



THURBER ENGINEERING LTD.

**DETAILED FOUNDATION INVESTIGATION AND DESIGN REPORT
ANGLER CREEK TRIBUTARY CULVERT REPLACEMENT
HIGHWAY 17, TOWNSHIP OF MCCOY
DISTRICT OF THUNDER BAY, ONTARIO
LATITUDE: 48.770526°, LONGITUDE: -86.380302°**

G.W.P. No. 6810-14-00, W.P. No. 6812-14-01, SITE No. 48E-079/C

GEOCRES Number: 42D-55

Report

to

HATCH

Date: December 18, 2018
File: 15595



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a detailed foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Angler Creek Tributary Corrugated Steel Pipe (CSP) Culvert on Highway 17, located in the Township of McCoy, District of Thunder Bay, Ontario. Thurber previously completed a preliminary foundation investigation at the culvert site in 2018.

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 to carry out this detailed foundation investigation under the Ministry of Transportation (MTO) Agreement 6016-E-0008.

The preliminary investigation previously conducted by Thurber is described in the following report:

- Preliminary Foundation Investigation and Design Report, Angler Creek Tributary Culvert Replacement, Highway 17, Township of McCoy, District of Thunder Bay, Ontario, GEOCRES Number 42D-52, prepared by Thurber Engineering Ltd.

The borehole logs from the preliminary investigation are included in this report.

2. SITE DESCRIPTION

The site is located on Highway 17, approximately 4.0 km west of Peninsula Road, in the Township of McCoy, District of Thunder Bay, Ontario. The existing culvert allows a tributary of Angler Creek to flow in a northeast to southwest direction under Highway 17. Highway 17 generally runs in an

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east-west direction at the culvert site.

The Ontario Structure Inspection Manual (Inspection Form) prepared by MTO on November 20, 2014 indicates that the existing structure is a corrugated steel round pipe culvert. The inspection report indicates that the diameter of the pipe is 3 m. The overall length of the structure is approximately 34 m. The estimated culvert invert is at approximate Elevation 270.31 m at the inlet (north) and 269.89 m at the outlet (south). The existing road grade at the culvert location is at approximate Elev. 274.3 m. The height of fill above the culvert approximately 1.2 m. The local creek water level downstream of the culvert was reportedly measured at Elev. 268.55 m in August 2012. The culvert currently sits high above the creek bed at the outlet.

The lands surrounding the culvert site predominantly consist of heavily forested areas with occasional lakes, gullies, rivers, and creeks. Local topography is jagged, rugged, cliffed, and knobby and is generally of medium to high relief. Bedrock outcrops are visible along Highway 17 within 50 m of the existing culvert. Large cobbles and boulders are present on the south embankment around the outlet 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 shallow or exposed bedrock with thin layers of till or peat overlying the bedrock. Based on local geological maps the bedrock in the area is identified as intrusive igneous rocks (syenite).

3. INVESTIGATION PROCEDURES

The current detailed field investigation for this project was carried out from July 21 to 28, 2018, and consisted of drilling and sampling five (5) boreholes, denoted as Boreholes 18-18 to 18-22, to depths ranging from 3.9 to 7.8 m below the existing ground surface. Boreholes 18-18, 18-19, 18-21 and 18-22 were located within the paved section of Highway 17, and Borehole 18-20 was located near the existing culvert outlet. Boreholes 18-18 and 18-19 were drilled at the locations of proposed abutments for a temporary modular bridge, Boreholes 18-20 and 18-21 were drilled along the culvert alignment to obtain additional information on the bedrock profile, and Borehole 18-22 was drilled near the location of the proposed creek diversion pipe.

The previous preliminary investigation for this project was carried out between July 16 and 17, and September 15 and 16, 2017, during which time three (3) boreholes (denoted as 17-11, 17-12, and 17-14) were drilled to depths of between approximately 2.1 m and 9.1 m below the existing ground surface.



The Record of Borehole sheets for the boreholes from the current and previous preliminary investigations are included in Appendix A. 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 14 was used for these boreholes.

For the boreholes located within the paved portion of Highway 17, a truck-mounted drill rig was used to advance the boreholes using wash boring and rock coring techniques. Borehole 18-20 was advanced using a Hilti DD 250 E portable drill with rock coring techniques. Soil samples were obtained in the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Bedrock was proven by NQ coring in all of the boreholes.

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 and rock samples for transport to Thurber's laboratory for further examination and testing.

All rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

Groundwater conditions were observed in the open boreholes throughout the drilling operations and in standpipe piezometers that were installed in Boreholes 18-18 and 18-19. The creek water level at the culvert outlet was also measured during the preliminary investigation. The boreholes and piezometers were backfilled on completion of the field investigation in general accordance with Ontario Regulation 903 as amended by Regulation 128/03.

Completion details of the boreholes and piezometers are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
18-18	7.3 / 267.1	4.6 / 269.8	Sand to 2.7 m, then bentonite holeplug to 0.3 m, then sand and gravel to 0.15 m, then asphalt to surface.



Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
18-19	7.5 / 266.8	6.1 / 268.1	Sand to 2.7 m, then bentonite holeplug to 0.15 m, then asphalt to surface.
18-20	3.9 / 265.5	None Installed	Bentonite holeplug to surface.
18-21	7.8 / 266.4	None Installed	Cuttings to 3.9 m, then bentonite holeplug to 0.6 m, then sand to 0.2 m, then asphalt to surface.
18-22	7.7 / 266.5	None Installed	Cuttings to 3.9 m, then bentonite holeplug to 0.6 m, then sand to 0.2 m, then asphalt to surface.
17-11	7.2 / 264.3	None Installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
17-12	9.1 / 265.2	None Installed	Borehole backfilled with bentonite holeplug to 0.9 m, auger cuttings to 0.6 m, concrete to 0.1m, then asphalt patch to surface
17-13	0.0 / 269.8	None Installed	Visual observation only. No excavation.
17-14	2.1 / 272.1	None Installed	Borehole backfilled with auger cuttings to 0.1 m then asphalt patch to surface.

4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and/or hydrometer). Point load tests were conducted on bedrock cores. 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, during the previous investigation, a sample



of the fill soil, 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 in the boreholes consisted of asphalt and sand and gravel embankment fill underlain by native sandy silt, sand and silt, gravel deposits and shallow syenite bedrock. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes 18-18, 18-19, 18-21, 18-22, 17-12 and 17-14 were drilled through the paved portion of Highway 17 and encountered a layer of asphalt that ranged in thickness from approximately 150 to 250 mm.

