



THURBER ENGINEERING LTD.

**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
BLACKBIRD CREEK CULVERT REPLACEMENT
HIGHWAY 17, UNSURVEYED TERRITORY
THUNDER BAY DISTRICT, ONTARIO
LATITUDE: 48.845825°, LONGITUDE: -87.037083**

G.W.P. 6808-14-00, W.P. 6808-14-01, SITE No. 48E-052C

GEOCRES Number: 42D-50

Report

to

HATCH

Date: September 7, 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 Blackbird Creek Culvert on Highway 17, located east of the township of Terrace Bay, 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 9 km east of the township of Terrace Bay, Ontario. The culvert allows Blackbird Creek to flow from the southeast to the northeast under Highway 17. Highway 17 generally runs in a northeast-southwest direction at the culvert site with the culvert running perpendicular to the roadway.

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, 1.8 m high and 30.6 m long. The culvert barrel is in overall poor condition with light to medium erosion along the bottom 0.7 m of both side walls. The side wall erosion is severe in some locations. There is a 750 mm long crack near the inlet on the west wall. Medium scaling and cracking were observed in the soffit, and severe scaling was observed on the southeast wall. The water level in the creek on June 7, 2016 was reported at approximate Elevation 205.6 m upstream of the inlet and 204.6 m downstream of the outlet.



The grade level of Highway 17 at the existing culvert is at an elevation of 209 m. The invert elevation (southeast) is approximately 204.4 m, and the outlet elevation (northwest) is approximately 204.2 m. The height of fill above the existing culvert is approximately 3 m.

The area on either side of the creek near the inlet and outlet of the culvert is vegetated with tall grass and trees, and the overall surrounding area is densely forested. There are also pine trees and grass growing on top of the culvert at the inlet and 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 August 20 and September 17, 2017, during which time four boreholes denoted as Boreholes 17-34 to 17-37 were drilled at selected locations at the culvert site. Boreholes 17-35 and 17-37 were located within the westbound lane of Highway 17 on either side of the culvert. Borehole 17-36 was located near the inlet of the culvert and 17-34 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 Boreholes 17-35 to 17-37 and a Hilti DD 250 E portable drill was used to drill Borehole 17-34. The boreholes were advanced using hollow stem and solid stem augers and wash boring techniques to depths between 2.1 m and 18.9 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). In locations where soft clay was observed, field vane shear tests were performed to measure the undrained shear strength of the soil. A dynamic cone penetration test (DCPT) was conducted at Borehole 17-36 from a depth of 13.4 m to 15.8 m. The results of the boreholes and DCPT are presented on the Record of Borehole sheets 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 in the open boreholes throughout the drilling operations and in a standpipe piezometer that was installed in Borehole 17-36. The standpipe piezometer consisted of a 25 mm diameter PVC pipe, with a 3 m long slotted screen installed to a depth of 11.2 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:

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
17-34	15.3/190.1	None Installed	Bentonite holeplug and cuttings to surface and covered with gravel
17-35	18.9/190.1	None Installed	Cuttings to 0.9 m, then dry cement to 0.1 m and asphalt to surface
17-36	15.8/190.1	11.2/194.7	Sand to 7.9 m, then bentonite holeplug and cuttings to surface
17-37	2.1/206.9	None Installed	Cuttings to 0.75 m, then concrete to 0.15 m and 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. 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.



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, topsoil and fill overlying varying thicknesses of silty sand, which was in turn underlain by silty clay and lower silty sand and sand layers. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes 17-35 and 17-37 were drilled through the westbound lane of Highway 17 and encountered a 140 to 150 mm thick layer of asphalt.

5.2 Fill

Fill material was encountered below the asphalt in Boreholes 17-35 and 17-37. The fill consisted of sand and gravel to gravelly sand, underlain by sand and silt fill. The fill layer was 2.9 m thick at Borehole 17-35 and extended to an Elevation of 205.9 m. Borehole 17-37 was terminated within the fill layer at a depth of 2.1 m (Elevation 206.9 m).

5.2.1 Sand and Gravel to Gravelly Sand Fill

A 1.2 m and 1.4 m thick layer of sand and gravel to gravelly sand was encountered in Boreholes 17-35 and 17-37 respectively.

SPT 'N' values within the sand and gravel to gravelly sand fill ranged from 64 to 80 blows per 0.3 m of penetration, indicating a very dense relative density. Moisture contents between 4 percent and 7 percent were measured in the granular 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 of Appendix B. The results of the grain size distribution analyses are summarized below:



Soil Particle	Percentage (%)
Gravel	22 to 42
Sand	50 to 59
Silt	15
Clay	4
Silt and Clay	8

5.2.2 Sand and Silt Fill

A 1.7 m thick layer of sand and silt fill was encountered below the sand and gravel fill in Borehole 17-35. Borehole 17-37 was terminated in the sand and silt fill at an elevation of 206.9 m.

SPT 'N' values within the sand and silt fill ranged from 10 to 26 blows per 0.3 m of penetration, indicating a compact relative density. Moisture contents between 14 percent and 19 percent were measured in the fill.

The results of grain size distribution analyses carried out on a selected sample of the sand and silt fill 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
Sand	34
Silt	63
Clay	3

5.3 Topsoil

Boreholes 17-34 and 17-36, which were drilled near the existing outlet and inlet of the culvert, encountered a surficial layer of topsoil that contained some sand, silt and roots. The topsoil layer was 0.6 m thick and extended to approximate Elevation 204.8 m to 205.3 m. A 2.5 m thick buried topsoil layer was encountered below the fill in Borehole 17-35 from a depth of 3.1 m to 5.6 m (base Elevation 203.4 m). The buried topsoil was mixed with inorganic soil and was sandy with occasional silt pockets, rootlets and wood fragments.



SPT 'N' values within the topsoil ranged from 4 to 9 blows per 0.3 m of penetration, indicating a very loose to loose consistency. The moisture content of the topsoil ranged from 11 percent to 65%.

5.4 Upper Silty Sand

An upper silty sand layer with some clay and occasional wood fragments was encountered in Boreholes 17-34 and 17-36 at Elevations 203.9 and 205.3 m respectively. The thickness of the silty sand layer was 2.6 m at Borehole 17-34 and 0.8 m at Borehole 17-36. The silty sand layer extended to elevations of 201.3 (17-34) and 204.5 m (17-36).

The SPT 'N' values for the silty sand ranged from 3 to 6 blows per 0.3 m penetration indicated a very loose to loose relative density. The silty sand had a measured moisture content ranging from 35 percent to 46 percent.

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

Soil Particle	Percentage (%)
Gravel	0
Sand	58
Silt	29
Clay	13

5.5 Silty Clay

An upper layer of silty clay with some sand to sandy was encountered below the topsoil in Boreholes 17-34 and 17-35 and extended to depths of 1.5 m (Elevation 203.9 m) and 7.2 m (Elevation 201.8 m) respectively. The thickness of the upper silty clay layer ranged for 0.9 m to 1.6 m. A layer of silty clay with trace to some sand was encountered below the upper silty sand deposit in Boreholes 17-34 to 17-36. The depth to the top of the silty clay layer ranged from 1.4 to 7.2 m (204.5 to 201.3). The thickness of the silty clay layer ranged from 6.8 to 8.8 m, and extended to depths of 10.2 to 14.0 m (Elevation 195.7 to 192.9 m).

