



THURBER ENGINEERING LTD.



**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
WAWIAG CREEK CULVERT REPLACEMENT
HIGHWAY 11, UNSURVEYED TERRITORY
DISTRICT OF THUNDER BAY, ONTARIO
LATITUDE: 48.647345°, LONGITUDE: -90.571420°**

G.W.P. No. 6805-14-00, W.P. No. 6805-14-01, SITE No. 48W-193/C

GEOCRES Number: 52B-33

Report

to

HATCH Corporation

Date: October 2, 2017
File: 15593

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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 Wawiag Creek Culvert on Highway 11, located west of Kashabowie, in Unsurveyed Territory, District of Thunder Bay, Ontario.

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.

Thurber was retained by Hatch Corporation (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0012.

2. SITE DESCRIPTION

The site is located on Highway 11, approximately 10 km west of Highway 802, in Unsurveyed Territory, District of Thunder Bay, Ontario. The existing culvert allows Wawiag Creek to flow in a north to south direction under Highway 11. Highway 11 generally runs in an east-west direction at the culvert site.

The Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on December 16, 2015 indicates that the existing structure is an open footing two span timber structure on the south side with a single span corrugated steel elliptical culvert extension on the north side. The inspection report indicates that the total span on the structure is 4.2 m, with each cell of the timber structure spanning 2.1 m. The overall length of the structure is 28 m. The estimated culvert invert

is at approximate Elevation 457.9 m at the inlet (north) and 457.8 m at the outlet (south) and the culvert is approximately 1.8 m high. The existing road grade at the culvert location is at approximate Elev. 461.5 m, which indicates approximately 1.8 m of fill above the culvert. The local creek water level was reportedly measured at Elev. 458.3 m in April 2015.

The lands surrounding the culvert site predominantly consist of densely forested areas, marsh areas, and small lakes. Wawiag Creek runs through swamp lands to the north of the culvert and outflows into a small lake approximately 100 m to the south of the culvert. Local topography is generally of moderate relief with hummocky bedrock outcrops and ridge bedrock outcrops. Bedrock outcrops are visible within 10 to 50 m of the creek alignment. Large rip rap rock pieces are present on the north embankment around the inlet of the culvert.

Photographs of the culvert and surrounding areas are presented in Appendix C.

Based on published geological information, the culvert lies within an area of mainly bedrock outcrops with nearby glacial outwash plain deposits of sand and gravel and organic deposits of peat and muck. Bedrock at the site is identified as metasedimentary rocks.

3. INVESTIGATION PROCEDURES

The site investigation and field testing program for this project was carried out between March 20 and 24, 2017, and consisted of drilling and sampling seven (7) boreholes (17-08 to 17-14) to depths of between approximately 1.2 m and 12.8 m below the existing ground surface. Boreholes 17-08, 17-10, and 17-12 to 17-14 were drilled through the paved portion of Highway 11. Boreholes 17-09 and 17-11 were drilled near the inlet and outlet of the existing culvert. Boreholes 17-12 to 17-14 were drilled to assess the existence and extent of any frost taper near the culvert.

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

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated from the cross sections and topographic drawings provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 15 was used for these boreholes.

A rubber buggy mounted drill rig was used to advance the boreholes using hollow stem and solid stem augers, with the exception of Borehole 17-09, which was advanced using portable tripod equipment. Soil samples were obtained in the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Dynamic Cone Penetration

Tests (DCPT) were driven to cone refusal adjacent to Boreholes 17-08 and 17-10.

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

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

Completion details of the boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Completion Details
17-08	11.3 / 450.2	Borehole backfilled with bentonite holeplug and auger cuttings, then concrete to surface.
17-09	1.2 / 457.7	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
17-10	12.8 / 448.8	Borehole backfilled with bentonite holeplug and auger cuttings, then concrete to surface.
17-11	5.2 / 453.2	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
17-12	5.2 / 456.4	Borehole backfilled with bentonite holeplug and auger cuttings, then concrete to surface.
17-13	3.7 / 458.0	Borehole backfilled with bentonite holeplug and auger cuttings, then concrete to surface.
17-14	3.7 / 458.2	Borehole backfilled with bentonite holeplug and auger cuttings, then concrete to surface.

4. LABORATORY TESTING

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

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, two samples of the native sand, 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

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

In general, the subsurface conditions encountered below the existing embankment fill consisted of sand and gravel to sand overlying shallow greywacke bedrock. Descriptions of the individual strata are presented below.

5.1 Asphalt

All boreholes, with the exception of Boreholes 17-09 and 17-11, were drilled through the paved portion of Highway 11, below Elev. 461.5 to 461.9 m. The asphalt was approximately 100 mm to 175 mm thick in all boreholes drilled in the paved portion.

5.2 Embankment Fill

Embankment fill was encountered in all boreholes drilled on Highway 11 beneath the asphalt. The fill generally consisted of gravelly sand, which was underlain by sand fill in Boreholes 17-08 and 17-10.

5.2.1 Gravelly Sand Fill

Gravelly sand fill was encountered beneath the asphalt in Boreholes 17-08, 17-10, and 17-12 to 17-14. The gravelly sand fill contained trace to some silt and some rock fill. The fill layer was 2.8 to 3.9 m thick and extended to depths of approximately 3.0 to 4.1 m below the existing road

surface (Elev. 457.5 to 458.6 m) or to the maximum depth drilled in Boreholes 17-13 and 17-14 of 3.7 m.

SPT 'N' values in the gravelly sand fill generally ranged from 10 to 37 blows for 0.3 m penetration, indicating a compact to dense relative density. Higher 'N' values from 97 blows to greater than 100 blows for 0.3 m penetration were also observed in Boreholes 17-08 and 17-10, and were likely a result of frozen material and the presence of rock fill. The measured moisture contents ranged from 2 to 7%.

The results of grain size analyses conducted on samples of the gravelly sand fill are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B1 of Appendix B. The results are summarized as follows:

Gravel %	20 to 34
Sand %	57 to 67
Silt and Clay %	9 to 13

5.2.2 Sand Fill

Sand fill containing some silt, some gravel and trace clay was encountered below the gravelly sand fill in Boreholes 17-08 and 17-10. The sand fill layer was 1.0 to 1.3 m thick and extended to depths of approximately 4.0 to 4.3 m below the existing road surface (Elev. 457.3 to 457.5 m).

SPT 'N' values in the sand fill ranged from 8 to 19 blows for 0.3 m penetration, indicating a loose to compact relative density. The measured moisture contents were 9 to 10%.

The results of a grain size analysis conducted on a sample of the sand fill are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B2 of Appendix B. The results are summarized as follows:

Gravel %	11
Sand %	68
Silt %	18
Clay %	3

5.3 Silty Sand

A deposit of silty sand containing some gravel and some organic material was encountered at the ground surface in Boreholes 17-09 and 17-11, which were drilled near the inlet and outlet of the

culvert, beyond the base of the embankment. The silty sand layer extended to depths of approximately 0.6 to 0.7 m below the ground surface (Elev. 457.7 to 458.3 m).

SPT 'N' values in the silty sand ranged from 5 to 10 blows for 0.3 m penetration, indicating a loose to compact relative density. The measured moisture contents were 18 to 27%.

The results of a grain size analysis conducted on a sample of the silty sand are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B3 of Appendix B. The results are summarized as follows:

Gravel %	0
Sand %	73
Silt %	21
Clay%	6

5.4 Gravelly Sand to Sand and Gravel

Gravelly sand to sand and gravel with trace to some silt was encountered beneath the embankment fill in Boreholes 17-08, 17-10, and 17-12, and below the silty sand in Boreholes 17-09 and 17-11. The deposit ranged in thickness from 0.6 to 1.6 m and extended to depths of approximately 1.2 to 5.6 m below the ground surface (Elev. 455.9 to 457.7 m), including to bedrock contact in Boreholes 17-09 and 17-11.

SPT 'N' values recorded in the gravelly sand to sand and gravel ranged between 13 to 25 blows for 0.3 m penetration, indicating a compact relative density. A higher 'N' value of greater than 100 blows for 0.3 m penetration was also observed in Borehole 17-11, which was likely indicative of the presence of boulders in the deposit. Measured moisture contents in the gravelly sand to sand and gravel ranged from 5 to 21%. A higher moisture content of 77% was also recorded, which is likely indicative of the presence of trace organic material in Borehole 17-10.

The results of grain size analyses conducted on samples of the gravelly sand to sand and gravel are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B4 of Appendix B. The results are summarized as follows:

Gravel %	21 to 52
Sand %	46 to 69
Silt and Clay %	2 to 10

5.5 Sand

A sand deposit containing trace to some silt and trace gravel was encountered below the gravelly sand to sand and gravel in Boreholes 17-08 and 17-10. The sand deposit ranged in thickness from 2.6 to 4.2 m and extended to bedrock contact at approximate depths from 8.2 to 9.8 m (Elev. 453.3 to 451.8 m).

SPT 'N' values recorded in the sand deposit ranged between 3 to 54 blows for 0.3 m penetration, indicating a very loose to very dense relative density. Measured moisture contents in the sand ranged from 13 to 28%.

The results of a grain size analysis conducted on a sample of the sand are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B5 of Appendix B. The results are summarized as follows:

Gravel %	7
Sand %	86
Silt and Clay %	7

5.6 Bedrock

Greywacke bedrock was encountered below the native deposits in Boreholes 17-08, 17-10, and 17-11, and tripod refusal occurred on probable bedrock in Borehole 17-09. Bedrock was inferred from tripod refusal at an approximate depth of 1.2 m (Elev. 457.7 m) in Borehole 17-09 at the inlet of the existing culvert. Bedrock was confirmed at a depth of 2.1 m (Elev. 456.3 m) in Borehole 17-11 at the outlet of the existing culvert; and 8.2 m to 9.8 m (Elev. 453.3 to 451.8 m) in Boreholes 17-08 and 17-10 below the existing road surface. Bedrock outcrops were also observed beside the road embankment, at approximately 10 m west of the culvert inlet and 50 m east of the culvert outlet.

