Spike:** A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

**Reference Material:** a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

**RL:** Reporting limit

**RPD:** Relative percent difference

**AC:** Acceptance criteria

**Multielement Scan Qualifier:** as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

**Duplicate Qualifier:** for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

**Matrix Spike Qualifier:** for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

## LEGEND

### FOOTNOTES

**NSS** Insufficient sample for analysis.

**RL** Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

**NA** The sample was not analysed for this analyte

**ND** Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

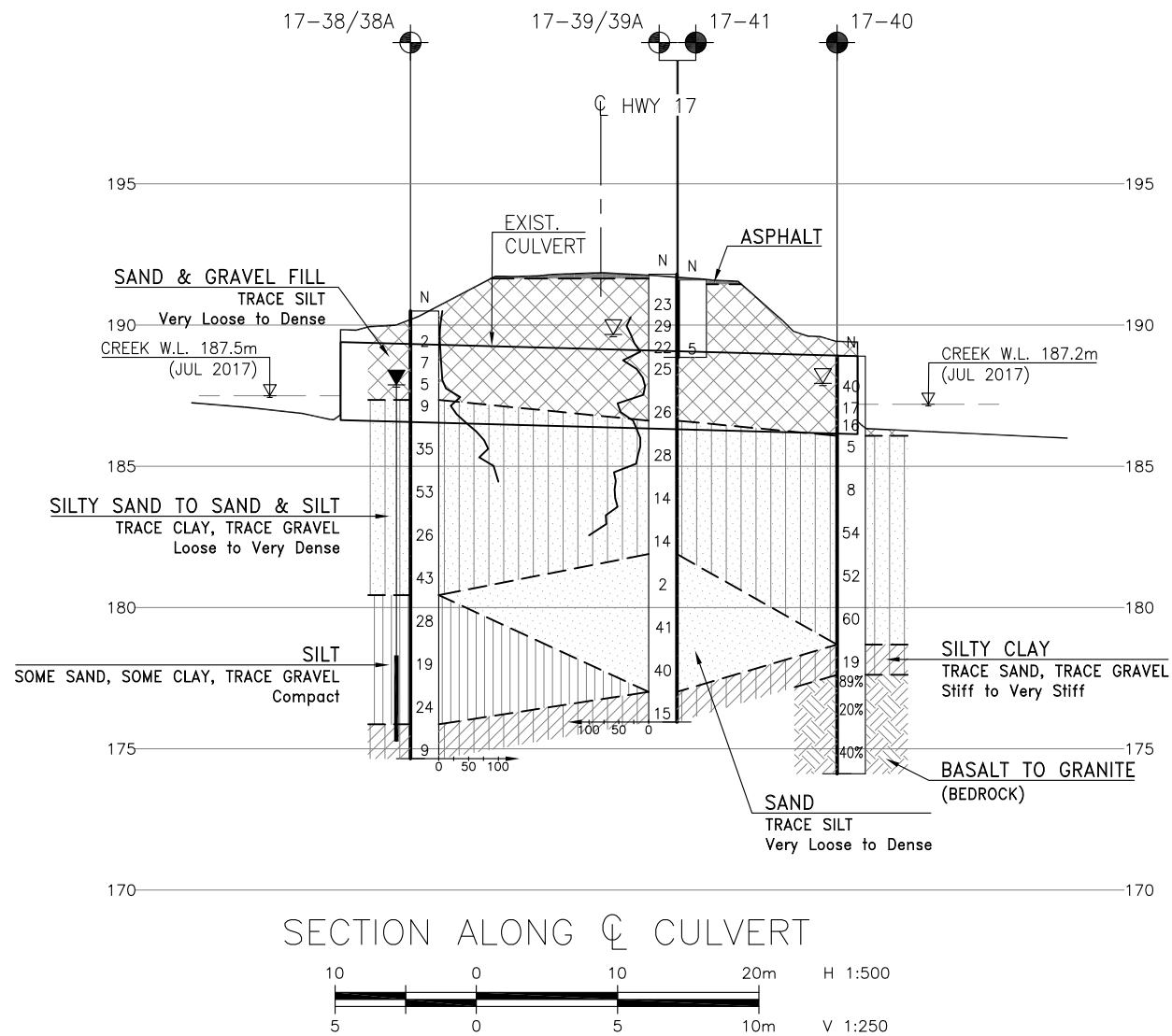
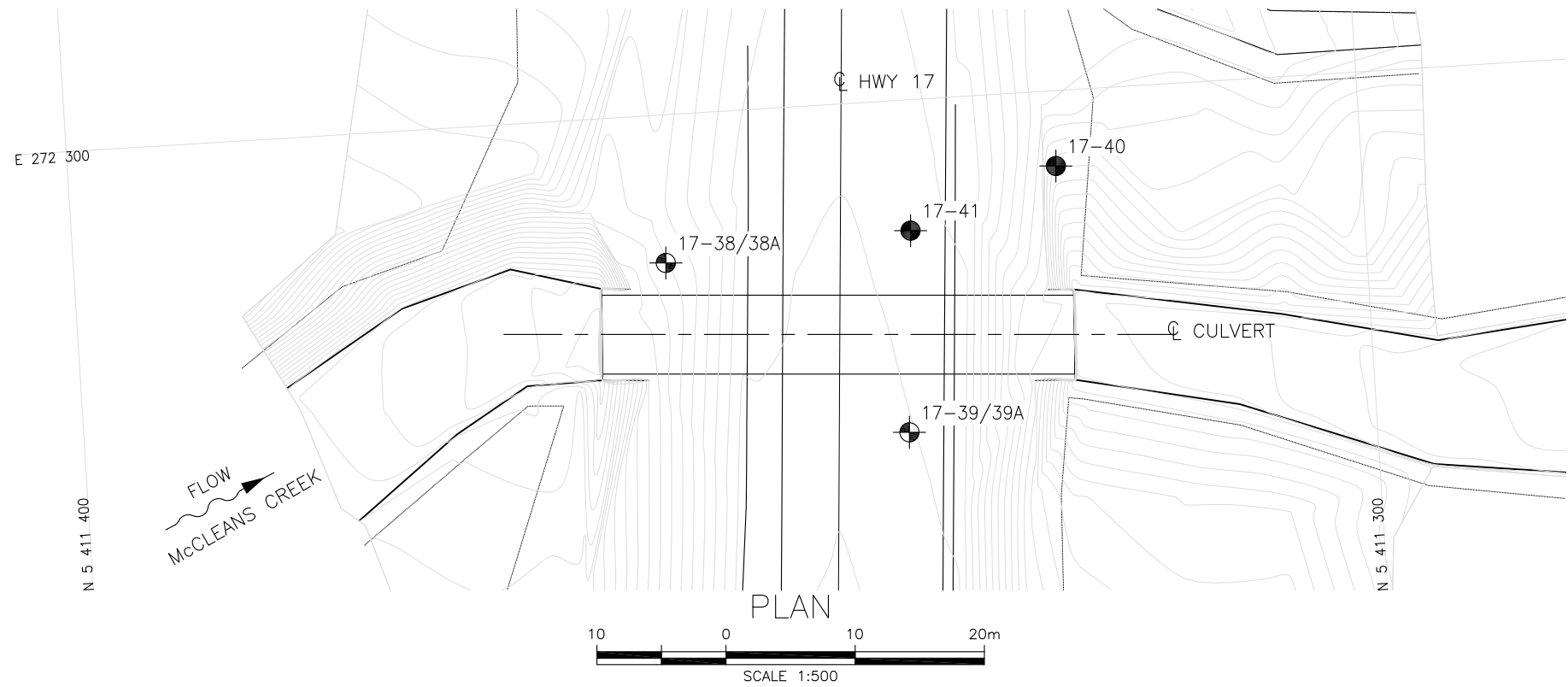
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-- End of Analytical Report --