SPT 'N' values ranging from 0 (weight of hammer) to 5 blows per 0.3 m penetration were recorded. In situ field vane tests measured undrained shear strengths ranging from 7 to 30 kPa (typically 10 to 30 kPa). Therefore, the silty clay is considered to generally have a very soft to firm



consistency. The sensitivity of the clay was measured to range between 1.1 and 3.5, indicating low to medium sensitivity. The silty clay had a measured moisture content ranging from 15 percent to 62 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 Figure B4 and B6 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	0
Silt	22 to 75
Clay	25 to 78

The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Plastic Limit	17 to 25
Liquid Limit	28 to 74
Plasticity Index	10 to 49

The results of the Atterberg Limits testing indicate the layer to be of low to high plasticity with group symbol CL, CI and CH.

5.6 Lower Silty Sand

A lower layer silty sand with trace gravel underlaid the silty clay layer in Boreholes 17-34, 17-35 and 17-36. The silty sand layer extended to depths ranging from 12.0 m to 17.1 m (Elevation 193.9 to 190.6 m) and had a thickness ranging from 1.8 m to 3.1 m.

SPT 'N' values within the silty sand deposit ranged from 0 (weight of hammer) to 18 blows per 0.3 m of penetration, indicating a very loose to compact relative density. Measured moisture contents within the silty sand deposit varied between 15 percent and 19 percent.

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



Soil Particle	Percentage (%)
Gravel	1
Sand	75
Silt and Clay	24

5.7 Sand

A sand layer with trace to some gravel and some silt was encountered below the lower silty sand layer in Boreholes 17-34 to 17-36 at depths ranging from 12.0 m to 17.1 m (Elevation 193.9 to 190.6 m). All three boreholes were terminated in the sand layer at depths ranging from 13.4 m to 18.9 (Elevation 192.5 to 190.1 m).

SPT 'N' values within the sand deposit ranged from 6 to over 100 blows per 0.3 m of penetration, indicating a loose to very dense relative density. Measured moisture contents within the sand deposit varied between 11 percent and 19 percent.

The results of grain size distribution analyses testing carried out on a selected sample of the sand are presented on the Record of Borehole sheets included in Appendix A and on Figure B5 Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	4
Sand	87
Silt and Clay	9

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 17-36 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	
17-34	August 17, 2017	Dry	Dry	Open Borehole
17-35	August 20, 2017	3.7	205.3	Open borehole
17-36	August 28, 2017	0.6	205.3	Standpipe piezometer
17-37	August 20, 2017	Dry	Dry	Open borehole

The creek water level on June 7, 2016, was reported to be Elevation 205.6 m upstream of the inlet and 204.6 m downstream of the outlet.

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

6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native silty sand from Borehole 17-36 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	
			17-36, SS#2, 0.8 m – 1.4 m	Blackbird Creek
			(Silty Sand)	(Creek Water)
Sulphide	mg/L	mg/L	<0.02	0.08
Chloride	mg/L	mg/L	340	110
Sulphate	mg/L	mg/L	10	180
pH	No unit	No unit	7.99	7.78
Electrical Conductivity	µS/cm	µS/cm	397	1180
Resistivity	Ohms.cm	Ohms.cm	2520	847
Redox Potential	mV	mV	137	224



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 to complete Boreholes 17-35 to 17-37 and Ohlmann Geotechnical Services (OGS) of Almonte, Ontario supplied and operated the drilling, sampling and in-situ testing equipment to complete Borehole 17-34. The field investigation was supervised on a full-time basis by Mr. Ty Tonus-Burman 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.

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HIGHWAY 17, UNSURVEYED TERRITORY
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G.W.P. 6808-14-00, W.P. 6808-14-01, SITE No. 48E-052C**

GEOCRES Number: 52D-50

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 Blackbird Creek Culvert replacement on Highway 17, located east of the township of Terrace Bay, in the 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, 1.8 m high and is 30.6 m long. The estimated culvert invert is at approximate Elevation 204.4 m at the inlet (southeast) and 204.2 m at the outlet (northwest). The existing road grade at the culvert location is at approximate Elev. 209 m, which indicates approximately 3.0 m of fill above the culvert.

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A Preliminary General Arrangement Drawing and discussions with Hatch indicate that the replacement options being considered at this site consist of a precast concrete box culvert or twin structural plate corrugated steel pipe culverts. The precast concrete box culvert option consists of a 7.6 m wide opening, 3.0 m high, 32.9 m long culvert with a proposed invert level (underside of box) at an approximate Elevation of 203.0 m at the inlet and 202.8 m at the outlet. The structural plate corrugated steel pipe (SPCSP) option would consist of two parallel 31.5 m long SPCSP culverts with a diameter of 4.0 m with a proposed invert level (outside of bottom of pipe) at an approximate Elevation of 203.3 m at the inlet and 203.2 m at the outlet.

For both options the new culvert will be installed along the same alignment as the existing culvert. A temporary creek diversion pipe is to be located approximately 15 m west of the culvert centreline while the culvert is being installed. The invert level of the diversion pipe is approximately at Elevation 204.2 m. No grade raise or embankment widening are anticipated. No wingwalls/headwalls are present at the existing culvert, and it is not known if any wingwalls/headwalls will be required for the replacement culvert.

Temporary roadway protection is being considered during installation of the culvert, as well as an offline diversion route using a temporary modular bridge.

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, Corrugated steel pipe (CSP) or Structural Plate Corrugated Steel Pipe (SPCSP)
- 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 to the low geotechnical capacities in the loose silty sand and silty clay foundation soils, the greater potential for differential settlement, and the need for deeper excavation in cohesionless soil below the water table and additional dewatering effort to provide adequate frost protection.

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

9.2 Summary of Subsurface Conditions

In general, the subsurface conditions encountered in the boreholes from the current investigation consisted of approximately 150 mm of asphalt overlaying 2.1 to 2.9 m of granular fill that is underlain by buried topsoil, silty sand and a thick deposit of silty clay. The clay was further underlain by silty sand and sand layers.

Water levels measured in the open boreholes and standpipe piezometer were approximately 205.3 m. The creek water level on June 7, 2016, was reported to be Elevation 205.6 m upstream of the inlet and 204.6 m downstream of the outlet.

9.3 Foundation Design for Culverts

The invert level of the proposed culvert is at approximate Elevation 202.8 m to 203.3 m. The founding soils encountered at this level consist of very soft to firm silty clay and very loose to loose silty sand. There is up to approximately 2.2 m of fill above the proposed culvert replacement.

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, CSPs or SPCSPs at 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, CSPs, or SPCSPs 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 Class II, and have a fabric opening size (FOS) not greater than 212 μm .