The bedrock was proven in Boreholes 17-08, 17-10, and 17-11 by coring approximately 3 m in each borehole. The bedrock is generally described as moderately weathered, grey, metasedimentary greywacke. Total Core Recovery (TCR) in the bedrock ranged from 93% to 100% with Solid Core Recovery (SCR) ranging from 53% to 98%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 38% to 95%, indicating poor to excellent quality. Average unconfined compressive strengths (UCS) of the rock ranged between 82 MPa to greater than 239 MPa based on correlations with the point load tests (PLT), indicating the rock was strong to very strong.

5.7 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. All boreholes were noted to be dry upon completion, with the exception of Boreholes 17-08, 17-10, and 17-11 where water was added to the borehole to prevent blowback of the sandy soils and used for bedrock coring purposes. As a result, groundwater levels in these boreholes could not be measured.

The groundwater level should be assumed to reflect the local creek water level, which was reportedly measured by at Elev. 458.3 m in April 2015.

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

6. CORROSIVITY AND SULPHATE TEST RESULTS

Samples of the native sand from Boreholes 17-08 and 17-10, and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

Table 6.1 – Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results		
			17-08 SS6	17-10 SS6	Wawiag Creek
			(Native Sand)	(Native Sand)	(Creek Water)
Sulphide	%	mg/L	<0.02	0.03	0.009
Chloride	µg/g	mg/L	120	78	5.8
Sulphate	µg/g	mg/L	26	420	1.8
pH	-	-	6.85	4.16	6.30
Conductivity	µS/cm	µS/cm	158	487	47
Resistivity	Ohms.cm	Ohms.cm	6330	2050	21200
Redox Potential	mV	mV	270	354	221

7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. The northing and easting

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coordinates and ground surface elevations were estimated based on field measurements relative to the topographic plans provided by Hatch.

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

Geotechnical laboratory testing was carried out in Thurber's geotechnical laboratory. Analytical laboratory testing was carried out by SGS Canada Inc.

Interpretation of the field data and preparation of this report was carried out by Mr. Cory Zanatta, EIT and 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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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 preliminary design of the proposed Wawiag Creek Culvert replacement on Highway 11, located in Unsurveyed Territory, 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 contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference, the Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on December 16, 2015, and the MTO site plan drawing provided by Hatch. The existing structure is an open footing two span timber structure on the south side with a single span corrugated steel elliptical culvert extension on the north side. The culvert measures 4.2 m wide and is approximately 28 m long. The estimated culvert invert is at approximate Elevation 457.9 m at the inlet (north) and 457.8 m at the outlet (south). The existing road grade at the culvert location is at approximate Elev. 461.5 m, which indicates approximately 1.8 m of fill above the culvert.

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

1. Multiple CSP Pipe Culvert

Multiple circular CSP pipes, with 2.7 m diameter are being considered to provide an increased hydraulic opening. It is anticipated that the pipes will be installed along the same alignment of the existing culvert, with an invert level (underside of pipes) of approximately Elev. 457 m. A temporary creek diversion pipe is to be located approximately 15 m west of the culvert centreline while the new pipes are being installed. The invert level of the diversion pipe is approximately Elev. 457.6 m.

2. Precast Concrete Box Culvert

A single precast concrete box culvert is the other option being considered. The preliminary general arrangement indicated a 4.5 m x 2.7 m box culvert. The proposed invert level (underside of box) is at approximately Elev. 456.5 m. The new culvert will be installed along the same alignment of the existing culvert. A temporary creek diversion pipe is to be located approximately 15 m west of the culvert centreline while the box culvert is being installed. The invert level of the diversion pipe is approximately Elev. 457.6 m.

No grade raise is proposed for either alternative.

9. CULVERT DESIGN

9.1 Culvert Alternatives

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill comprising gravelly sand with some rock fill to sand, underlain by compact gravelly sand to sand and gravel, very loose to very dense sand, and bedrock. The bedrock is at shallow depth at the inlet and outlet and the rock surface dips towards the middle of the culvert. The water level in the creek was measured at approximately Elev. 458.3 m in April 2015.

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

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

- Concrete pipe, Structural Plate Corrugated steel pipe (SPCSP) or Helical Corrugated Steel Pipe (CSP)
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete open frame culvert on spread footings

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

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

Recommendations for the design and installation of concrete pipe, SPCSP, CSP and concrete box and culverts are presented below. An open footing culvert is not recommended at this site since it will involve deeper excavation and more dewatering effort. Hence, recommendations for this option have not been developed.

9.2 Foundation Design for Culverts

The founding soils encountered at the proposed invert level (approximately Elev. 457 to 456.5 m) consist of compact native gravelly sand to sand and gravel for most of the length of the culvert, and shallow bedrock near the inlet and outlet. There is approximately 1.5 m of fill above the proposed culvert replacement. Foundation design aspects for the replacement culvert include subgrade conditions and preparation, geotechnical capacities, settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.

9.2.1 Concrete Pipe or Corrugated Steel Pipe Culvert

Replacement of the culvert with a concrete pipe, SPCSP, CSP or multiple pipes on the same alignment may be considered for this site. Since there is no grade raise proposed, 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 pipe, SPCSP or CSP should be placed on a minimum 300 mm thick layer of bedding material conforming to Ontario Provincial Standard Specification (OPSS) OPSS.PROV 1010 Granular A or Granular B Type II requirements as per Ontario Provincial Standard Drawing (OPSD) 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 and placement and compaction of bedding must be carried out in the dry. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction. 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 µm.

The underside of the bedding material should be placed at or below Elevation 456.7 m, which corresponds to compact sand fill or native gravelly sand to sand and gravel subgrade. Any loose fill, large cobbles and boulders, and any soft, very loose, organic, or other detritus material should be sub-excavated and replaced with compacted material to provide a uniformly competent subgrade condition. Bedrock was encountered at shallow depths at both the inlet and outlet of the existing culvert at Elev. 457.7 and Elev. 456.3 m, respectively, and bedrock outcrops were observed in close proximity to the site (within 10 to 50 m of the culvert). Depending on final foundation culvert invert grades there may be a need to excavate bedrock at one or both ends of the culvert. It is recommended that additional investigation, including rock coring, be conducted during detailed design in order to confirm the bedrock elevation along the alignment of the replacement culvert. This additional investigation will be required to situate the culvert in a location which minimizes the chance of encountering bedrock.

9.2.2 Concrete Box Culvert

Replacement of the culvert with a concrete box culvert on the same alignment is considered a viable alternative for this site. Since there is no grade raise proposed, 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 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, as shown on OPSD 803.010. The bedding material must be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation and placement and compaction of the bedding material must be carried out in the dry. 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 μm . The surface prepared to support the box units should have a minimum 75 mm thick top levelling course consisting of uncompacted Granular A as per OPSS 422.

The underside of the bedding material should be placed at or below Elevation 456.4 m, which corresponds to compact sand fill or native gravelly sand to sand and gravel subgrade. Any boulders or large cobbles, and soft, very loose, organic, or other detritus material should be sub-excavated and replaced with compacted material to provide a uniformly competent subgrade condition. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction. Bedrock was encountered at shallow depths at both the inlet and outlet of the existing culvert at Elev. 457.7 and Elev. 456.3, respectively, and bedrock outcrops were observed in close proximity to the site (10 to 50 m). Depending on final design culvert invert grades there may be a need to excavate bedrock at one or both ends of the culvert. It is recommended that additional investigation, including rock coring, be conducted during detailed design in order to confirm the bedrock elevation along the alignment of the replacement culvert, particularly at the inlet and outlet. This additional investigation will be required to situate the culvert in a location which minimizes the chance of encountering bedrock.

The following geotechnical capacities could be used for design of a box culvert of 4 to 6 m in width founded at or below Elevation 456.4 m on the compact gravelly sand to sand and gravel:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Geotechnical Resistance at SLS (for up to 25 mm of settlement) of 200 kPa

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

The geotechnical resistances provided above are for vertical, concentric loading conditions. 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 slabs and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.45.

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

9.2.3 Culvert Headwall / Wingwalls

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

The borehole information indicates that the founding soils at the inlet/outlet generally consist of shallow bedrock or compact gravelly sand to sand and gravel deposits.

9.2.3.1 RSS Walls

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

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS mass and, in severe cases, to possible failure of the system. The foundation

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

The RSS mass should be founded on a 0.5 m thick engineered fill pad resting on the compact sand fill or native gravelly sand to sand and gravel subgrade at or below approximate Elevation 457.5 m, or on shallow bedrock. Due to the possibility of an uneven bedrock surface, additional investigation is recommended during the detailed design stage to confirm the elevation of the bedrock surface along the alignment of the RSS walls to determine the appropriate founding level to avoid bedrock excavation.

An RSS wall founded on gravelly sand to sand and gravel subgrade material or bedrock may be designed using a factored geotechnical resistance at ULS of 250 kPa and a geotechnical reaction at SLS of 170 kPa (up to 25 mm of settlement). The engineered fill pad placed under the RSS mass must consist of OPSS.PROV 1010 Granular A or Granular B Type II compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must be at least 300 mm beyond the limits of the RSS mass and levelling strip.

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

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

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

A geotextile filter fabric must be incorporated in the RSS design to prevent loss of fines from granular material behind the wall subject to fluctuating water level. 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 and the strips must be corrosion resistant.

The RSS walls may be founded on native gravelly sand to sand and gravel soil which is erodible. Adequate rock 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.

9.2.3.2 Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on the compact gravelly sand to sand and gravel subgrade, or on bedrock. Due to the possibility of an uneven bedrock surface, additional investigation is recommended during the detailed design stage to confirm the elevation of the bedrock surface along the alignment of the concrete retaining walls.