5.2 Sand and Gravel Fill

Sand and gravel embankment fill, ranging to gravelly sand fill, and containing trace to some silt, trace clay, and occasional cobbles and boulders, was encountered beneath the asphalt in Boreholes 18-18, 18-19, 18-21, 18-22, 17-12 and 17-14. The thickness of the sand and gravel fill, where fully penetrated (in all of these boreholes except Borehole 17-14) ranged from 1.9 to 3.8 m and extended to depths from 2.1 to 4.0 m (Elevation 272.1 to 270.2 m). Borehole 17-14 was terminated within the fill at a depth of 2.1 m (Elevation 272.1 m).

SPT 'N' values in the sand and gravel fill ranged from 4 to greater than 50 blows for 0.3 m penetration, indicating a loose to very dense relative density (typically compact to dense). The measured moisture contents in the fill ranged from 2 to 15 percent.



The results of grain size analyses conducted on samples of the sand and gravel 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:

Soil Particle	Percentage
Gravel	23 to 59
Sand	39 to 70
Silt & Clay	2 to 10

5.3 Sandy Silt with organics

A layer of sandy silt, containing organics, some gravel, and trace clay, and occasional cobbles was encountered at the surface of Borehole 17-11. The sandy silt layer with organics was approximately 1.8 m thick, extending to a depth of 1.8 m (Elevation 269.7 m).

The SPT 'N' value recorded in the sandy silt was 50 blows for 50 mm penetration on refusal, indicating the presence of cobbles or boulders. Measured moisture contents in the sandy silt were 32 to 37 percent.

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

Soil Particle	Percentage
Gravel	11
Sand	26
Silt	58
Clay	5

5.4 Sand and Silt

A layer of sand and silt, containing trace clay, trace gravel and trace organics was encountered at depths of 1.8 and 2.4 m in Boreholes 17-11 and 18-18 respectively. The sand and silt layer was approximately 1.6 to 2.4 m thick and extended to a depths from 4.0 to 4.2 m (Elevation 270.3 to 267.3 m).



SPT 'N' values measured in the sand and silt ranged from 8 to greater than 50 blows for 0.3 m penetration, indicating a loose to very dense relative density (typically loose to compact). Measured moisture contents in the sand and silt ranged from 11 to 40 percent.

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

Soil Particle	Percentage
Gravel	0 to 2
Sand	44
Silt	47 to 51
Clay	5 to 7

5.5 Gravel

A gravel deposit containing some sand and some cobbles and boulders was encountered below the fill in Boreholes 18-19, 18-21, 18-22 and 17-12 at depths from 2.1 to 4.0 m (Elevation 272.1 to 270.2 m), and at the creek bed level (Elevation 268.7 m) in Borehole 18-20. The gravel deposit ranging from 0.3 to 2.3 m thick and extended to bedrock contact at depths from 1.2 to 5.7 m (Elevation 270.0 to 268.2 m).

SPT 'N' values recorded in the gravel deposit ranged from 11 to 33 blows for 0.3 m penetration indicating a compact to dense relative density. The measured moisture content of the gravel ranged from 8 to 10 percent.

5.6 Bedrock

The overburden soils described above are underlain by igneous bedrock described as syenite. The bedrock was grey to pinkish grey and was described as moderately weathered to fresh.

Bedrock was proven by coring approximately 3 m of bedrock in Boreholes 18-18 to 18-22, 17-11 and 17-12. In addition to the coring, exposed bedrock was observed at the ground surface at Test Pit 17-13 near the outlet of the culvert. The exposed bedrock was located on the east bank of the creek, approximately 3 to 5 m south of the culvert outlet. The table below summarizes the depths and elevations to the top of bedrock.



Table 5.1 - Depths and Elevations of Top of Bedrock

Borehole/ Test Pit	Top of Bedrock	
	Depth (m)	Elevation (m)
18-18	4.0	270.3
18-19	4.4	269.8
18-20	1.2	268.2
18-21	4.3	269.9
18-22	4.2	270.0
17-11	4.2	267.3
17-12	5.7	268.6
17-13	0.0	269.8

Total Core Recovery (TCR) in the bedrock ranged from 77 to 100 percent. Solid Core Recovery (SCR) ranged from 67 to 100%. The Rock Quality Designation (RQD) determined from the recovered cores ranged from 17% to 100%, indicating fair to excellent rock quality (typically fair to excellent).

Average unconfined compressive strengths (UCS) of the rock typically ranged between 57 MPa and 218 MPa, indicating the rock is strong to very strong. These estimated rock strength values are interpreted from point load tests that were conducted on rock cores recovered from the boreholes. A summary of the Point Load Test Results is presented in Appendix B.

5.7 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes 18-18 and 18-19 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the standpipe piezometers are summarized in Table 5.2 below.

Groundwater levels were not measured in Boreholes 18-21 and 17-11, because water was added to the boreholes for drilling and coring purposes and had not dissipated by the time that the boreholes were backfilled.

Table 5.2 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
18-18	July 23, 2018	2.2	272.2	Standpipe piezometer
	July 24, 2018	2.4	271.9	
18-19	July 22, 2018	4.6	269.6	Standpipe piezometer
	July 24, 2018	4.7	269.5	
18-20	July 28, 2018	0.0	269.4	In creek
18-22	July 21, 2018	Dry	Dry	Open borehole
17-12	July 17, 2017	3.7	270.6	Open borehole
17-13	August 25, 2017	Dry	Dry	Bedrock outcrop
17-14	July 16, 2017	Dry	Dry	Open borehole

The groundwater level should be assumed to reflect the local creek water level. The creek water level at the culvert outlet was measured by Thurber during the previous investigation at Elevation 269.1 m on August 25, 2017, based on the depth below the bottom of the existing pipe. The water level at the outlet was subsequently measured by Thurber at Borehole 18-20 on July 28, 2018 at Elevation 269.4 m, and the water depth was 0.7 m to the creek bed. The creek water level downstream of the culvert was reported at Elevation 268.6 m on August 21, 2012.

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

A sample of the sand and gravel fill from Borehole 17-12, 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	
			17-12 SS4	Angler Creek
			(Sand and Gravel Fill)	(Creek Water)
Sulphide	mg/L	mg/L	<0.02	<0.006
Chloride	mg/L	mg/L	25	1.6
Sulphate	mg/L	mg/L	7	2.4
pH	-	-	9.62	6.82
Conductivity	µS/cm	µS/cm	168	55
Resistivity	Ohms.cm	Ohms.cm	5950	18000
Redox Potential	mV	mV	264	217

7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. The northing and easting coordinates and ground surface elevations were estimated based on field measurements relative to the topographic plans provided by Hatch.