The underside of the bedding layer should be placed at or below Elevation 203.0 m, which corresponds to very soft to firm silty clay and very loose to loose silty sand subgrade. Any buried topsoil, excessively loose soil, large cobbles and boulders, and any soft, very loose organic or other deleterious 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 one or twin concrete box culverts 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 OPSD 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 Class II, and have a fabric opening size (FOS) not greater than 212 μm . 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 202.5 m, which corresponds to a very soft to firm silty clay and very loose to loose silty sand subgrade. Any buried topsoil, excessively loose soil, large cobbles and boulders, and any soft, very loose organic or other deleterious 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 box culvert with an 8 to 9 m bearing width founded at or below Elevation 202.6 m on the very soft to firm silty clay and very loose to loose silty sand:

Geotechnical Resistance	8 to 9 m wide Culvert
Factored Geotechnical Resistance at ULS	110 kPa
Geotechnical Resistance at SLS (for up to 25 mm settlement)	70 kPa

The geotechnical capacity can be increased if required by excavating to Elevation 201.6 m and placing an additional 1 m thick layer of compacted Granular A or Granular B Type II below the culvert. In this case, the factored geotechnical resistance at ULS can be increased to 165 kPa, and the geotechnical resistance at SLS can be increased to 130 kPa, for up to 25 mm of settlement.

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

A grade raise or embankment widening would cause settlement of the soft clay foundation, and therefore should be avoided.

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 very soft to firm silty clay and very loose to loose silty sand subgrade at or below an approximate elevation of 203.0. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 90 kPa and a geotechnical reaction at SLS of 60 kPa (for up to 25 mm of settlement). 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 silty sand, 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 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 very soft to firm native silty clay and very loose to loose native silty sand subgrade. Any buried topsoil, 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 202.0 m or lower. A factored geotechnical resistance at ULS of 90 kPa and a geotechnical reaction at SLS of 60 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 0.30 for the very soft to firm silty clay and very loose to loose silty sand.

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.

As moderately frost susceptible soils were encountered within the existing embankment, and it is anticipated that backfill of the new culvert will be completed using granular material, it is recommended that frost tapers be constructed in accordance with OPSD 803.031. Provided existing granular fill, Granular B Type II (or Type III), or Granular A material shall be used to backfill the excavation, the “d” value should be 1.4 m, and a “k” value should equal to the frost depth of 2.2 m. Frost tapers should be constructed at a minimum slope of 10H:1V.

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, buried 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. If encountered along the culvert alignment, the buried topsoil noted below the embankment fill in Borehole 17-35 must be removed to expose the underlying silty clay at or below Elevation 203.4 m.

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 very soft to firm silty clay and very loose to loose silty sand 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.

A grade raise or embankment widening should be avoided, as they would cause foundation settlement in the soft clay.

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 at this site is classified as a Type 3 soil above the water table and Type 4 soils below the water table, and the native buried topsoil, silty clay and silty sand is classified as a Type 4 soil. 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 extend into the buried topsoil, native silty sand and silty clay.



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. Although the permeability of the native silty clay is expected to be relatively low, seepage should be anticipated from the embankment fill and the silty sand 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. Additional recommendations for cofferdams will be provided in the detailed foundation design report.

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 "No". Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing dewatering systems of similar nature and scope to the required work is required, and thus Designer Fill-In ***** in SP517F01 should be "Yes".

The dewatering scheme must be effective to maintain the groundwater level 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 204.2 m, which corresponds to native silty clay and silty sand, or possible sandy topsoil. If buried topsoil is encountered at the invert level, it should be subexcavated to expose the underlying silty clay or silty sand and replaced with well compacted granular material.

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.

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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)
	γ	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

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



Table 12.1 – Lateral Earth Pressure Coefficients (K)

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

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

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

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

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and 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 E 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 (modified) or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})**	0.51	0.55

Note 1: Mononobe and Okabe, 1929, World Engineering Congress 9: 179-187

Note 2: Passive case assumes a horizontal surface in front of the wall.

Note 3: Wood, J. H. 1973, earthquake induced soil pressures on structures, PhD Thesis, California Institute of Technology, Pasadena, CA.

Although the site is underlain by soft to firm silty clay, 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

A temporary roadway protection system, if utilized, 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 Silty Clay	Native Silty Sand
Φ (angle of internal friction)	32°	25°	28°
γ (total unit weight)	20 kN/m ³	19 kN/m ³	20 kN/m ³
γ_w (submerged unit weight)	10 kN/m ³	9 kN/m ³	10 kN/m ³
K_a	0.31	0.41	0.36
K_p	3.3	2.5	2.8



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

15. 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 208.0 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 150 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 100 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 0.55.

It is anticipated that the offline diversion approaches to the temporary modular bridge will require placement of additional fill to partially widen the existing highway embankment. The fill placement



will cause settlement of the embankment and culvert foundations due to the presence of native very soft to firm silty clay. The magnitude of settlement must be assessed during detailed design. It is therefore recommended that the modular bridge foundations should be placed on the existing embankment fill rather than widening the embankment.

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. A grade raise or embankment widening should be avoided as they will cause settlement of the soft foundation clay.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. 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 Northwest 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 in accordance with OPSD 810.010, OPSS 511 and OPSS PROV 1004.

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

A concrete cut-off wall 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.

Selection of streambed material should be in accordance with OPSS 1005.

19. CORROSION AND SULPHATE ATTACK POTENTIAL

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



- The potential for corrosion or sulphate attack on concrete foundations from the surrounding native soil is considered to be negligible due to the low concentration of sulphate and chloride in the sample tested. The sulphate level in the water indicates a moderate risk of sulphate attack on concrete. The effect of road deicing salt should be considering while selecting the class of concrete.
- The potential for soil corrosion on metal is considered to be mild. However, the low resistivity measured in the water sample indicates that there is a high risk of corrosion to steel, cast iron and other metal culverts.
- Appropriate protection measures are recommended for metal or concrete 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 construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at a higher elevation at the time of construction than indicated in the report.
- The foundation soils at this site consist of a thick deposit of soft to firm clay. The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment and foundation soils 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. An NSSP to this effect is included in Appendix E.
- A grade raise or embankment widening should be avoided as they will cause settlement of the soft foundation clay.



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.

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Sept 7, 2018

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No 17-34

1 OF 2

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 964.3 E 302 071.6 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE BW Casing COMPILED BY MP
 DATUM Geodetic DATE 2017.09.17 - 2017.09.17 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
205.4	GROUND SURFACE													
0.0	TOPSOIL, silt, some sand, roots Loose Dark Brown Moist		1	SS	6		205							
204.8														
0.6	Silty CLAY, some sand, rootlets Soft Brown Moist		2	SS	3		204							
203.9														
1.5	Silty SAND, some clay, occasional wood fragments Loose to Very Loose Brown Moist		3	SS	5		203							0 58 29 13
			4	SS	6		202							
			5	SS	3		201							
201.3														
4.1	Silty CLAY, trace to some sand Firm to Very Soft Grey Moist to Wet (CI)		6	SS	5		200							
							199	1.4						
							198							
			7	SS	0		197							0 0 52 48
							196	1.3						

Continued Next Page

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

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE							
						● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page														
	Silty CLAY , trace to some sand Soft Grey Wet (CI)		8	SS	3										
192.9			9	SS	18										
12.5	Silty SAND , trace gravel Compact to Very Loose Grey Moist														
			10	SS	0										
190.6															
14.8	SAND , some gravel, some silt Very Dense Grey Wet		11	SS	100/										
190.1															
15.3	END OF BOREHOLE AT 15.3m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS, THEN GRAVEL TO SURFACE.				0.025										