If founded on soil, the walls should be provided with a sufficient frost cover (minimum 2.3 m at this site) and founded at Elevation 457.7 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 wall footing. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to sliding between precast concrete and the underlying gravelly sand to sand and gravel should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.55.

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.

9.2.4 Frost Cover

The depth of frost penetration at this site is approximately 2.3 m. The base of retaining wall footings, if employed, should be provided with a minimum of 2.3 m of earth cover as protection against frost action. The frost cover requirement does not apply to the concrete pipe, CSP or box culvert.

The frost taper investigation in Boreholes 17-12 to 17-14 indicated the presence of at least 3.5 m of granular fill below the asphalt to at least 30 m west of the existing culvert. It is not known whether the granular fill material was intentionally placed as a frost taper, or as road embankment and base material.

The native gravelly sand to sand and gravel and the underlying native sand have low frost susceptibility. Accordingly, no frost taper will be required.

9.2.5 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, peat, streambed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with bedding materials 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, subgrade preparation and placement and compaction of granular material must be carried out in the dry.

9.2.6 Settlement

It is anticipated that the replacement culvert will have approximately the same alignment and opening size as the existing culvert with no grade raise. Since there is no grade raise

and the foundation soils consist of compact gravelly sand to sand and gravel soils or bedrock, very little post construction settlement is expected at this site.

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, native gravelly sand to sand and gravel, and native sand at this site are classified as Type 3 soils above the water level and type 4 soils below the water level. Surficial alluvial deposits and any cohesionless soils 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. Excavation for culvert replacement will be carried out through the existing embankment fill and extended into the native gravelly sand to sand and gravel deposit and possibly bedrock. It must be noted that obstructions may be encountered within the fill, including rock fill and possibly cobbles and boulders.

Bedrock was encountered at shallow depths at the inlet and outlet of the existing culvert. Depending on final design grades of the proposed culvert, some excavation of the bedrock may be necessary.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level, and diversion of the creek flow will be required. Seepage should also be anticipated from the embankment fill. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps will be required to maintain dry excavations during the course of staged construction. Dewatering operations should be carried out in accordance with OPSS 517 and SP 517F01 Amendment to OPSS 517. 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.

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

11. STREAM DIVERSION PIPE

It is anticipated that a stream diversion pipe consisting of a CSP will be required to facilitate construction of the permanent culvert replacement. Based on the preliminary general

arrangement drawings, the invert level of the diversion pipe is approximately at Elev. 457.6 m. The pipe invert is expected to lie within embankment fill materials consisting of compact gravelly sand or in the native gravelly sand.

Due to the variability of the bedrock elevations across the site, and the presence of existing bedrock outcrops in this area, excavation of bedrock may be necessary depending on the final design grades of the diversion pipe.

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

12. 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, 803.010 or 802.034, as appropriate. Backfilling for the culvert should be in accordance with OPSS.PROV 401 for a CSP or OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS.PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS.PROV 501.

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

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

where

p_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below)
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 coefficient 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
Passive	3.7	-	3.3	-

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

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

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

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

13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2014, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the stratigraphy. In view of the presence of shallow greywacke bedrock on site, the site can be classified as Site Class B in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2,475-year return period seismic event at this site is 0.040 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 $\phi = 32^\circ$, $\gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 32^\circ$; $\gamma = 20 \text{ kN/m}^3$
Active (K_{AE})*	0.28	0.32	0.32
At Rest (K_{OE})**	0.46	0.51	0.51

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

** After Woods

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

14. TEMPORARY PROTECTION SYSTEM

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

Options for roadway protection are a soldier pile-lagging system or sheet piles, although it may be difficult to drive sheet piles at this site due to the presence of rock fill in the embankment fill, and the presence of shallow bedrock with a varying profile.

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

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

Table 14.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Gravelly Sand/Sand Fill	Gravelly Sand to Sand and Gravel	Sand
ϕ (angle of internal friction)	32°	32°	30°
γ (total unit weight)	20 kN/m^3	20 kN/m^3	20 kN/m^3
γ' (submerged unit weight)	10 kN/m^3	10 kN/m^3	10 kN/m^3
K_a	0.31	0.31	0.33
K_p	3.3	3.3	3.0

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

15. EMBANKMENT RESTORATION

The existing Highway 11 embankment is approximately 4.0 m in height at the culvert location and the existing embankment slopes appear to be stable. Provided that the embankment is reconstructed at the same slope inclination as the existing embankment, but not steeper than 2H:1V, the restored embankment slope should remain stable.

It is anticipated that there will be no grade raise or embankment widening at this site for the culvert replacement, and therefore settlement of the embankment is not a concern. Any settlement due to changes in the culvert configuration is expected to be less than 25 mm. Additional settlement would be induced if the final configuration includes additional fill to raise or widen the embankment, including placement of fill behind wingwalls.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS.PROV 206 and OPSS.PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material. Alternatively, the existing granular fill may be used above the culvert cover and below the roadbase granular fill, provided it is free of organics, unfrozen, and at a moisture content that is suitable for compaction.

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

16. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field and 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 or clay seal should be used at the inlet to minimize the potential for erosion or piping around the culvert. The clay seal should be provided at the inlet and should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geo-synthetic clay liner may be used in place of a compacted clay seal.

17. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The low pH in one sample of the sand indicates that there is a potential for corrosion on concrete foundations from the surrounding soil. However, the sulphate and chloride concentrations were low for both the soil and water samples tested.
- The potential for sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be negligible.
- The potential for soil or surface water corrosion on metal is considered to be moderate to mild due to the low to moderate resistivity and pH of the sand samples tested.
- Appropriate protection measures are recommended if metal structural elements are used.

18. CONSTRUCTION CONCERNS

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

- Shallow bedrock is anticipated at the site, particularly at the north and south ends of the culvert, and in the area of the proposed temporary diversion pipe. There may be a requirement for rock excavation. Additional investigation is recommended during the detailed design stage to confirm the bedrock surface profile along the culvert, retaining wall and diversion pipe alignments to situate them in locations which minimize the chance of encountering bedrock.
- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent sloughing and instability of the excavation walls.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.

- Rock fill was encountered in the embankment fill; therefore, rock pieces or cobbles and boulders should be anticipated and dealt with during construction. These materials may interfere with the excavation and cofferdam installation. The Contractor must be prepared to remove or otherwise penetrate these obstructions. Suggested wording for an NSSP on obstructions is included in Appendix F.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

19. DETAILED DESIGN INVESTIGATION

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

- No additional investigation required through the existing embankment along the culvert alignment. Existing borehole information is sufficient for detailed design.
- An additional borehole is recommended near the inlet of the proposed culvert. Borehole 17-09, which was advanced with a tri-pod, encountered refusal on probable bedrock at a depth of 1.2 m below the ground surface. It is recommended that a borehole be drilled using equipment that is capable of coring rock in order to confirm the depth to the bedrock surface at this location.
- Based on the MTO's typical Minimum Investigation Requirements, it is recommended that 2 boreholes be drilled at each proposed cofferdam location. Depending on the cofferdam locations, Borehole 17-11 may be used for the outlet, and should be supplemented by 1 additional borehole at the outlet cofferdam. At the inlet cofferdam, the new borehole recommended above near 17-09 may be used, and should be supplemented with 1 additional borehole. The boreholes should be advanced to minimum depths of 10 m, and if bedrock is encountered, it should be cored for a minimum depth of 3 m. If the cofferdams are too far away from the inlet and outlet, then 2 new boreholes should be drilled at each location instead.
- Additional boreholes are recommended along the alignment of the proposed temporary diversion pipe, if the pipe is to be installed using trenchless methods. 3 boreholes should be advanced, including 1 near each end of the pipe and 1 through the embankment, in order to

assess the presence of any obstructions that may impede a trenchless installation. The boreholes should be drilled to depths of 3 times the pipe diameter below the proposed invert level. If bedrock is encountered, it should be cored for a minimum depth of 3 m below the pipe invert. No boreholes are required if the temporary diversion pipe will be installed in an open trench.

20. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Cory Zanatta, 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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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.

EXPLANATION OF ROCK LOGGING TERMS


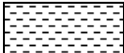



ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No 17-08

1 OF 2

METRIC

W.P. 6805-14-01 LOCATION Wawiag Creek Culvert, MTM NAD 83 Zone 15 N 5 390 031.0 E 262 713.7 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.03.20 - 2017.03.22 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
461.5	GROUND SURFACE							20 40 60 80 100						
0.0	ASPHALT: (100mm)							20 40 60 80 100						
0.1	Gravelly SAND , some silt, some rockfill Very Dense to Compact Brown Moist (FILL)		1	GS			461							
			1	SS	100/									
					0.125									
			2	SS	37		460							
			3	SS	14		459							22 67 11 (SI+CL)
458.5	SAND , some silt, some gravel, trace clay Loose Brown Wet (FILL)		4	SS	8		458							11 68 18 3
457.5	Gravelly SAND , some silt Compact Brown Wet		5	SS	25		457							
455.9	SAND , trace gravel, trace silt Very Loose to Very Dense Brown Wet		6	SS	3		456							
5.6			7	SS	54		455							
453.3	GREYWACKE moderately weathered, strong, grey Highly broken zone (125mm) at 8.2m Sub-vertical fracture (200mm) at 8.4m and (175mm) at 9.4m Sub-horizontal fracture at 8.5m and 8.6m Horizontal fracture at 9.0m, 9.1m, 9.2m, 9.7m, 10.3m, 10.7m and 11.2m		1	RUN			454							7 86 7 (SI+CL)
8.2							453						FI >10	
							452						2	
													2	
													1	RUN #1 TCR=100% SCR=62% ROD=50% UCS=85MPa (Average)
													2	
													0	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-08

2 OF 2

METRIC

W.P. 6805-14-01 LOCATION Wawia Creek Culvert, MTM NAD 83 Zone 15 N 5 390 031.0 E 262 713.7 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.03.20 - 2017.03.22 CHECKED BY CZ

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										WATER CONTENT (%)
	Continued From Previous Page							20	40	60	80	100						
450.2	Sub-horizontal fracture at 10.2m and 10.5m Vertical fracture (150mm) at 11.1m Highly broken zone (225mm) at 10.9m		2	RUN			451										2 1 3 >10	RUN #2 TCR=100% SCR=70% RQD=67% UCS=82MPa (Average)
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CUTTINGS AND CONCRETE TO SURFACE. DYNAMIC CONE PENETRATION TEST CONDUCTED ADJACENT TO BOREHOLE.																	