## **Appendix C**

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



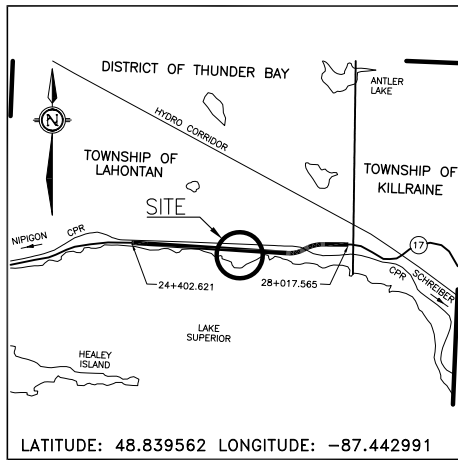
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 6809-14-01

HIGHWAY 17  
MCLEAN'S CREEK  
CULVERT  
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH

THURBER ENGINEERING LTD.



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
- W Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-38/38A	190.5	5 411 354.2	272 288.6
17-39/39A	191.8	5 411 336.2	272 274.3
17-40	188.9	5 411 323.6	272 294.2
17-41	191.6	5 411 335.2	272 289.9

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 14

GEOCRES No. 42D-53



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	NLB	CHK MEF	CODE
DRAWN	AN	CHK NLB	SITE 48C-178C STRUCT
			LOAD
			DATE
			SEP 2018
			DWG 1



## **Appendix D**

### **Site Photographs**





**Photo 1: Road approach looking east (May 18, 2017)**



**Photo 2: Road approach looking west (May 18, 2017)**





**Photo 3: Culvert Inlet looking south (July 24, 2017)**



**Photo 4: Culvert outlet looking north, showing delamination of soffit and scaling and spalling of lower wall (June 14, 2013)**





**Photo 5: Looking east at north side of road (inlet) (July 24, 2017)**



**Photo 6: Looking west at north side of road (inlet) (July 24, 2017)**





**Photo 7: Looking east on south side of road (outlet) (July 26, 2017)**



**Photo 8: Looking west on south side of road (outlet) (July 26, 2017)**





## **Appendix E**

### **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 313 (Construction Specification for Hot Mix Asphalt - End Result)
- OPSS PROV 401 (Construction Specification for Trenching, Backfilling and Compacting)
- OPSS 421 (Pipe Culvert Installation in Open Cut)
- OPSS 422 (Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, And Granular Sheeting)
- OPSS 517 (Construction Specification for Dewatering)
- SP 517F01 (Temporary Flow Passage System)
- OPSS PROV 539 (Construction Specification for Temporary Protection Systems)
- OPSS PROV 804 (Construction Specification for Seed and Cover)
- OPSS 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 1101 (Material Specification for Performance Graded Asphalt Cement)
- OPSS PROV 1151 (Material Specification for Superpave And Stone Mastic Asphalt Mixtures)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSD 208.010 (Benching of Earth Slopes)



- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.014 (Flexible Pipe Embedment in Embankment)
- OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock)
- OPSD 803.010 (Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m)
- 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 Depths for Northern Ontario)

## **2. Suggested Wording for NSSP**

- **Suggested Text for Notice to Contractor on “Dewatering”**

Dewatering will be required to install the new culvert and the diversion pipe in the dry. The design of an effective dewatering system is the responsibility of the contractor. The dewatering system must be effective to lower the groundwater table at a minimum of 0.5 m below the final subgrade level to avoid basal heave and base boiling. The dewatering system is to be designed in accordance with SP FOUN0003, OPSS.PROV. 517 and SP517F01. A preconstruction survey is not required. A dewatering engineer with a minimum of 5 years of experience in designing dewatering systems shall be retained by the contractor for design of an effective dewatering system.

- **Suggested Wording for NSSP on “Approval Process for RSS Walls”**

The RSS wall types listed on the MTO DSM are not pre-approved for use within or adjacent to watercourses or floodplains. If consideration is given to the use of an RSS wall at this site then the Contractor will be required to submit a project/site specific design submission to the



MTO RSS Committee for approval. The Contractor will need to assume a minimum of 8-weeks of review time by the MTO RSS Committee. The submission shall include working drawings, supporting design documentations and commentary which will specifically address the proposed RSS design with respect to the following:

- RSS embedment depth and scour protection;
- Backfill material and the control of migration of fines;
- Performance in differential hydrostatic pressures;
- Pullout capacity and frictional resistance between reinforcements and select backfill under fully saturated conditions; and,
- CHBDC structure design requirement for a 75-year service life – stability, durability, long-term performance.



## **Appendix F**

### **Comparison of Alternative Culvert Types**



### **COMPARISON OF ALTERNATIVE CULVERT TYPES**

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