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-35

1 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 958.4 E 302 086.0 ORIGINATED BY TY
HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
DATUM Geodetic DATE 2017.08.20 - 2017.08.20 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
209.0	GROUND SURFACE							20	40	60	80	100		
0.0	ASPHALT: (150mm)													
0.2	SAND and GRAVEL , trace silt Very Dense Brown Dry (FILL)		1	SS	80								○	42 50 8 (SI+CL)
			2	SS	64								○	
207.6														
1.4	SAND and SILT , trace clay Compact Brown Moist (FILL)		3	SS	26								○	
			4	SS	10								○	0 34 63 3
205.9														
3.1	TOPSOIL , sandy, some silt, trace clay, occasional silt pockets, rootlets and wood fragments Very Loose Dark Brown Moist		5	SS	4								○	
			6	SS	4								○	
203.4														
5.6	Silty CLAY , sandy, trace gravel Firm Dark Brown Moist		7	SS	4								○	
201.8														
7.2	Silty CLAY , trace sand Very Soft to Firm Grey Moist (CL)		8	SS	1								○	0 0 75 25
			9	SS	3								○	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-35

2 OF 3

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 958.4 E 302 086.0 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.20 - 2017.08.20 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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _P W W _L WATER CONTENT (%)							
								20 40 60 80 100					20 40 60							
	Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
								20	40	60	80	100								

Continued Next Page

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

METRIC

[illegible]

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-36

2 OF 2

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 932.8 E 302 095.1 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE Solid Stem Augers/Dynamic Cone Penetration Test COMPILED BY MP
 DATUM Geodetic DATE 2017.08.22 - 2017.08.22 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
195.7																	
10.2	Silty SAND Very Loose Grey Wet		7	SS	0												
193.9																	
12.0	SAND , some silt, trace gravel Loose Grey Wet		8	SS	6												
192.5																	
13.4	End of sampling and start DCPT at 13.4m																
190.1																	
15.8	END OF DCPT AT 15.8m. BOREHOLE OPEN TO 11.3m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.08.26 0.6 205.3																

RECORD OF BOREHOLE No 17-37

1 OF 1

METRIC

W.P. 6808-14-01 LOCATION BlackBird Creek Culvert, MTM NAD 83 Zone 14 N 5 411 939.3 E 302 076.6 ORIGINATED BY TY
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2017.08.20 - 2017.08.20 CHECKED BY NLB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
209.0	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT: (140mm)																
0.1	Gravelly SAND , some silt, trace clay Brown Dry (FILL)		1	GS			208										22 59 15 4
207.5																	
1.5	SAND and SILT Compact Brown Moist (FILL)		1	SS	15		207										
206.9																	
2.1	END OF BOREHOLE AT 2.13m. HOLE FILLED WITH CUTTINGS TO 0.6m, DRY CEMENT TO 0.2m, THEN COLD-PATCH ASPHALT TO THE SURFACE.																

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



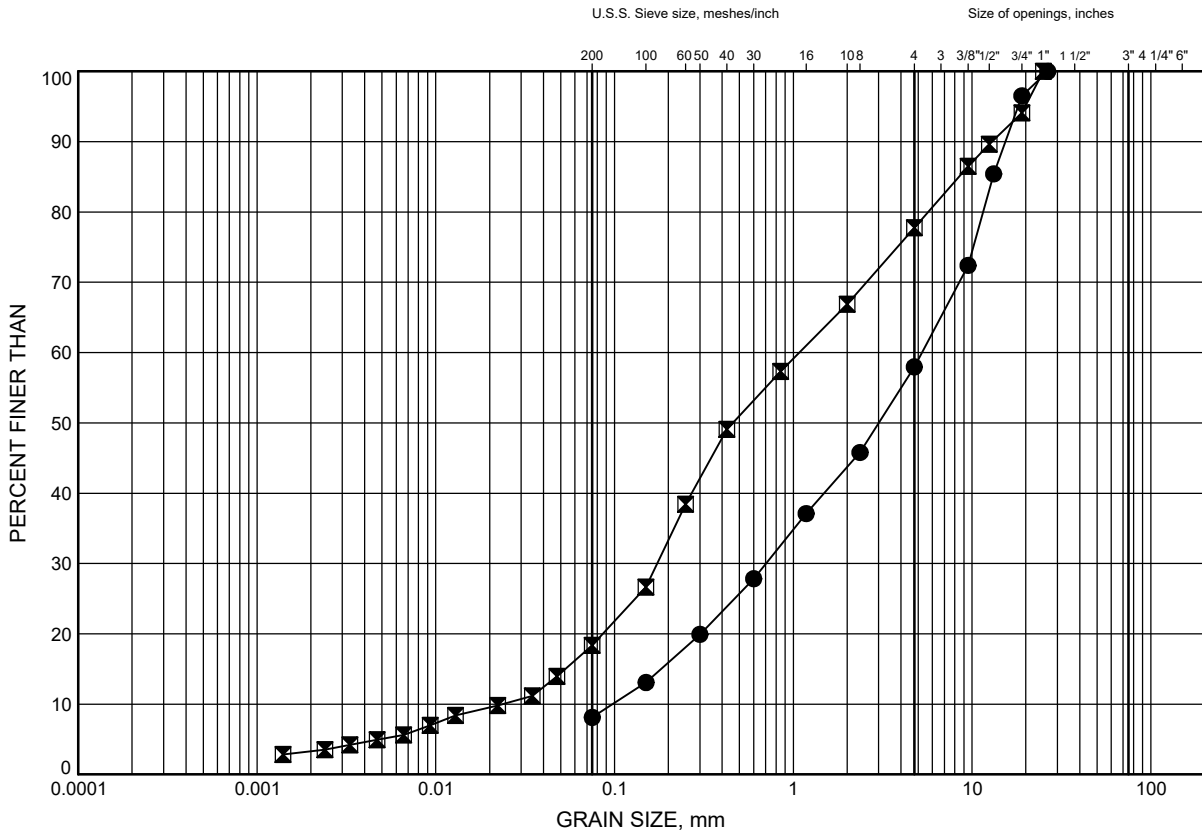
Appendix B

Laboratory Test Results

BlackBird 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)
●	17-35	0.3	208.7
■	17-37	0.8	208.2