RECORD OF BOREHOLE No 17-09

1 OF 1

METRIC

W.P. 6805-14-01 LOCATION Wawia Creek Culvert, MTM NAD 83 Zone 15 N 5 390 045.1 E 262 706.1 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2017.03.23 - 2017.03.23 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)						
						20	40	60	80	100	20	40	60	kn/m ³	GR SA SI CL		
458.9	GROUND SURFACE																
0.0	Silty SAND , some gravel, some organics, trace roots and rootlets		1	SS	10												
458.3	Compact Brown Wet																
0.6	SAND and GRAVEL , trace silt		2	SS	14										52 46 2	(SI+CL)	
457.7	Compact Dark Brown Wet																
1.2	END OF BOREHOLE AT 1.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

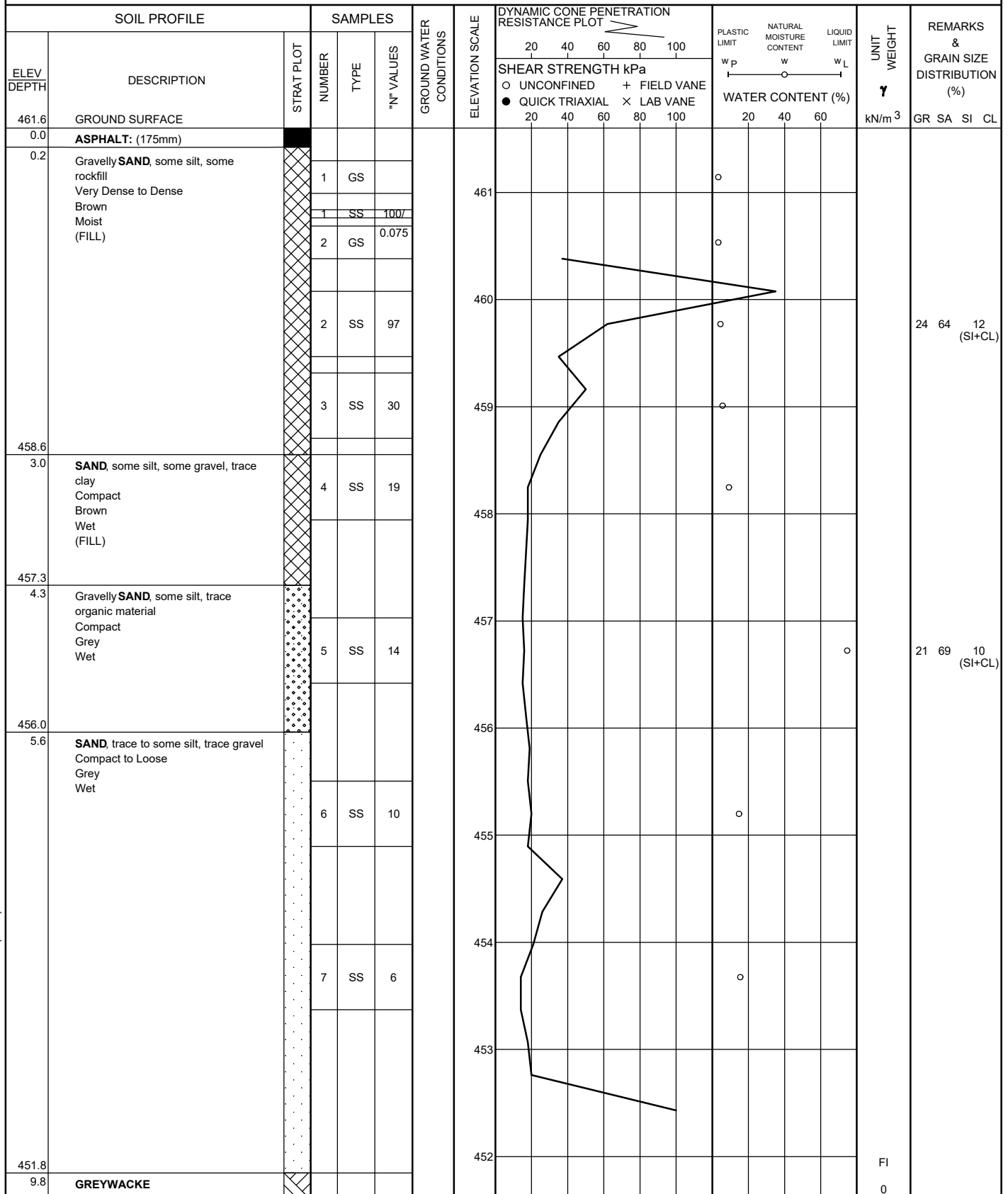
ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

RECORD OF BOREHOLE No 17-10

1 OF 2

METRIC

W.P. 6805-14-01 LOCATION Wawia Creek Culvert, MTM NAD 83 Zone 15 N 5 390 027.1 E 262 704.9 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.03.24 - 2017.03.24 CHECKED BY CZ



ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-11

1 OF 1

METRIC

W.P. 6805-14-01 LOCATION Wawia Creek Culvert, MTM NAD 83 Zone 15 N 5 390 013.7 E 262 711.5 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.03.23 - 2017.03.23 CHECKED BY CZ

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20	40	60	80	100	W _P	W		
458.4	GROUND SURFACE															
0.0	Silty SAND , trace clay, some organics, trace roots and rootlets Loose Brown Wet		1	SS	5								○			0 73 21 6
457.7																
0.7	Gravelly SAND , trace silt, some boulders Compact to Very Dense Brown Wet		2	SS	20								○			
			3	SS	100/ 0.125								○			
456.3																
2.1	GREYWACKE moderately weathered, very strong, grey Horizontal fracture at 2.2m, 2.5m, 2.7m, 2.9m, 3.1m and 3.2m Sub-horizontal fracture at 2.5m, 3.3m and 3.4m Sub-vertical fracture (50mm) at 2.2m, (125mm) at 2.6m, (25mm) at 2.7m, (100mm) at 3.0m and 3.2m, (200mm) at 3.3m Sub-vertical fracture (175mm) at 3.7m and (450mm) at 4.6m Sub-horizontal fracture at 4.3m		1	RUN												RUN #1 TCR=100% SCR=53% RQD=38% UCS=227MPa (Average)
			2	RUN												RUN #2 TCR=100% SCR=53% RQD=52% UCS=239MPa (Average)
453.2																
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.															



ONTMT4S MTO-15593.GPJ 2017TEMPLATE(MTO).GDT 10/2/17

RECORD OF BOREHOLE No 17-12

1 OF 1

METRIC

W.P. 6805-14-01 LOCATION Wawiag Creek Culvert, MTM NAD 83 Zone 15 N 5 390 030.5 E 262 697.1 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.03.20 - 2017.03.20 CHECKED BY CZ

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									WATER CONTENT (%)	
461.6	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT: (175mm)																	
0.2	Gravelly SAND , trace silt Brown Moist (FILL)		1	GS														
			2	GS														
	Compact		1	SS	11													
457.5																		
4.1	Gravelly SAND , some silt Compact Brown Wet																	
			2	SS	13													
456.4																		
5.2	END OF BOREHOLE AT 5.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CUTTINGS AND CONCRETE TO SURFACE.																	

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

RECORD OF BOREHOLE No 17-13

1 OF 1

METRIC

W.P. 6805-14-01 LOCATION Wawia Creek Culvert, MTM NAD 83 Zone 15 N 5 390 030.1 E 262 687.1 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.03.20 - 2017.03.20 CHECKED BY CZ

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									
461.7	GROUND SURFACE																
0.0	ASPHALT: (175mm)																
0.2	Gravelly SAND, trace silt Brown Moist (FILL)		1	GS													
			2	GS													
	Compact		1	SS	12											34 57 9 (SI+CL)	
458.0																	
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CUTTINGS AND CONCRETE TO SURFACE.																



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

RECORD OF BOREHOLE No 17-14

1 OF 1

METRIC

W.P. 6805-14-01 LOCATION Wawia Creek Culvert, MTM NAD 83 Zone 15 N 5 390 030.2 E 262 677.0 ORIGINATED BY AHF
 HWY 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.03.20 - 2017.03.20 CHECKED BY CZ

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												
461.9	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (175mm)																			
0.2	Gravelly SAND , some silt Brown Moist (FILL)		1	GS																
			2	GS																
		Compact		1	SS	10														
458.2																				
3.7	END OF BOREHOLE AT 3.7m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CUTTINGS AND CONCRETE TO SURFACE.																			