OGS Inc. of Almonte, Ontario, and Eastern Ontario Diamond Drilling of Hawkesbury, Ontario, supplied and operated the drilling, sampling and in-situ testing equipment for the current field investigation. The field investigation was supervised on a full time basis by Mr. Ryan McCourt and Mr. Liam Steers of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. 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. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Thurber Engineering Ltd.



Mark Farrant, P.Eng.
Geotechnical Engineer



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



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report, and presents detailed foundation design recommendations for the proposed Angler Creek Tributary Corrugated Steel Pipe (CSP) culvert replacement on Highway 17, located in the Township of McCoy, District of Thunder Bay, Ontario. This detailed foundation report should be read in conjunction with the Preliminary Foundation Report.

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 November 20, 2014, and the MTO site plan drawing provided by Hatch. The existing structure is a round CSP culvert. The culvert has a 3 m diameter and is approximately 34 m long. The estimated culvert invert is at approximate Elevation 270.31 m at the inlet (north) and 269.89 m at the outlet (south). The existing road grade at the culvert location is at approximate Elevation 274.3 m, and there is approximately 1.2 m of fill above the culvert. The culvert currently sits high above the creek bed at the outlet.

The preliminary foundation report provided recommendations for pipe culvert, concrete box

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culvert, and open footing concrete culvert replacement options. General Arrangement Drawings and discussions with Hatch, indicate that a single structural plate corrugated steel pipe (SPCSP) culvert is the preferred replacement option. The new pipe will have a diameter of 3.99 m, with invert levels (underside of the pipe) at approximate Elevations of 269.02 and 268.18 m at the inlet and outlet, respectively.

The new SPCSP culvert replacement will be constructed along the same alignment as the existing CSP culvert. No grade raise or embankment widening is proposed for the culvert replacement. No headwalls or wingwalls are proposed.

A temporary creek diversion pipe is to be located approximately 8 m west of the culvert centreline while the culvert is being installed. The invert level of the diversion pipe is at approximate Elevation 270 m. A temporary modular bridge is proposed to accommodate vehicular traffic during installation of the replacement culvert, and temporary roadway protection may also be used.

9. CULVERT FOUNDATION DESIGN

In general, the subsurface conditions encountered in the boreholes consisted of embankment fill comprising of sand and gravel, underlain by compact to dense gravel, loose to compact sandy silt to sand and silt, and bedrock. The bedrock is at shallow depth at the site and borehole and visual observations of bedrock outcrops suggest an irregular bedrock surface topography. The water level in the creek was measured at approximately Elevation 269.4 m in August 2018 at the outlet.

The founding soils encountered at the proposed invert level (approximately Elevation 268.2 to 269 m) vary from loose to compact native sand and silt to bedrock.

Bedrock was encountered at shallow depths at the site, and was confirmed by coring in Boreholes 18-18 to 18-22, 17-11 and 17-12 at Elevations 267.3 m to 270.3 m. In addition, bedrock outcrops were observed at Test Pit 17-13 at Elevation 269.8 m on the bank of the creek at the outlet and along the highway within 50 m of the existing culvert. The General Arrangement drawing for the SPCSP shows that the proposed invert levels will be significantly lower than the existing culvert, and at or below the bedrock level encountered in Boreholes 18-20 to 18-22, 17-12 and Test Pit 17-13. Therefore, it is anticipated that there will be a need to excavate bedrock along the alignment of the replacement culvert.

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, temporary modular bridge foundation design, groundwater control, cofferdams, staged construction, and restoration of the roadway embankment.

The preliminary report provided foundation recommendations for different types of culverts and these recommendations are not repeated here but may be used for detailed design where applicable.

9.1 Foundations

Replacement of the culvert with a single SPCSP on the same alignment is being considered for this site. Since there is no proposed grade raise or embankment widening, 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. Due to the variable founding materials along the culvert alignment, construction of the culvert is anticipated to require placing the culvert on the varying founding materials that include bedrock and native sand and silt.

The pipe culvert 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 802.014 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 267.9 to 268.5 m, which corresponds to loose to compact sand and silt to bedrock subgrade. In order to reduce the potential for non-uniform and abrupt settlement and associated cracking of the culvert (i.e. hard point effect) between the bedrock and sand and silt soils, the bedding thickness should be increased to 500 mm where the subgrade consist of soils.

Any loose fill, large cobbles and boulders, and any soft, very loose, organic, or other deleterious material should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition.



9.2 Frost Cover

The depth of frost penetration at this site is approximately 2.2 m, based on OPSD 3090.100. The single SPCSP does not require frost cover / protection.

Based on the results of the field investigation, the existing embankment and underlying subgrade soil at the culvert location consists mainly of sand and gravel material to below the frost penetration depth; therefore, construction of new frost tapers should not be required as part of the culvert replacement.

9.3 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.

9.4 Settlement

The replacement culvert will be constructed approximately on the same alignment, with a larger opening size as the existing culvert with no grade raise or embankment widening. Since there is no grade raise or embankment widening and the foundation soils consist of gravel to sand and silt 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 gravel, and sand and silt 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 gravel and sand and silt deposits and bedrock. It must be noted that obstructions may be encountered within the fill, including cobbles and boulders.

Bedrock was encountered at shallow depths along the alignment of the existing culvert, and some excavation of the bedrock will be necessary.

Installation of the culvert should be carried out in the dry. 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. Recommendations for cofferdam design are provided in Sections 14 and 15 below. The dewatering scheme must be effective to lower the groundwater level at least 0.5 m below the final subgrade level to avoid base boiling in the native silty soils.

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. A preconstruction survey is not required, thus Designer Fill-In ** in SP FOUN0003 should be "N/A". Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing systems of similar nature and scope to the required work is not required.

Suggested wording for an NSSP in this regard is included in Appendix E. Further assessment of dewatering requirements and the need for a Permit to Take Water (PTTW) should be carried out by specialists experienced in the field.

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 general arrangement drawings, the invert level of the diversion pipe is approximately at Elev. 269 m. The pipe invert is expected to lie within native gravel deposits, or bedrock.