Date November 2017
W.P. 6808-14-01

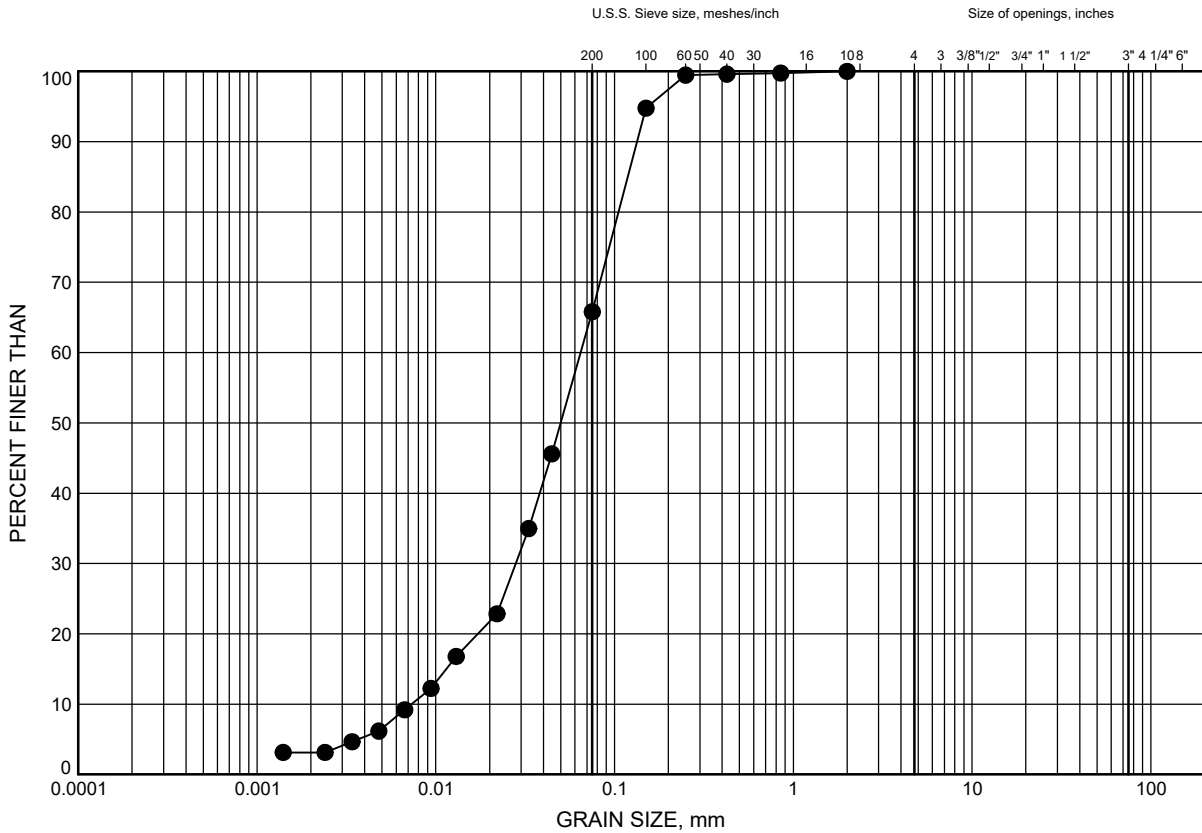


Prep'd AN
Chkd. MEF

BlackBird Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND and SILT FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-35	2.6	206.4

Date November 2017
W.P. 6808-14-01



Prep'd AN
Chkd. MEF

FIGURE B3

U.S.S. Sieve size, meshes/finch

Size of openings, inches

PERCENT FINER THAN

GRAIN SIZE, mm

Grain Size (mm)	U.S.S. Sieve Size	Size of Opening (inches)	Percent Finer Than (No. 1)	Percent Finer Than (No. 2)
0.075	20	0.003	11	11
0.15	10	0.006	13	13
0.25	60	0.0085	15	15
0.425	40	0.0106	18	18
0.6	30	0.0118	20	20
0.85	20	0.0135	22	22
1.18	15	0.0149	24	24
1.75	10	0.0177	26	26
2.5	60	0.0208	28	28
3.55	40	0.025	30	30
4.75	30	0.0295	32	32
7.5	20	0.0425	42	24
10.6	15	0.0475	63	57
15.0	10	0.054	87	83
20.0	75	0.063	100	88
28.0	60	0.0707	100	93
38.0	40	0.085	100	97
48.0	30	0.095	100	99
60.0	25	0.106	100	100
75.0	20	0.118	100	100
100.0	15	0.149	100	100
150.0	10	0.208	100	100
200.0	75	0.25	100	100
250.0	60	0.295	100	100
300.0	48	0.354	100	100
350.0	42	0.425	100	100
400.0	38	0.475	100	100

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

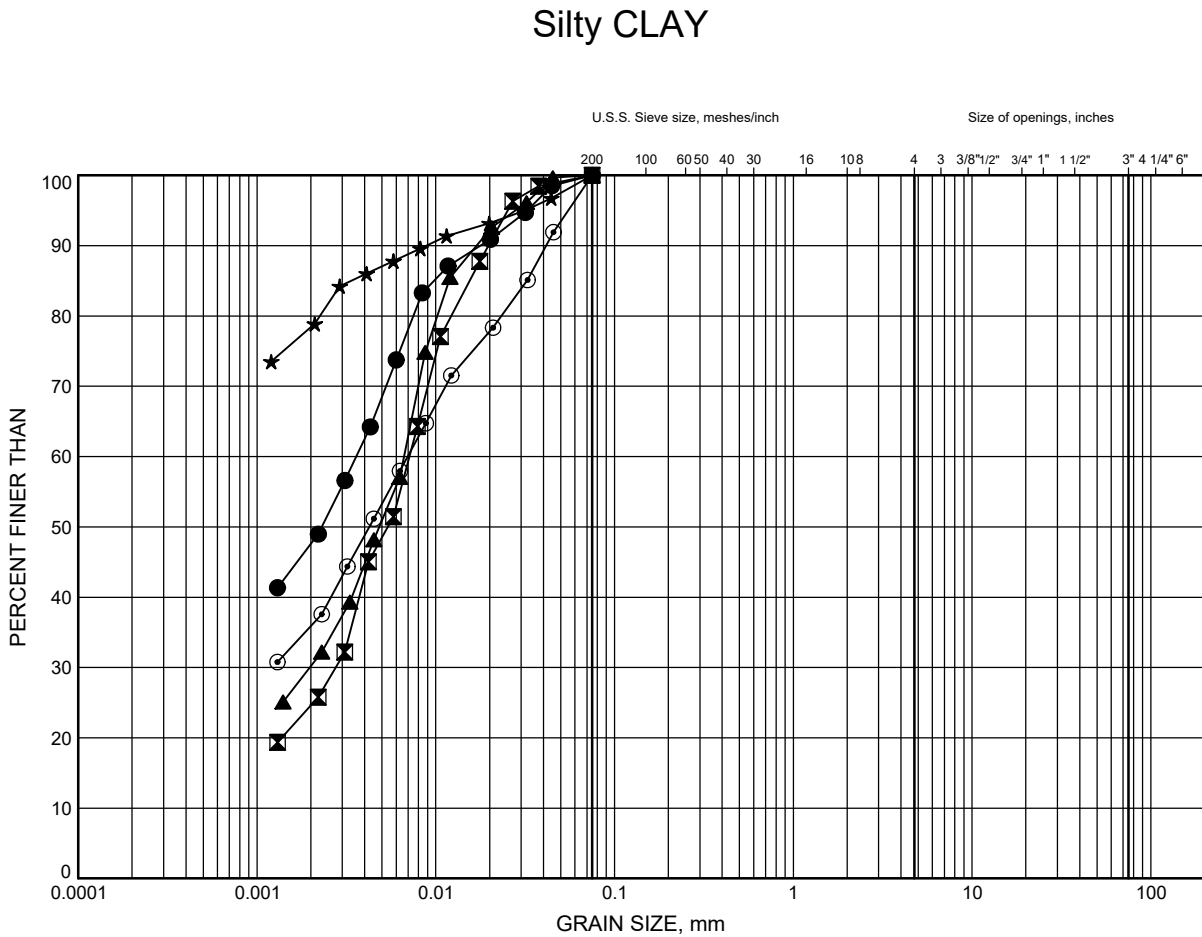
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-34	1.8	203.6
☒	17-34	14.0	191.4