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

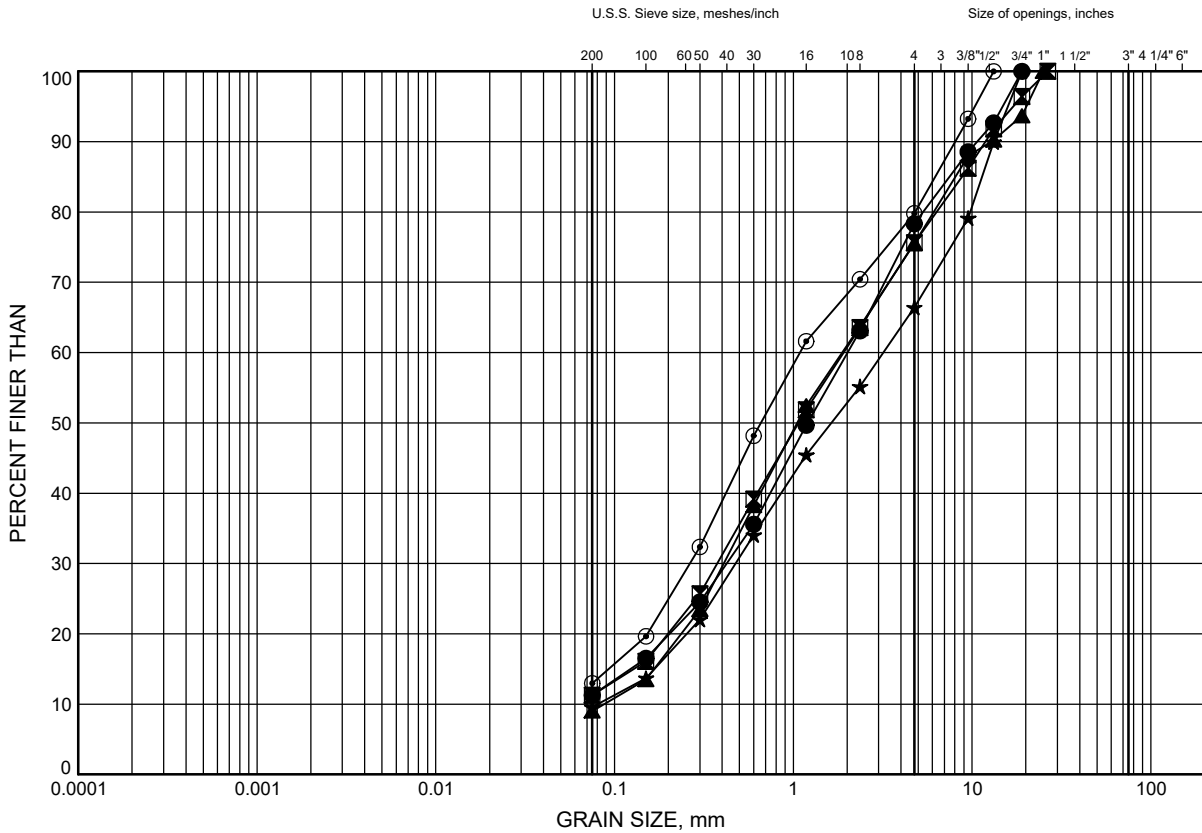
Appendix B

Geotechnical and Analytical Laboratory Test Results

Wawiag Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-08	2.6	458.9
⊠	17-10	1.8	459.8
▲	17-12	3.4	458.2
★	17-13	3.4	458.3
⊙	17-14	3.4	458.5