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E file: H:\15000-15999\15595 Replace 9 Culverts 6016-E-0008\Reports and Memos\Angler Creek CSP\Detailed Design\FINAL\Angler Creek CSP Detailed FIDR-FINAL.docx



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. Consideration should be given to raising the invert level of the diversion pipe above approximate Elevation 270 m to avoid rock excavation.

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 or 802.014, as appropriate. Backfilling for the culvert should be in accordance with OPSS.PROV 401. 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, 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 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 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 0.033 g as per the National Building Code of Canada (NBCC).

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



Table 13.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 32^\circ; \gamma = 20 \text{ kN/m}^3$
Active (K_{AE}) ^{1, 2}	0.28	0.32	0.32
Passive (K_{PE})	3.7	3.2	3.2
At Rest (K_{OE}) ³	0.46	0.50	0.50

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.

The site is underlain by dense gravel, loose to compact sand and silt, 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. COFFERDAMS

Construction of cofferdams will be required to construct the culvert replacement in the dry. It is recommended that the temporary culvert excavations be carried out within an enclosure. Sand bag cofferdams are considered feasible at this site. Unbraced sheet pile cofferdams are not likely to be feasible at this site due to the presence of shallow bedrock and therefore internally braced sheet pile cofferdams may be considered. If sheet pile cofferdams are considered for this site, the recommendations provided in Section 15 below for Temporary Protection Systems are also applicable to sheet pile cofferdams, however a Professional Engineer experienced in design must check that the appropriate lateral resistance can be achieved.

Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field. Design of a suitable and effective dewatering system is the responsibility of the Contractor as indicated in Section 10. The dewatering system must be effective to lower the water table a minimum of 0.5 m below the final culvert subgrade.

15. 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 shallow bedrock with a varying profile. Since bedrock is shallow, sheet piles will likely not be suitable for roadway protection. Therefore, this site may require drilled-in soldier pile and lagging to provide sufficient penetration into rock.

The soil parameters in Table 15.1 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 15.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Sand and Gravel Fill	Gravel	Sand and Silt	Rock Fill
ϕ (angle of internal friction)	32°	32°	28°	42 °
γ (total unit weight)	20 kN/m ³	20 kN/m ³	20 kN/m ³	24 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	0.36	0.20
K_p	3.3	3.3	2.8	5.0

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

The design of temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the 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.

16. TEMPORARY MODULAR BRIDGE

It is understood that a Temporary Modular Bridge (TMB) is the preferred method to maintain a lane for traffic for staging purposes. The design of the abutment foundation for the TMB is the responsibility of the contractor. The contractor must retain a Professional Engineer, experienced in bridge design, to design the TMB.



Boreholes 18-18 and 18-19 were drilled near the potential abutments of the TMB.

The modular bridge may be supported on precast concrete bearing pads founded on engineered granular fill pads. 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 minimum footing width should be 1.5 m and the footing should be embedded a minimum of 0.5 m below the finished grade in front of the footing. The front edge of the footing should be set back a minimum of 2 m from the crest of the temporary excavation slope at the top of the footing level.

The recommended geotechnical resistance at the ULS and SLS for a minimum 1.5 m wide concrete pad footing founded on the engineered granular fill at or below Elev. 273.0 m for the east or west abutment, are given below:

- Factored Geotechnical Resistance at ULS of 150 kPa
- Factored 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. A resistance factor of 0.8 should be applied to this ultimate value.

In order to achieve a stability safety factor of 1.3, the temporary excavation slope in front of the TMB abutments should be no steeper than 1.5H:1V after dewatering (3H:1V below the groundwater level before dewatering) as shown in Figure 1 in Appendix F. The temporary excavation slope for the modular bridge must be protected from erosion by covering the slope with tarp. Dewatering will be required during excavation of the temporary slopes as described in Section 10.

It is recommended that the contractor retain a geotechnical consultant who is RAQS qualified at the medium complexity level (RAQS Category – Geotechnical Structures and Embankment – Medium Complexity) to design the footings and stable slopes in front of the footings for the temporary modular bridge. All final reports and drawings must be sealed and signed by a Professional Engineer, who shall also be a RAQs Designated Contact. An NSSP for this effect is attached in Appendix E.



17. EMBANKMENT RESTORATION

The existing Highway 17 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. The embankment 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 inlet and outlet, and within the embankment footprint. Inspection and approval of the foundation subgrade by qualified geotechnical personnel should be conducted.

18. SCOUR AND EROSION PROTECTION

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

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

19. CORROSION AND SULPHATE ATTACK POTENTIAL

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

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested. The effect of road deicing salt should be considered while selecting the class of concrete.
- The potential for soil or surface water corrosion on metal is considered to be mild.
- Appropriate protection measures commensurate with the above 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:

- Shallow bedrock is anticipated at the site along the existing culvert alignment and in the area of the proposed temporary diversion pipe. There will likely be a requirement for rock excavation.
- 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.
- Cobbles were encountered in the embankment fill; therefore, cobbles, boulders, and other buried obstructions should be anticipated and dealt with during construction. These materials may interfere with the excavation and installation of the temporary roadway protection system. The Contractor must be prepared to remove or otherwise penetrate these obstructions. Suggested wording for an NSSP on obstructions is included in Appendix E.



- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

21. CLOSURE

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

Thurber Engineering Ltd.



Cory Zanatta, P. Eng.
Geotechnical Engineer



Mark Farrant, P.Eng.
Geotechnical Engineer



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



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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


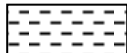



 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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

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

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No 18-18

1 OF 1

METRIC

W.P. 6812-14-01 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 746.4 E 350 370.2 ORIGINATED BY BRM
DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.07.23 - 2018.07.23 LATITUDE LONGITUDE CHECKED BY MEF

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						
274.4	GROUND SURFACE													
0.0	ASPHALT (150mm)													
0.2	SAND and GRAVEL to Gravelly SAND, some silt Very Dense to Dense Brown Moist (FILL)		1	SS	50/ 0.100		274							33 57 10 (SI+CL)
			2	SS	46		273							
272.7			3	SS	50/ 0.025		272							
1.7	Boulders from 1.7m to 2.4m													2 44 47 7
271.9			4	SS	21		271							
2.4	SILT and SAND, trace clay, trace gravel, trace organics Compact to Very Dense Dark Brown to Grey Wet		5	SS	50/ 0.100									
270.3														RUN #1 TCR=100% SCR=97% RQD=74% UCS=163MPa (Average)
4.0	BEDROCK(SYENITE), moderately weathered, medium to fresh, very strong, grey		1	RUN			270							
	Sub vertical fracture (125mm) at 4.2m and (150mm) at 4.8m Horizontal fracture at 4.3m, 4.9m and 5.2m Sub horizontal fracture at 4.7m						269							
	Sub vertical fracture (225mm) at 5.7m, (125mm) at 5.9m, (300mm) at 6.4m, (75mm) at 6.7m, at 6.8m and (75mm) at 7.0m Sub horizontal fracture at 6.0m		2	RUN			268							RUN #2 TCR=100% SCR=88% RQD=48% UCS=159MPa (Average)
	Horizontal fracture at 6.1m and 6.4m													
267.1	END OF BOREHOLE AT 7.3m. WATER LEVEL AT 2.2m UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.5m slotted screen.													
7.3														
	WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.07.24 2.4 271.9													