Prep'd AN
Chkd. MEF

BlackBird 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)
●	17-34	7.9	197.5
⊠	17-35	7.9	201.1
▲	17-35	12.5	196.5
★	17-36	1.8	204.1
⊙	17-36	6.4	199.5

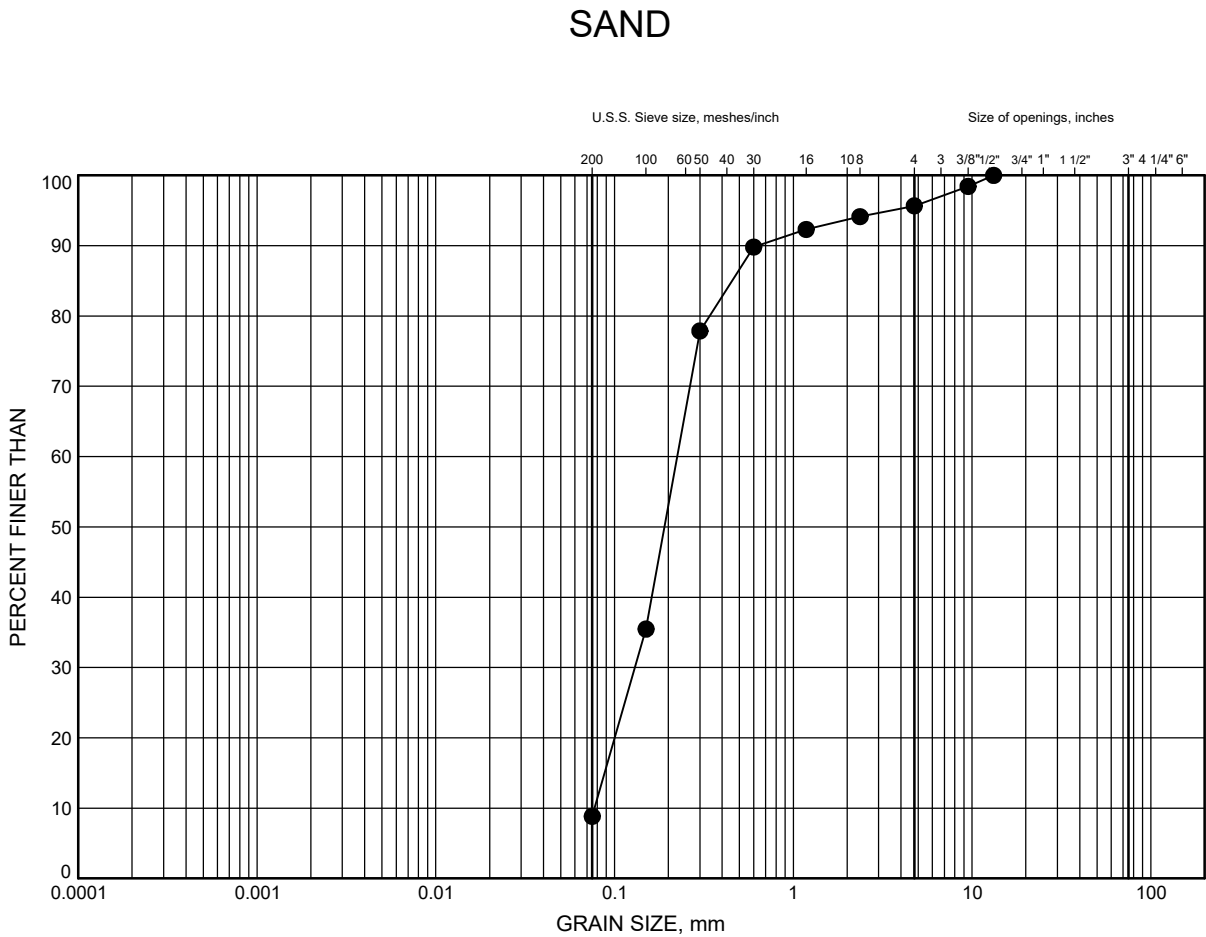
Date November 2017
W.P. 6808-14-01



Prep'd AN
Chkd. MEF

BlackBird Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B5



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-36	13.1	192.8

Date November 2017
W.P. 6808-14-01

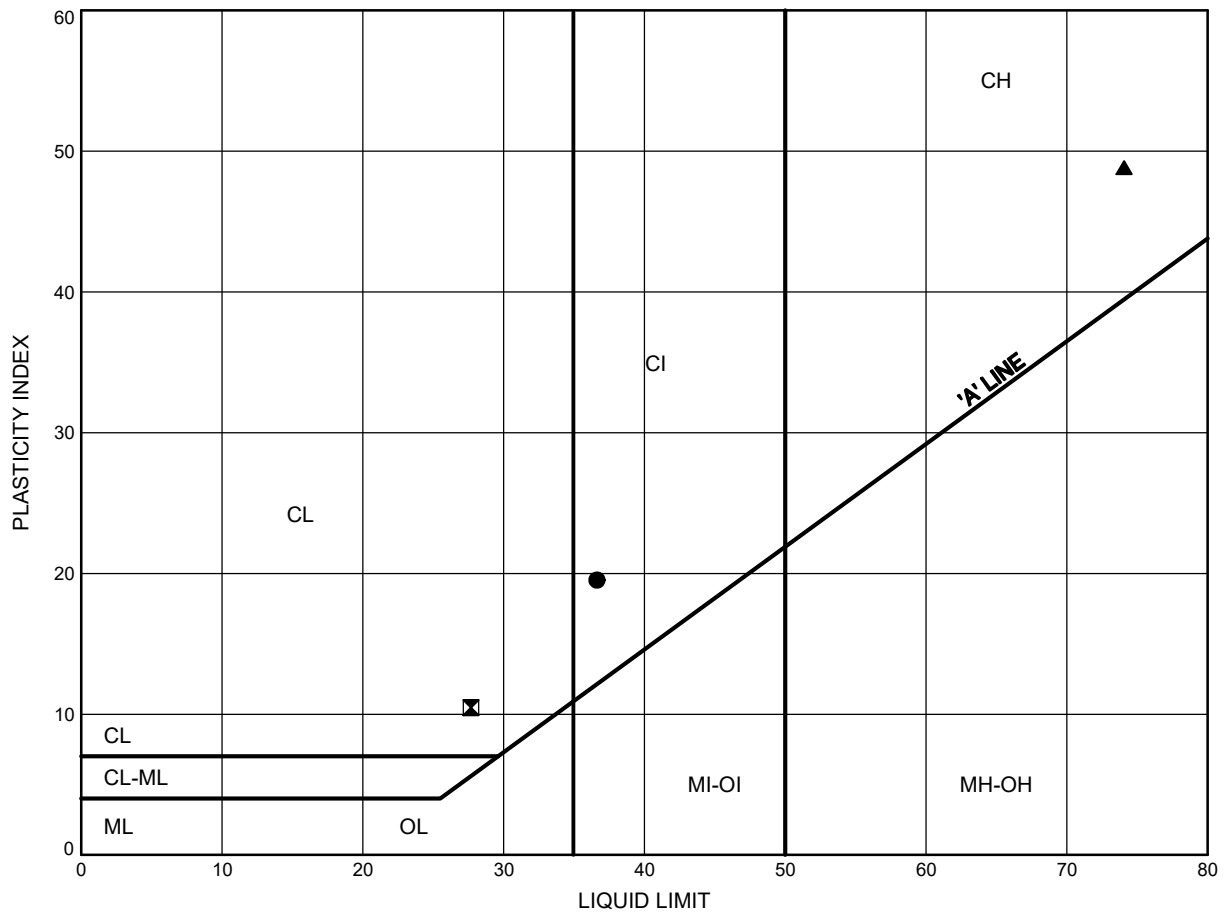


Prep'd AN
Chkd. MEF

BlackBird Creek Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Silty CLAY



LEGEND

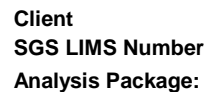
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-34	7.9	197.5
⊠	17-35	12.5	196.5
▲	17-36	1.8	204.1

Date November 2017
W.P. 6808-14-01



Prep'd AN
Chkd. MEF

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



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

Sample ID	Unit	BH-36, SS#2, 2.5'-4.5'
-----------	------	------------------------

Sample Date/Time 22-Aug-17

Moisture	%	27.9
pH	no unit	7.99
Corrosivity Index	none	2.0