Date June 2017
W.P. 6805-14-01

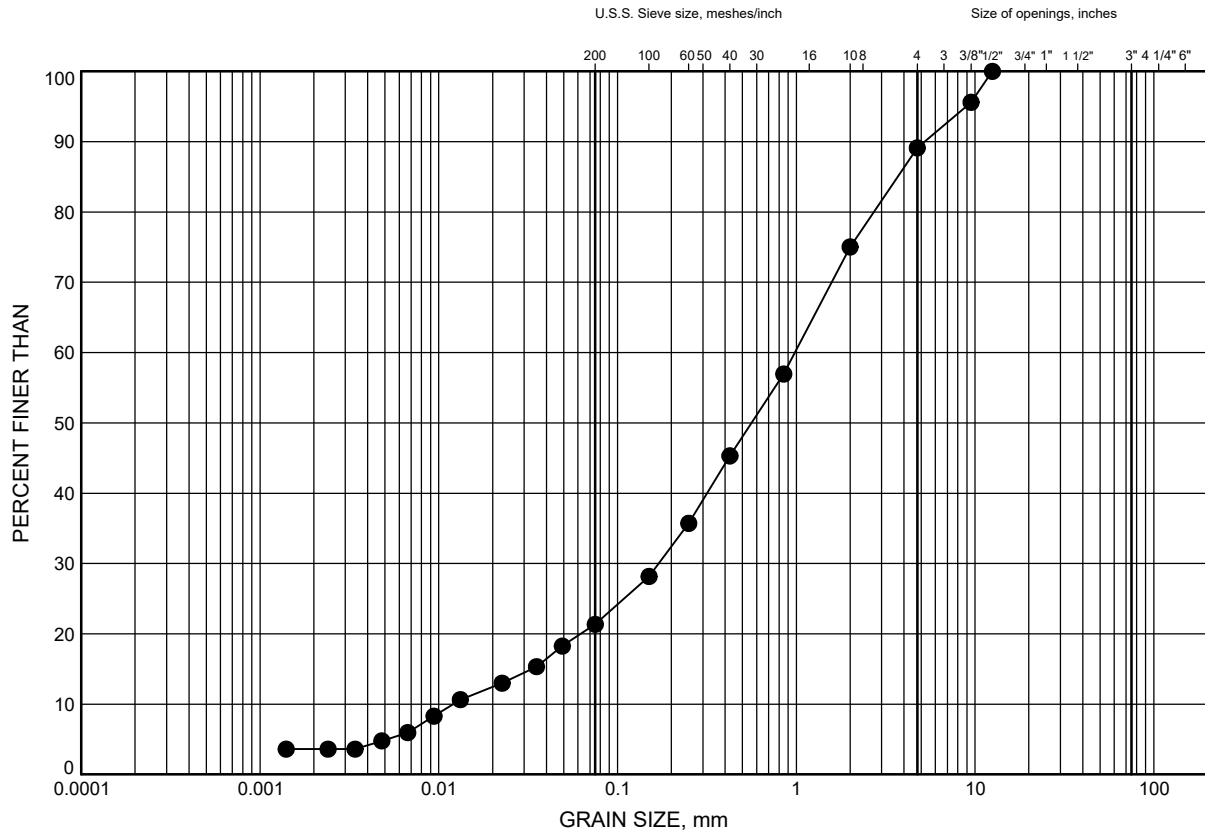


Prep'd AN
Chkd. MEF

Wawiag Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-08	3.4	458.1

Date June 2017
W.P. 6805-14-01

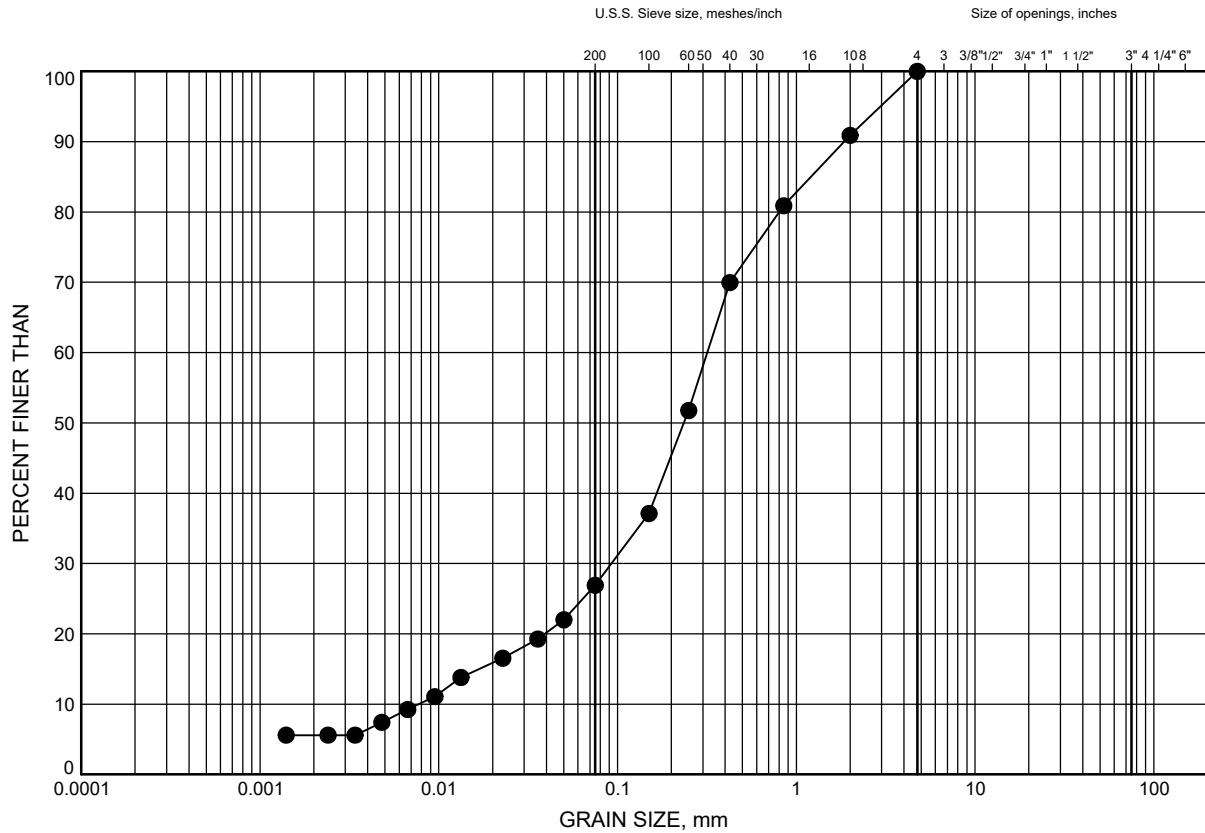


Prep'd AN
Chkd. MEF

Wawiag Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-11	0.3	458.1

Date June 2017
W.P. 6805-14-01

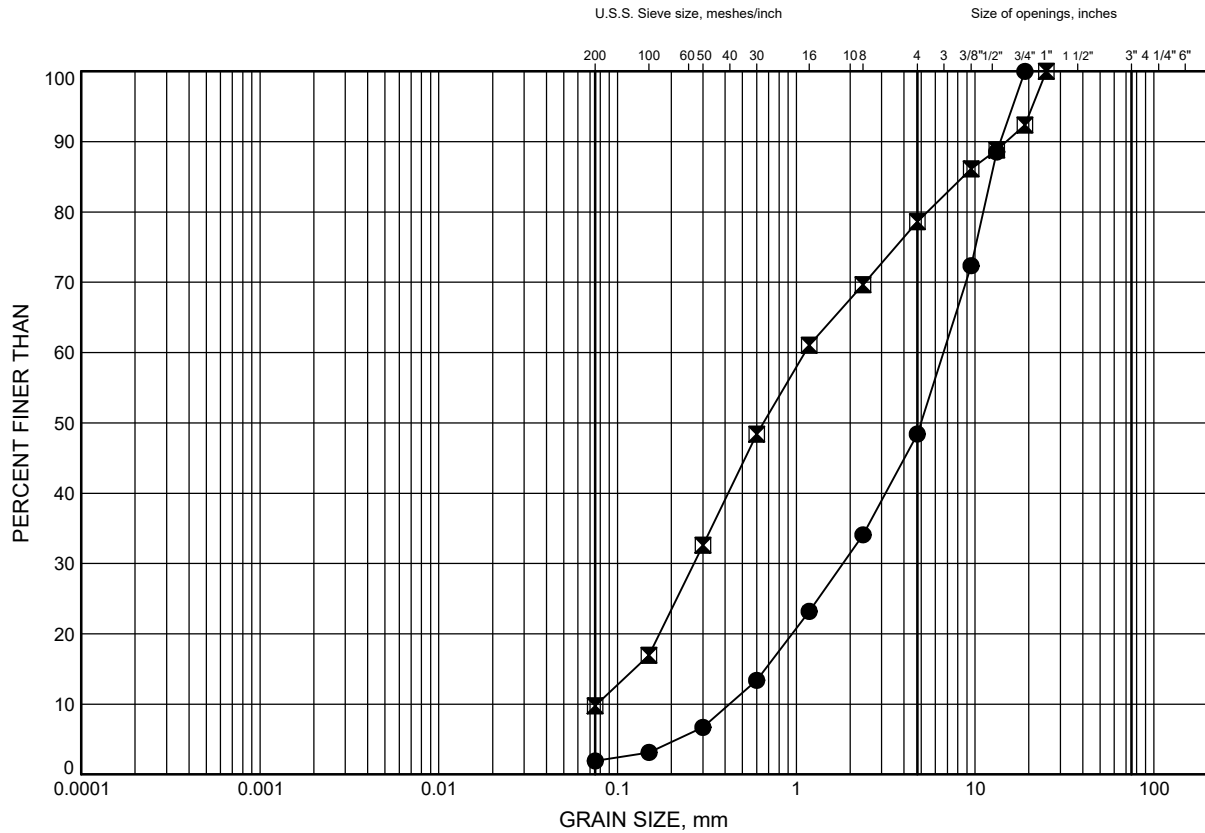


Prep'd AN
Chkd. MEF

Wawiag Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B4

Gravelly SAND to SAND and GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-09	0.9	458.0
⊠	17-10	4.9	456.7

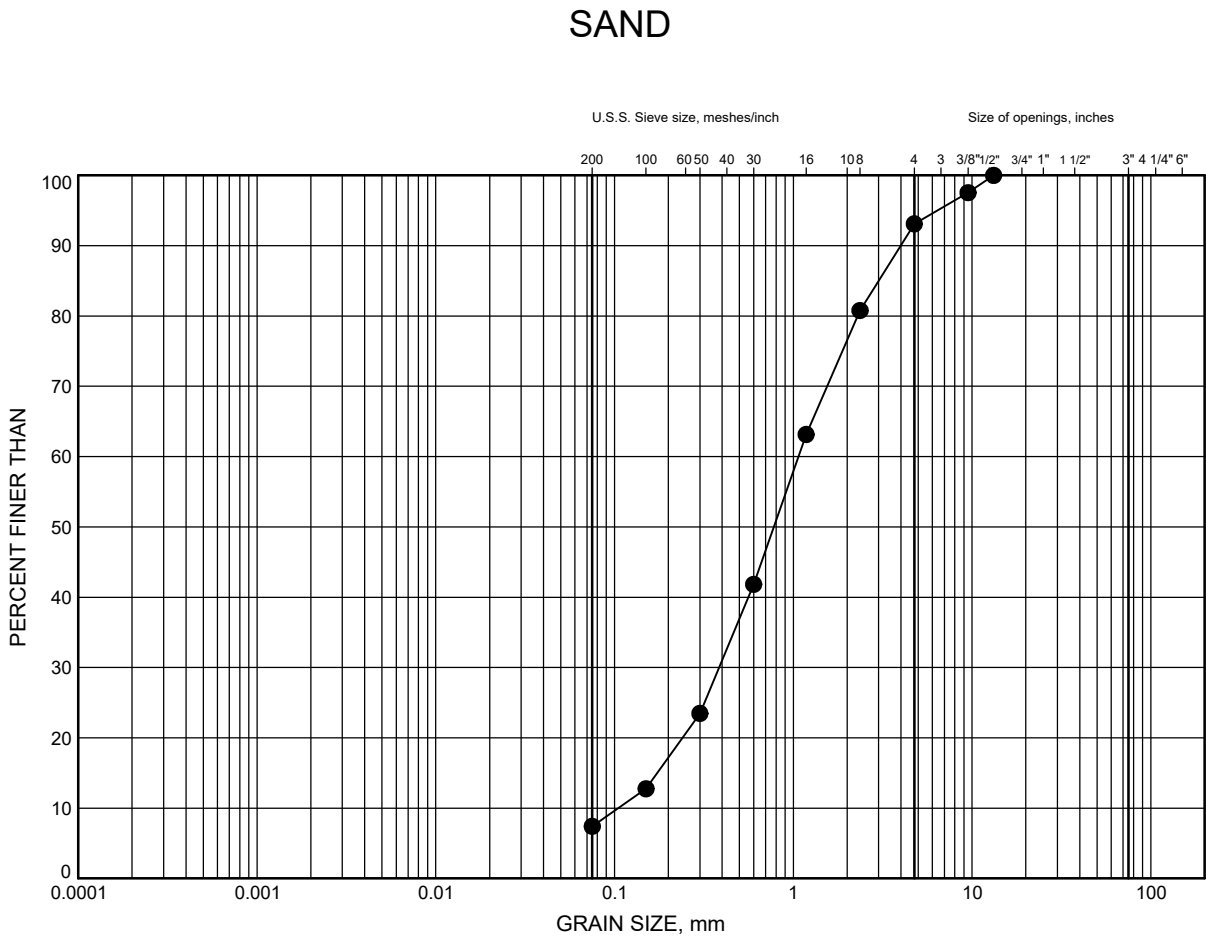
Date June 2017
W.P. 6805-14-01



Prep'd AN
Chkd. MEF

Wawiag 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)
●	17-08	7.9	453.6

Date June 2017
W.P. 6805-14-01



Prep'd AN
Chkd. MEF



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 15593
Client: Hatch
Project Name: Wawiag Culvert
Core Size: NQ BH No : 17-08

Date Drilled: 22-Mar-17
Date Tested: 21-Apr-17
Tester: WHW
Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	8.6	D	6.9	47.0	57.7	2.9	68.6	Greywacke	Strong
2	1	9.1	A	11.4	47.3	36.2	4.8	115.8	Greywacke	Very Strong
3	1	9.3	D	7.1	47.1	59.8	3.0	70.9	Greywacke	Strong
4	2	10.0	D	7.8	47.3	63.2	3.2	77.2	Greywacke	Strong
5	2	10.4	A	11.2	47.2	50.6	3.7	87.6	Greywacke	Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

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

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

* Correlation factor to obtain UCS values is 24.



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 15593
 Client: Hatch
 Project Name: Wawiag
 Core Size: NQ BH No : 17-10

Date Drilled: 24-Apr-17
 Date Tested: 01-May-17
 Tester: GA
 Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	7.1	D	24.7	47.1	15.7	10.3	246.6	Greywacke	Very Strong
2	1	7.8	A	27.0	47.1	59.8	7.7	186.0	Greywacke	Very Strong
3	1	7.5	D	20.0	47.1	90.8	8.3	200.0	Greywacke	Very Strong
4	1	7.3	D	17.7	47.1	111.2	7.4	177.1	Greywacke	Very Strong
5	1	7.6	A	24.9	47.1	73.1	6.1	146.7	Greywacke	Very Strong
6	2	7.8	D	8.2	47.1	102.1	3.4	82.3	Greywacke	Strong
7	2	8.0	D	23.8	47.1	117.8	9.9	238.0	Greywacke	Very Strong
8	2	8.4	D	20.2	47.1	270.1	8.4	201.5	Greywacke	Very Strong
9	2	8.8	D	24.1	47.1	92.1	10.0	240.2	Greywacke	Very Strong
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- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
 Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.

**THURBER ENGINEERING LTD.****POINT LOAD TEST SHEET****ASTM D5731-08**

Job No: 15593
 Client: Hatch
 Project Name: Wawiag Culvert
 Core Size: NQ BH No : 17-11

Date Drilled: 23-Mar-17
 Date Tested: 20-Apr-17
 Tester: RT
 Reviewed by: CZ

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	2.3	D	18.4	46.6	150.0	7.8	186.4	Greywacke	Very Strong
2	1	2.6	D	25.0	46.6	150.0	10.6	253.8	Greywacke	Extremely Strong
3	1	3.0	D	19.9	46.6	150.0	8.4	202.4	Greywacke	Very Strong
4	1	3.3	D	25.0	46.6	150.0	10.6	253.8	Greywacke	Extremely Strong
5	1	3.5	D	23.6	46.6	150.0	10.0	239.8	Greywacke	Very Strong
6	2	4.0	D	20.6	46.6	150.0	8.7	208.9	Greywacke	Very Strong
7	2	4.3	D	25.0	46.6	150.0	10.6	253.8	Greywacke	Extremely Strong
8	2	4.6	D	25.0	46.6	150.0	10.6	253.8	Greywacke	Extremely Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

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

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

* Correlation factor to obtain UCS values is 24.