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

RECORD OF BOREHOLE No 18-19

1 OF 1

METRIC

W.P. 6812-14-01 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 764.9 E 350 328.7 ORIGINATED BY BRM
DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.07.22 - 2018.07.22 LATITUDE LONGITUDE CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								○ UNCONFINED + FIELD VANE		● QUICK TRIAXIAL × LAB VANE								
274.2	GROUND SURFACE						20	40	60	80	100							
0.0	ASPHALT (175mm)																	
0.2	SAND and GRAVEL to Gravelly SAND, trace silt, occasional rock fragments Very Dense Brown Moist (FILL)		1	SS	57/ 0.150													
			2	SS	51													
			3	SS	28													
272.1																		
2.1	GRAVEL, some sand, some cobbles and boulders Compact Brown Wet																	
			4	SS	11													
269.8																		
4.4	BEDROCK (SYENITE), moderately weathered, pinkish grey to grey, strong to very strong Sub horizontal fracture at 4.5m, 4.8m and 5.3m Horizontal fracture at 4.8m, 5.2m, 5.3m, 5.4m and 5.6m Vertical fracture from 5.5m to 7.0m Horizontal fracture at 5.6m, 5.8m, 5.9m, 6.0m, 6.3m, 6.4m and 6.8m Sub horizontal fracture at 5.7m and 6.2m Sub vertical fracture (75mm) at 6.5m and (100mm) at 7.4m		1	RUN														
			2	RUN														
266.8																		
7.5	END OF BOREHOLE AT 7.5m. WATER LEVEL AT 4.6m 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) 2018.07.24 4.7 269.5																	

ONTMT452 MTO-15595.GPJ 2017TEMPLATE(MTO).GDT 9/27/18

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

RECORD OF BOREHOLE No 18-20

1 OF 1

METRIC

W.P. 6812-14-01 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 742.6 E 350 334.5 ORIGINATED BY LS
DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.07.28 - 2018.07.28 LATITUDE LONGITUDE CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
269.4	GROUND SURFACE																
0.0	WATER																
268.7																	
0.7	GRAVEL , some sand, some cobbles and boulders																
268.2																	
1.2	BEDROCK (SYENITE), moderately weathered, strong to very strong, grey		1	RUN													
	Sub-horizontal fracture (38mm) at 1.7m and (75mm) at 1.8m		2	RUN													
	Sub-horizontal fracture (75mm) at 3.4m, 3.6m and (25mm) at 3.7m		3	RUN													
	Vertical fracture (125mm) at 3.5m		4	RUN													
			5	RUN													
	Rubble zone (100mm) at 3.8m		6	RUN													
265.5																	
3.9	END OF BOREHOLE AT 3.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-21

1 OF 1

METRIC

W.P. 6812-14-01 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 754.2 E 350 342.2 ORIGINATED BY BRM
DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.07.22 - 2018.07.22 LATITUDE LONGITUDE CHECKED BY MEF

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
274.2	GROUND SURFACE															
0.0	ASPHALT															
0.2	SAND and GRAVEL, trace silt Loose to very Dense Brown Moist to Wet (FILL)		1	SS	58											
			2	SS	10											
			3	SS	4											
			4	SS	23											
			5	SS	19											
270.2																
4.0	GRAVEL, some sand, some cobbles and boulders															
269.9																
4.3	BEDROCK (SYENITE), moderately weathered, very strong, grey															
	Horizontal fracture at 4.3m, 4.5m, 4.7m, 4.9m and 5.5m		1	RUN												
	Sub horizontal fracture at 5.0m, 5.2m, 5.5m and 5.8m															
	Sub horizontal fracture at 6.2m, 6.4m, 6.8m, 7.2m and 7.7m															
	Sub vertical fracture at 6.3m, 6.5m, (100mm) at 6.9m, (150mm) at 7.0m, (75mm) at 7.2m, (100mm) at 7.4m, 7.5m, (125mm) at 7.6m and 7.7m		2	RUN												
266.4	Horizontal fracture at 7.1m															
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE BACKFILLED WITH CUTTINGS TO 3.9m, BENTONITE HOLEPLUG TO 0.6m, SAND TO 0.2m, THEN COLD PATCH ASPHALT TO SURFACE.															

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-22

1 OF 1

METRIC

W.P. 6812-14-01 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 760.6 E 350 343.1 ORIGINATED BY BRM
DIST Thunder Bay HWY 17 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.07.21 - 2018.07.21 LATITUDE LONGITUDE CHECKED BY MEF

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					
274.2	GROUND SURFACE												
0.0	ASPHALT (150mm)												
0.2	SAND and GRAVEL, trace silt Very Dense to Compact Brown Moist (FILL)		1	SS	50/ 0.125		274						
			2	SS	33		273						59 39 2 (SI+CL)
			3	SS	26		272						
			4	SS	36		271						
270.6													
3.7	GRAVEL, some sand, some cobbles and boulders						270						
270.0													
4.2	BEDROCK (SYENITE), moderately weathered, very strong, pinkish grey to grey		1	RUN			269						
	Sub vertical fracture at 4.5m, (125mm) at 5.2m												
	Sub horizontal fracture at 4.7m, 4.8m, 5.2m and 5.3m												
	Horizontal fracture at 4.9m, 5.1m and 5.3m						268						
	Sub vertical fracture at 6.7m												
	Sub horizontal fracture at 6.3m and 6.7m												
	Horizontal fracture at 7.0m						267						
266.5													
7.7	END OF BOREHOLE AT 7.7m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 3.9m, BENTONITE HOLEPLUG TO 0.6m, SAND TO 0.2m, THEN COLD PATCH ASPHALT TO SURFACE.												