Soil Redox Potential	mV	137
Sulphide	mg/L	<0.02
Chloride	mg/L	340.0
Sulphate	mg/L	10
Conductivity	uS/cm	397
Resistivity (calculated)	ohms.cm	2520

Corrosivity Scale according to AWWA C-105.

An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

Deanna Edwards

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



Client
SGS LIMS Number
Analysis Package:

Attention: Cory Zanatta
Project#: 15595, North Superior Lake Region
Thurber Engineering Ltd.
CA15829-AUG17
Corrosivity (Solution)

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

Sample ID	Unit	Blackbird Creek
Sample Date/Time		21-Aug-17
Moisture	%	NA
pH	no unit	7.78
Corrosivity Index	none	NA
Redox Potential	mV	224
Sulphide	mg/L	0.076
Chloride	mg/L	110
Sulphate	mg/L	180
Conductivity	uS/cm	1180
Resistivity (calculated)	ohms.cm	847

Corrosivity Scale according to AWWA C-105.
An index greater than 10 indicates the
soil matrix may be corrosive to cast iron alloys.

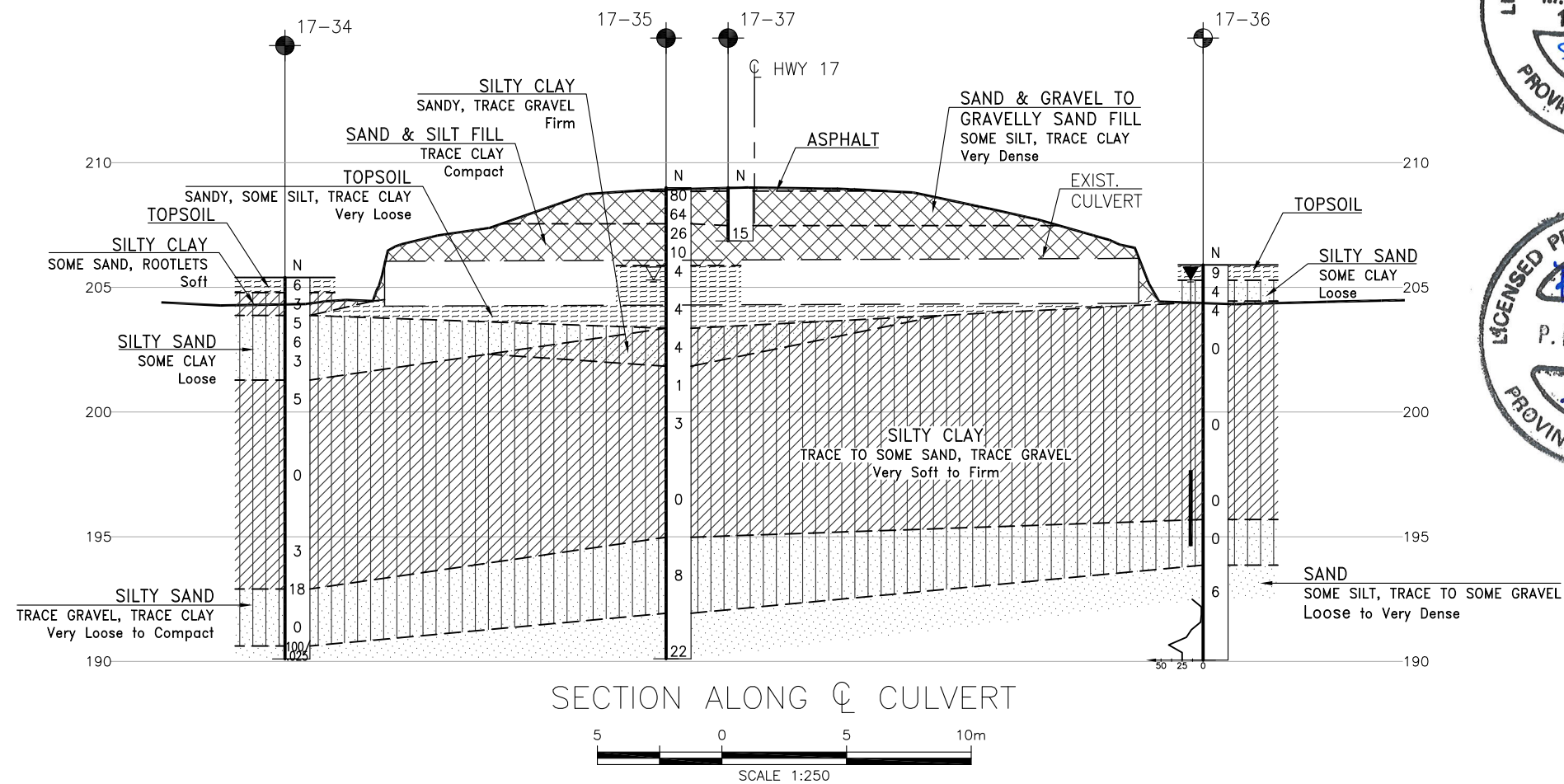
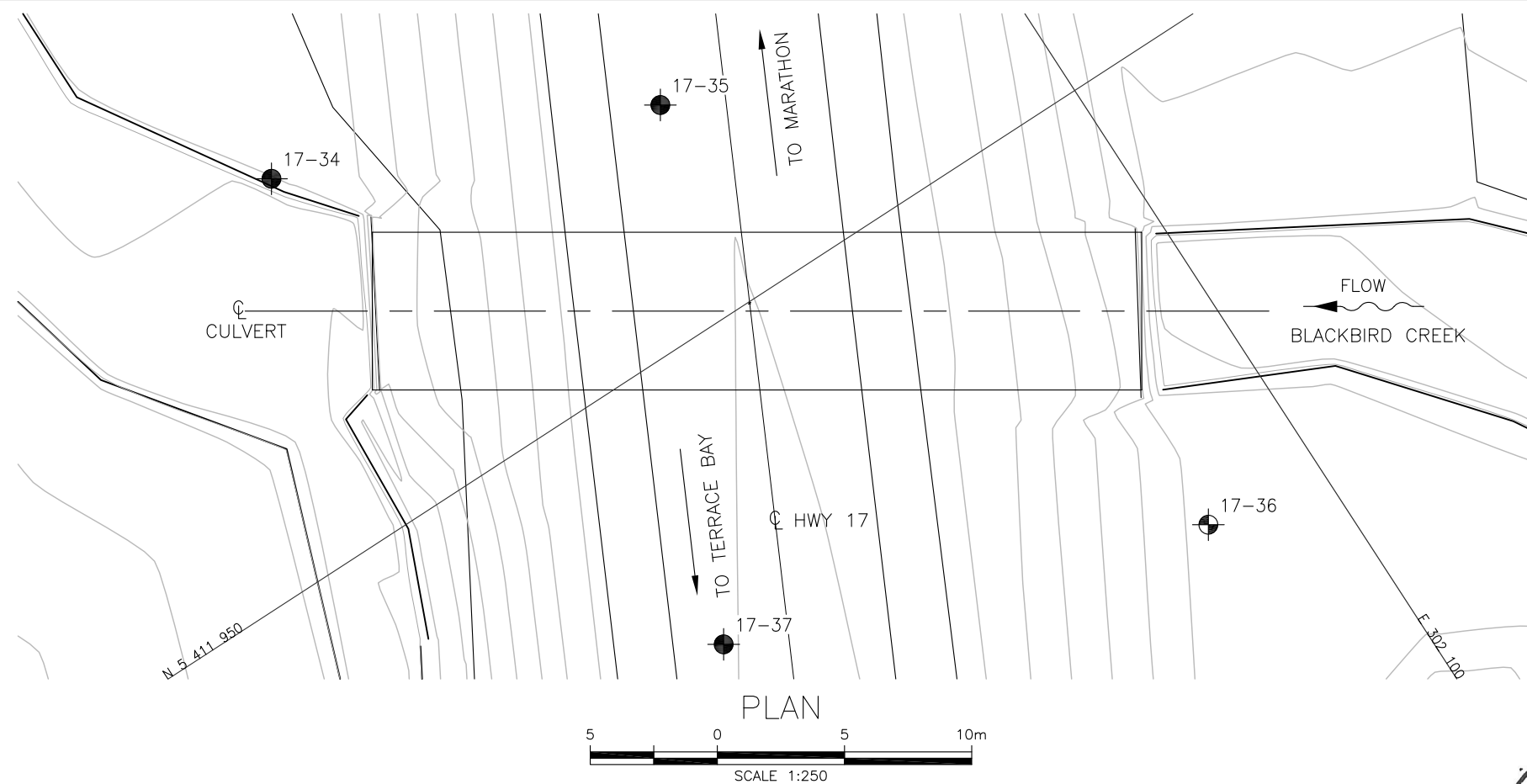
Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