Photo 1: Borehole 17-08 Bedrock Core Sample



Photo 2: Borehole 17-10 Bedrock Core Sample



Photo 3: Borehole 17-11 Bedrock Core Sample



SGS Canada Inc.

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

Thurber Engineering Ltd

Attn : Cory Zanatta

2010 Winston Park Dr
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 240

Fax:

Project : 15593

08-May-2017

Date Rec. : 02 May 2017

LR Report: CA14060-MAY17

Reference: 15593 Cory Zanatta

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	7: 17-08 SS6	8: 17-10 SS6
Sample Date & Time					26-Mar-17	26-Mar-17
Temperature Upon Receipt [°C]	---	---	---	---	6.0	6.0
Corrosivity Index [none]	08-May-17	14:35	08-May-17	14:35	1.0	7.5
Soil Redox Potential [mV]	03-May-17	16:33	04-May-17	14:12	270	354
Sulphide [%]	05-May-17	13:47	05-May-17	15:54	< 0.02	0.03
% Moisture (wet wt) [%]	04-May-17	13:57	04-May-17	14:37	15.8	12.0
pH [no unit]	03-May-17	15:41	05-May-17	09:17	6.85	4.16
Chloride [µg/g]	05-May-17	17:42	08-May-17	14:40	120	78
Sulphate [µg/g]	05-May-17	17:42	08-May-17	14:40	26	420
Conductivity [uS/cm]	03-May-17	15:41	05-May-17	09:17	158	487
Resistivity (calculated) [Ohms.cm]	03-May-17	15:41	08-May-17	14:21	6330	2050

Temperature of Sample upon Receipt: 12 degrees C

Cooling Agent Present: Yes

Custody Seal Present: No

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



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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

Project : 15593

LR Report : CA14060-MAY17

Method Descriptions

Parameter	SGS Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013
pH	ME-CA-[ENV]EWL-LAK-AN-001

Deanna Edwards, B.Sc, C.Chem

Project Specialist

Environmental Services, Analytical



SGS Canada Inc.

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Project : 15593

LR Report : CA14060-MAY17

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0108-MAY17												
Chloride	0.4	µg/g	<0.4		3	20	101	80	120	105	75	125
Sulphate	0.4	µg/g	<0.4		2	20	97	80	120	87	75	125
Carbon/Sulphur - QCBatchID: ECS0006-MAY17												
Sulphide	0.02	%	<0.02		ND	20	113	80	120			
Conductivity - QCBatchID: EWL0047-MAY17												
Conductivity	2	uS/cm	< 2		2	10	93	90	110	NA		
pH - QCBatchID: EWL0047-MAY17												
pH	0.05	no unit	NA		0		100			NA		

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Project : 17840/17792

31-May-2017

Thurber Engineering Ltd**Attn :** Cory Zanatta

2010 Winston Park Dr
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 240

Fax:

Date Rec. : 10 May 2017**LR Report:** CA14294-MAY17**Reference:** 17840/17792 Cory Zanatta**Copy:** #2

CERTIFICATE OF ANALYSIS


Final Report - Reissue

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	8: Wawia Creek
Sample Date & Time						25-Apr-17
Temperature Upon Receipt [°C]	---	---	--	--	---	9.0
pH [no unit]	11-May-17	10:30	15-May-17	10:54	0.05	6.30
Conductivity [µS/cm]	11-May-17	10:41	15-May-17	10:51	2	47
Resistivity (calculated) [ohms.cm]	---	---	---	---	---	21200
Redox Potential [mV]	11-May-17	13:57	15-May-17	10:32	---	221
Chloride [mg/L]	15-May-17	18:20	16-May-17	13:24	0.04	5.8
Sulphate [mg/L]	15-May-17	18:20	16-May-17	13:24	0.04	1.8
Sulphide [mg/L]	11-May-17	12:10	12-May-17	16:01	0.006	0.009

Temperature of Sample upon Receipt: 9 degrees C

Cooling Agent Present: yes

Custody Seal Present: no


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Project : 17840/17792**LR Report :** CA14294-MAY17

Method Descriptions

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



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LR Report : CA14294-MAY17

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank		RPD		LCS / Spike Blank			Matrix Spike / Reference Material		
					Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)		
							Low	High		Low	High	
Anions by IC - QCBatchID: DIO0256-MAY17												
Chloride	0.04	mg/L	<0.04		2	20	97	80	120	100	75	125
Sulphate	0.04	mg/L	<0.04		0	20	96	80	120	89	75	125
Anions by IC - QCBatchID: DIO0269-MAY17												
Chloride	0.04	mg/L	<0.04		0	20	100	80	120	119	75	125
Sulphate	0.04	mg/L	<0.04		0	20	97	80	120	102	75	125
Conductivity - QCBatchID: EWL0183-MAY17												
Conductivity	2	µS/cm	< 2		0	10	99	90	110	NA		
pH - QCBatchID: EWL0182-MAY17												
pH	0.05	no unit	NA		1		100			NA		
Redox Potential - QCBatchID: EWL0192-MAY17												
Redox Potential	no	mV	NA		0	20	103	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0095-MAY17												
Sulphide	0.006	mg/L	<0.006		ND	20	80	80	120	NV	75	125
Sulphide by SFA - QCBatchID: SKA0105-MAY17												
Sulphide	0.006	mg/L	0.009		ND	20	96	80	120	125	75	125

Appendix C

Site Photographs



**Photo 1: Highway 11 embankment over Wawiag Creek Culvert,
looking southwest – drill rig setting up**



**Photo 2: Highway 11 embankment over Wawiag Creek Culvert,
facing east – drill rig setting up**



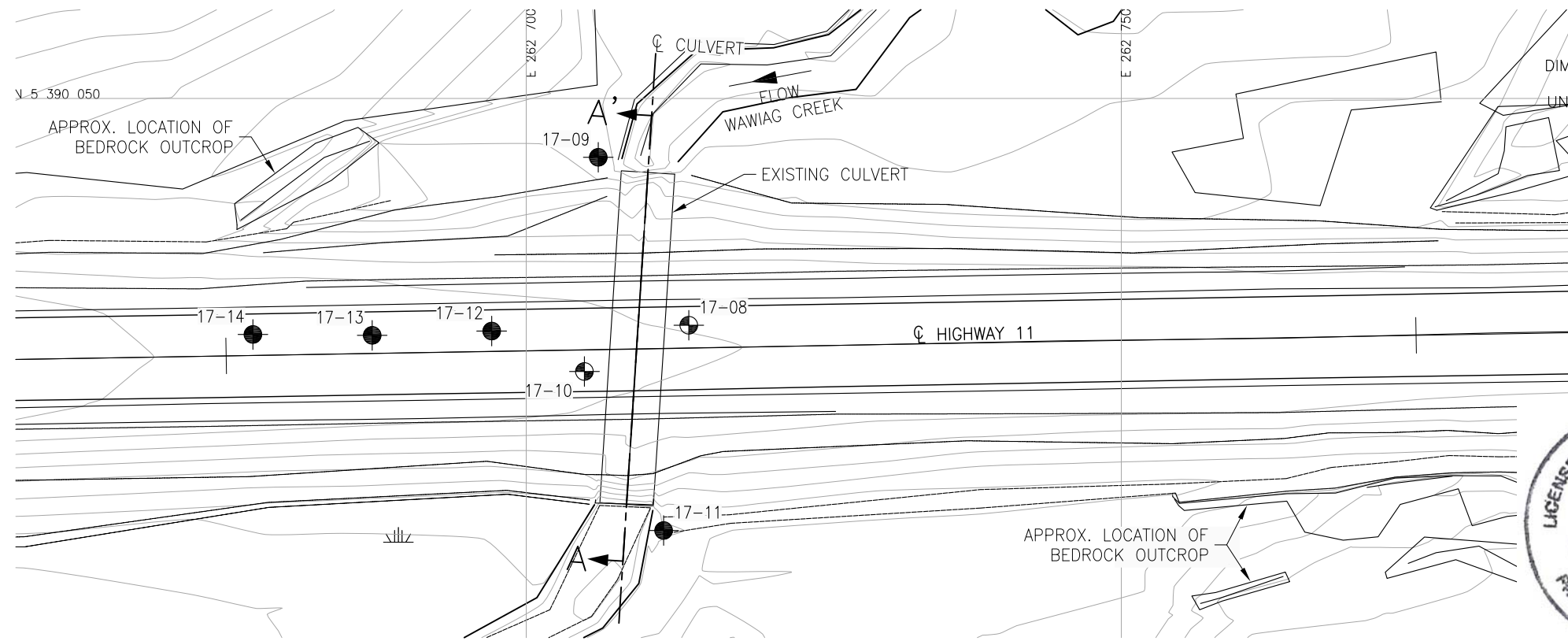
Photo 3: Wawiag Creek Culvert, north side – CSP extension