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-11

1 OF 1

METRIC

W.P. 6810-14-00 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 771.5 E 350 355.0 ORIGINATED BY TTB
 HWY 17 BOREHOLE TYPE Tripod/BW Casing/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.09.15 - 2017.09.16 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 (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
271.5	GROUND SURFACE							20	40	60	80	100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
0.0	Sandy SILT , with organics, some gravel, trace clay, occasional cobbles Brown Moist		1	SS	50/ 0.050		271							o		
			1	GS												
269.7			2	GS			270							o		11 26 58 5
1.8	SAND and SILT , trace clay Loose to Compact Brown Moist													o		
			2	SS	8		269									
			3	SS	24		268							o		0 44 51 5
267.3																
4.2	BEDROCK (SYENITE) , slightly to moderately weathered, very strong to strong, grey		1	RUN			267									RUN #1 TCR=100% SCR=100% RQD=100% UCS=144MPa (Average)
			2	RUN			266									RUN #2 TCR=100% SCR=100% RQD=87% UCS=181MPa (Average)
			3	RUN			265									RUN #3 TCR=100% SCR=94% RQD=94% UCS=218MPa (Average)
264.3																
7.2	END OF BOREHOLE AT 7.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.															

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

RECORD OF BOREHOLE No 17-12

1 OF 2

METRIC

W.P. 6810-14-00 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 752.9 E 350 351.2 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE Solid Stem Augers/NW/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.07.17 - 2017.07.17 CHECKED BY MEF

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				
274.3	GROUND SURFACE							20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
0.0	ASPHALT: (250mm)							20 40 60 80 100	W _P	W	W _L	
0.3	SAND and GRAVEL , trace silt and clay, occasional cobbles Compact to Loose Brown Moist (FILL)		1	GS			274					42 49 9 (SI+CL)
			1	SS	23		273					
			2	SS	7		272					41 53 6 (SI+CL)
			3	SS	19		271					
			4	SS	18		270					
270.3												
4.0	GRAVEL , some sand Dense Brown Wet		5	SS	33		269					
268.6												
5.7	BEDROCK (SYENITE) , slightly to moderately weathered, very strong, grey Sub-vertical fracture (25mm) at 6.6m Sub-horizontal fracture (25mm) at 7.1m, 7.2m and 8.0m Sub-vertical fracture (75mm) at 7.2m, (50mm) at 7.4m and 7.9m Vertical fracture (50mm) at 8.1m		1	RUN			268					RUN #1 TCR=77% SCR=77% RQD=56% UCS=131MPa (Average)
			2	RUN			267					RUN #2 TCR=100% SCR=100% RQD=68% UCS=161MPa (Average)
			3	RUN			266					RUN #3 TCR=100% SCR=100% RQD=100% UCS=145MPa (Average)
265.2												
9.1	END OF BOREHOLE AT 9.1m. WATER LEVEL AT 3.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.9m, CUTTINGS TO 0.6m, CONCRETE											

Continued Next Page

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

METRIC

[illegible]

RECORD OF TEST PIT No 17-13

1 OF 1

METRIC

W.P. 6810-14-00 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 740.0 E 350 335 ORIGINATED BY JZ
 HWY 17 BOREHOLE TYPE Visual Observation COMPILED BY AN
 DATUM Geodetic DATE 2017.08.25 - 2017.08.25 CHECKED BY MEF

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									
							20	40	60	80	100						
269.8	GROUND SURFACE																
0.0	BEDROCK OUTCROP EXPOSED AT GROUND SURFCE (SYENITE).																

RECORD OF BOREHOLE No 17-14

1 OF 1

METRIC

W.P. 6810-14-00 LOCATION Angler Creek Tributary Culvert, MTM NAD 83 Zone 14 N 5 403 757.9 E 350 333.6 ORIGINATED BY ES
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.07.16 - 2017.07.16 CHECKED BY MEF

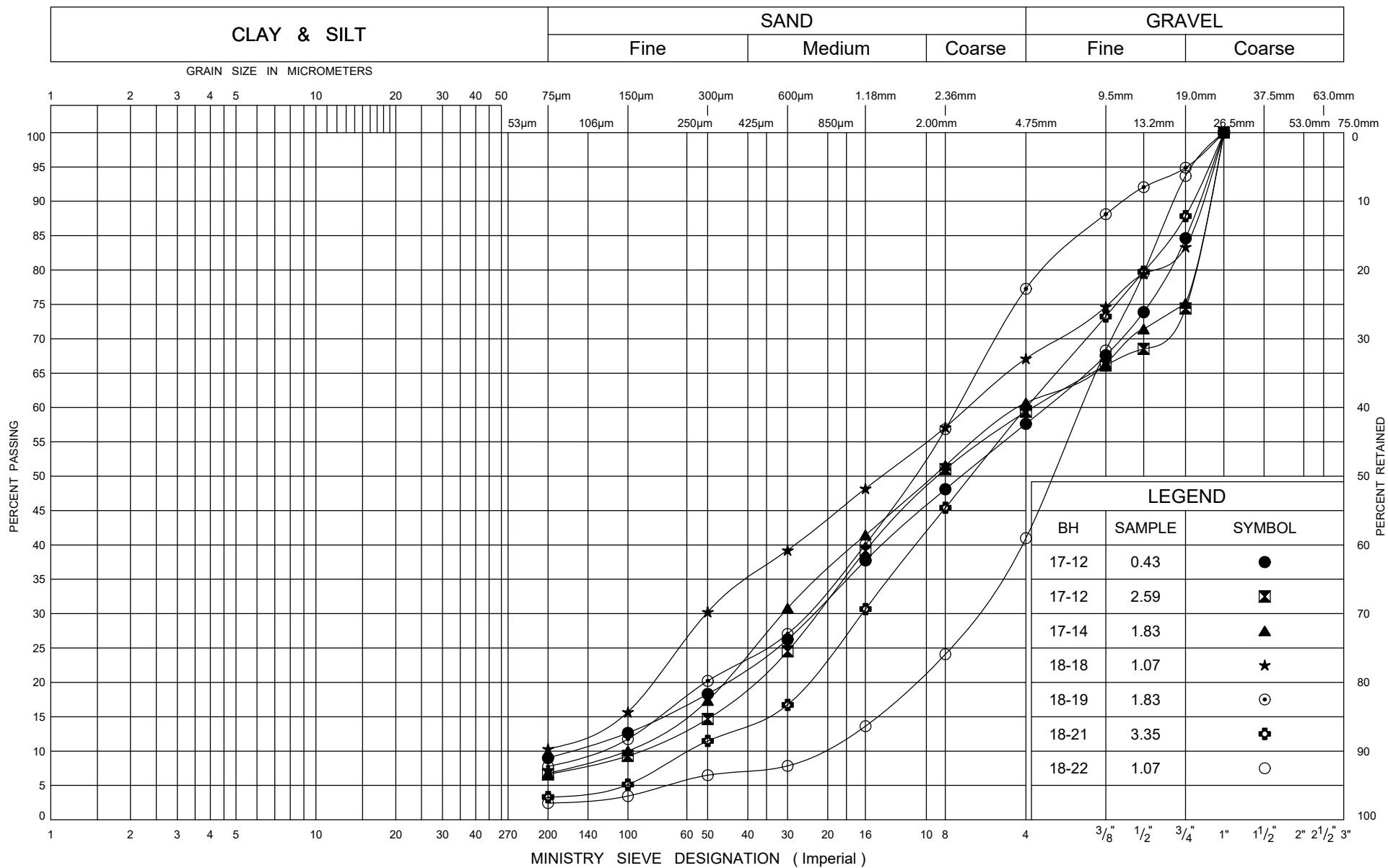
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
274.2	GROUND SURFACE							20	40	60	80	100				
0.0	ASPHALT: (250mm)						274									
273.9																
0.3	SAND and GRAVEL,trace silt and clay Compact Brown Moist (FILL)		1	GS			273									
			1	SS	17											39 54 7 (SI+CL)
272.1																
2.1	END OF BOREHOLE AT 3.1m. BOREHOLE OPEN TO 1.1m AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.															