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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.



Appendix C

Borehole Locations and Soil Strata Drawing



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

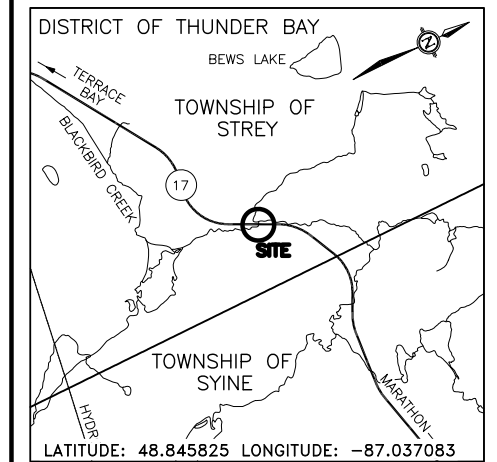
CONT No
WP No 6808-14-01

HIGHWAY 17
BLACKBIRD CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

[illegible]

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No. 52D-50

[illegible]



Appendix D

Site Photographs



Photo 1: Road approach looking south. Photo taken May 16, 2017.



Photo 2: Road approach looking north. Photo taken October, 2015.



Photo 3: East embankment looking north (inlet). Photo taken June 27, 2017.



Photo 4: East embankment looking south (inlet). Photo taken June 27, 2017.



Photo 5: West embankment looking south (outlet). Photo taken June 27, 2017.



Photo 6: Culvert outlet looking south. Photo taken May 16, 2017.



Photo 7: Culvert inlet looking west. Photo taken May 16, 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 209 (Construction Specification for Embankments over Swamps and Compressible Soils)
- OPSS PROV 313 (Construction Specification for Hot Mix Asphalt - End Result)
- OPSS PROV 401 (Construction Specification for Trenching, Backfilling and Compacting)
- 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 of Pipeline, Utility, And Associated Structure Excavation
- SP 517F01 Design Storm Return Period and Preconstruction Survey Distance
- 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)
- Special Provision No. 110S13 (Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material)
- OPSS PROV 1151 (Material Specification for Superpave And Stone Mastic Asphalt Mixtures)



- Special Provision No. 103 F49 (Anti-Stripping Additive Requirements)
- Special Provision No. 111F10 (HMA Mix Design and Additional Materials Requirements)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- 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 NSSP on “Groundwater and Dewatering”**

Dewatering will be required to install the new culvert and diversion pipe in the dry. Design and provision 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 text for NSSP on “Use of Heavy Construction Equipment”**

The use of heavy construction equipment and in particular heavy lift cranes may be required during removal of the existing culvert, erection of the temporary modular bridge, and construction of the new culvert. The impact of the heavy equipment loads on the existing embankment, the



soft foundation soils (silty clay) underlying the embankment, and the existing and new culvert foundations must be considered during selection of the methodology and equipment employed for construction.

Prior to commencement of construction, the Contractor shall retain a Geotechnical Consultant to assess the impact of the proposed equipment loads and methodology, and determine requirements and/or restrictions necessary to safely support the loads. All Foundation Engineering services required for this project shall be performed by consultant(s) listed as accepted under the MTO's RAQS for providing services under the specialty of Geotechnical (Structures and Embankments) – High Complexity.

The assessment shall include, but not be limited to, the following:

- Determining appropriate setbacks for heavy equipment from the existing and new foundations;
- Determining the permissible ground pressure that may be applied to the foundation soils by the equipment; and
- Providing recommendations for crane pad design to distribute the crane loads without causing foundation and creek bank failure.

The Contractor shall submit the findings of the geotechnical assessment and details of the proposed equipment and construction methodology to the Contract Administrator for information purposes a minimum of two weeks prior to the start of construction.

- **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

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