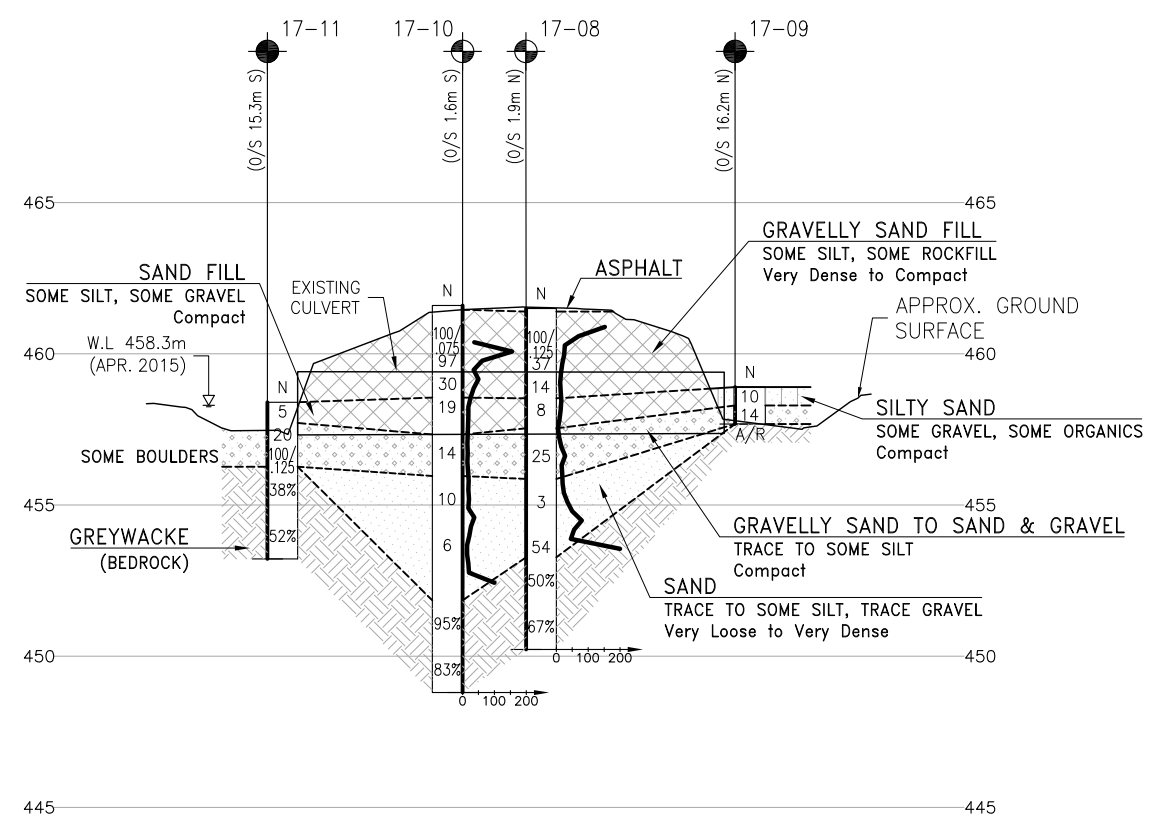
Photo 4: Wawiag Creek Culvert, south side – timber cells

Appendix D

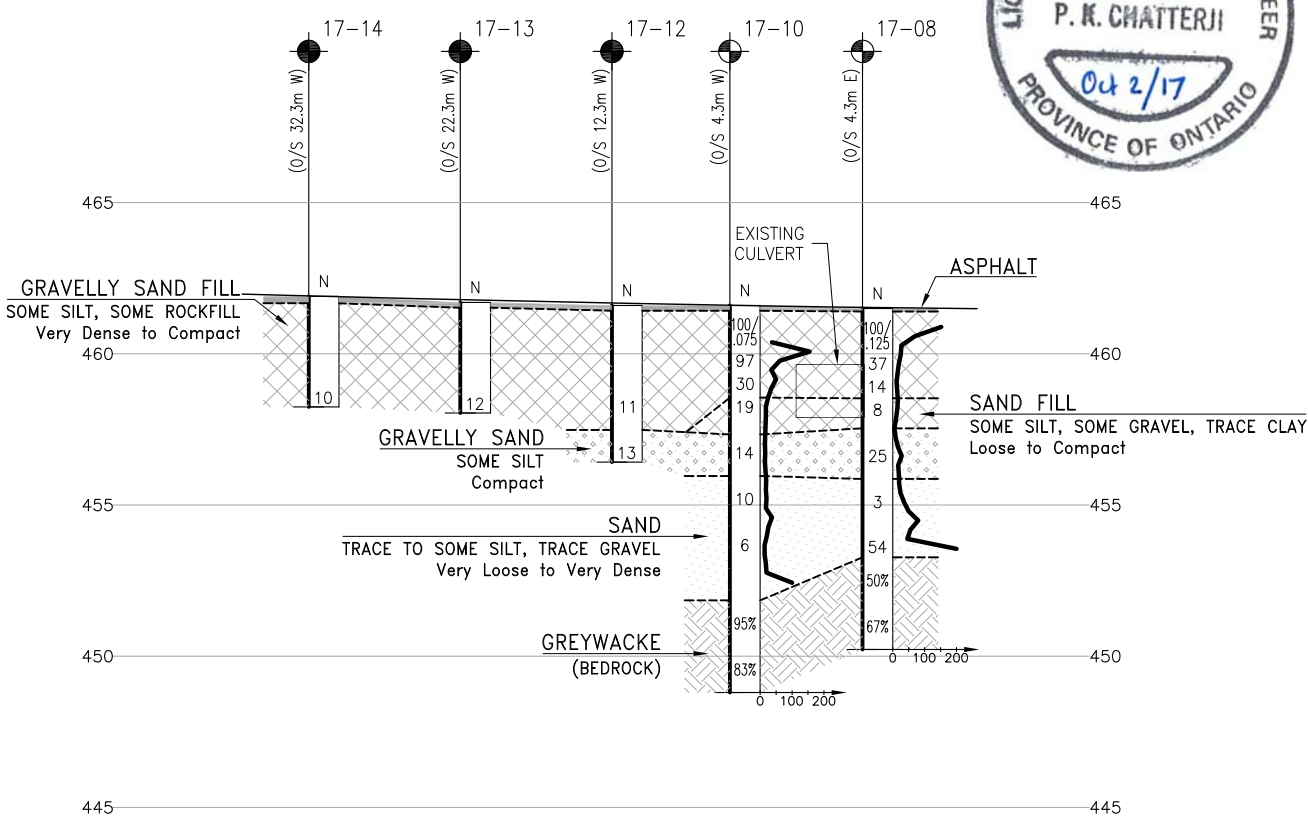
Borehole Locations and Soil Strata Drawing



PLAN
SCALE 1:500



SECTION A-A'



PROFILE ALONG CL HWY 11

SCALE 1:500
H 1:500
V 1:250

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



CONT No 6016-E-0012
WP No 6805-14-01

HIGHWAY 11
WAWIAG CREEK
CULVERT REPLACEMENT
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		
NO	ELEVATION	NORTHING	EASTING
17-08	461.5	5 390 031.0	262 713.7
17-09	458.9	5 390 045.1	262 706.1
17-10	461.6	5 390 027.1	262 704.9
17-11	458.4	5 390 013.7	262 711.5
17-12	461.6	5 390 030.5	262 697.1
17-13	461.7	5 390 030.1	262 687.1
17-14	461.9	5 390 030.2	262 677.0

- NOTES-**
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
 - This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
 - Coordinate system is MTM NAD 83 Zone 15
- GEOCRES No. 52B-33**

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CZ	CHK MEF	CODE LOAD DATE OCT 2017
DRAWN	AN	CHK CZ	SITE 48W-193/C/STRUCT DWG 1

Appendix E

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
<u>Advantages:</u> i. Ease of construction. ii. CSP's can accommodate small differential settlement along culvert axis iii. Concrete or steel pipes are likely to be more cost effective than concrete box or open footing culverts.	<u>Advantages:</u> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Segmental option can accommodate potential differential settlement along culvert axis.	<u>Advantages:</u> i. Conventional construction. ii. May have less environmental issues such as those involving spawning fish species.
<u>Disadvantages:</u> i. Multiple pipes may be needed to meet hydraulic requirements.	<u>Disadvantages:</u> i. More expensive than a concrete pipe or CSP culvert.	<u>Disadvantages:</u> i. Requires deeper excavation and potentially longer dewatering requirements. ii. Requires higher soil geotechnical resistances to support strip footings. iii. Cannot tolerate differential settlement.
FEASIBLE	FEASIBLE	NOT RECOMMENDED

Appendix F

List of OPSSs and OPSDs and Suggested Wording for NSSP

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

- OPSS 422 (Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut)
- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, and Granular Sheet piling)
- OPSS 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation)
- SP 517F01 Amendment to OPSS 517 (Design Storm Return Period and Preconstruction Survey Distance)
- OPSS 902 (Construction Specification for Excavating and Backfilling – Structures)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSS PROV 206 (Construction Specification for Grading)
- OPSS PROV 209 (Construction Specification for Embankments over Swamps and Compressible Soils)
- OPSS PROV 401 (Construction Specification for Trenching, Backfilling and Compacting)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS PROV 539 (Construction Specification for Temporary Protection Systems)
- OPSS PROV 804 (Construction Specification for Seed and Cover)
- OPSS PROV 1004 (Material Specification for Aggregates – Miscellaneous)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSD 802.010 (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)

2. Suggested Wording for NSSP on Dewatering

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

3. Suggested Wording for NSSP on Obstructions

Excavations and installation of cofferdams and roadway protection systems will encounter obstructions such as rock fill or cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths. Vibrating equipment is not permitted for installation of sheet piles.

4. Suggested Wording for Sub-Excavation and Backfilling for Culvert at Headwall

Refer to Special Provision No. 109S12 Amendment to OPSS 902, November 2010.

After the temporary excavation reaches the design subgrade elevation for the replacement culvert or headwall, the exposed surface should be inspected by a geotechnical engineer to confirm that the subgrade is suitable and uniformly compact. Any remaining topsoil, peat, soft creek bed deposits, soft or loose soil, or disturbed soils within the replacement culvert footprint should be removed and replaced with Granular A or Granular B type II material compacted as per OPSS. PROV. 501 before placing the bedding layer.

In the event that sub excavation is required, the width of the sub excavation shall be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V