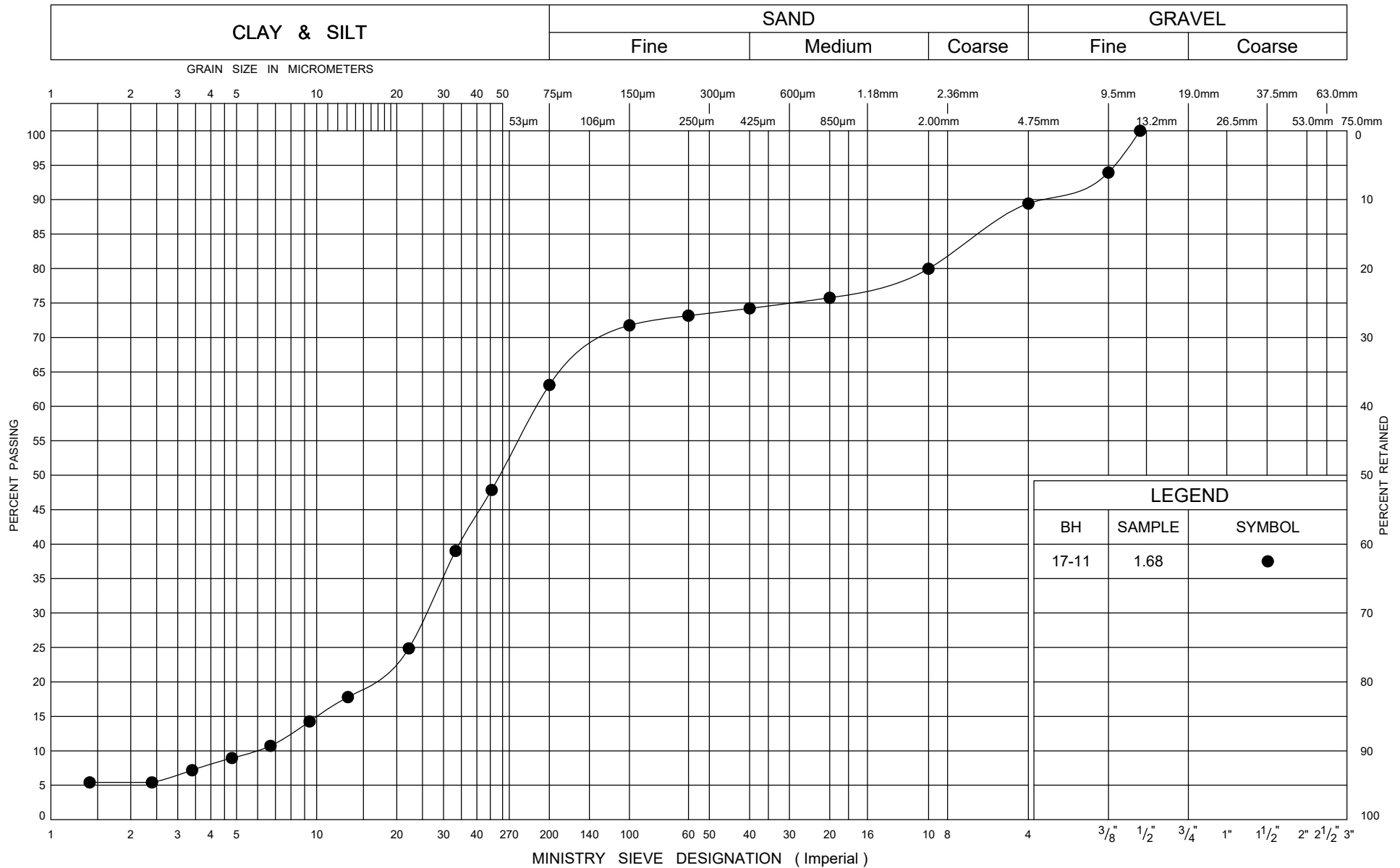
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE



Appendix B

Geotechnical and Analytical Laboratory Test Results





Ministry of
Transportation

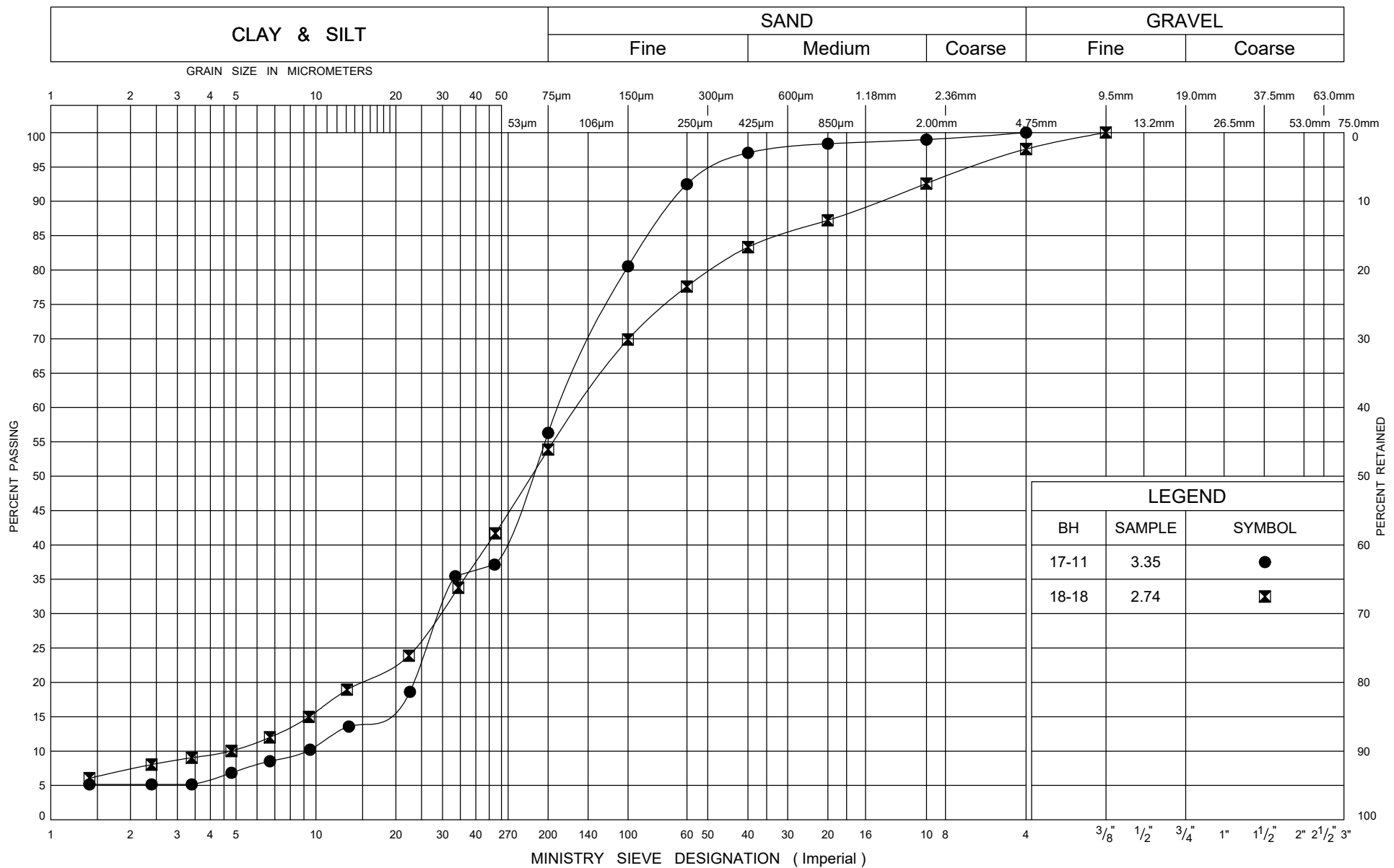
GRAIN SIZE DISTRIBUTION

Sandy SILT, with organics

FIG No B2

W P 6812-14-01

Angler Creek Tributary Culvert





ASTM D5731-08

Date Drilled:	July 23/18
Date Tested:	August 17/18
Tester:	BS
Reviewed by:	MEF

[illegible]



ASTM D5731-08

Date Drilled:	July 22/18
Date Tested:	August 8/18
Tester:	KF
Reviewed by:	MEF

[illegible]

**ASTM D5731-08**

Date Drilled:	July 29/18
Date Tested:	August 17/18
Tester:	BS
Reviewed by:	MEF

[illegible]



ASTM D5731-08

Date Drilled:	July 22/18
Date Tested:	August 17/18
Tester:	BS
Reviewed by:	MEF

[illegible]



ASTM D5731-08

Date Drilled:	July 21/18
Date Tested:	August 17/18
Tester:	BS
Reviewed by:	MEF

[illegible]



ASTM D5731-08

Date Drilled:	Sep 15-16/17
Date Tested:	Sep 25/17
Tester:	GA
Reviewed by:	WM

[illegible]



ASTM D5731-08

Date Drilled:	July 17/17
Date Tested:	Sep 6/17
Tester:	JZ
Reviewed by:	WM

[illegible]

Certificate of Analysis

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



Client
SGS LIMS Number
Analysis Package:

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

Sample ID Unit BH-12, SS#4, 10'-12'

Sample Date/Time 17-Jul-17

Moisture	%	2.8
pH	no unit	9.62
Corrosivity Index	none	3.0
Soil Redox Potential	mV	264
Sulphide	mg/L	<0.02
Chloride	mg/L	25.0
Sulphate	mg/L	7
Conductivity	uS/cm	168
Resistivity (calculated)	ohms.cm	5950

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

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

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

Certificate of Analysis

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



Client
SGS LIMS Number
Analysis Package:

Attention: Mark Farrant
Project#: 15595
Thurber Engineering Ltd.
CA15528-JUL17
Corrosivity (Soil)

Sample ID Unit Angler Creek CSP

Sample Date/Time 17-Jul-17 16:10

Moisture	%	N/A
pH	no unit	6.82
Corrosivity Index	none	
Redox Potential	mV	217
Sulphide	mg/L	<0.006
Chloride	mg/L	1.6
Sulphate	mg/L	2.4
Conductivity	uS/cm	55
Resistivity (calculated)	ohms.cm	18000

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

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

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



Appendix C

Site Photographs



**Photo 1: Looking east along Highway 17 from outlet of culvert
(Date taken: August 23, 2017)**



**Photo 2: Looking West along Highway 17 from outlet of culvert
(Date taken: August 23, 2017)**



**Photo 3: Looking east along Highway 17 from inlet of culvert
(Date taken: June 27, 2017)**



**Photo 4: Looking west along Highway 17 and inlet of culvert
(Date taken: June 27, 2017)**



Photo 5: Inlet of culvert, looking southwest (Date taken: May 16, 2017)



Photo 6: Outlet of culvert, looking northeast (Date taken: August 23, 2017)



**Photo 7: Looking southwest from inside culvert outlet
(bedrock outcrops visible on left bank) (Date taken: August 23, 2017)**



Photo 8: Outlet of culvert resting on sand, gravel and cobbles (possibly fill)
(Date taken: August 23, 2017)



Appendix D

Borehole Locations and Soil Strata Drawing

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

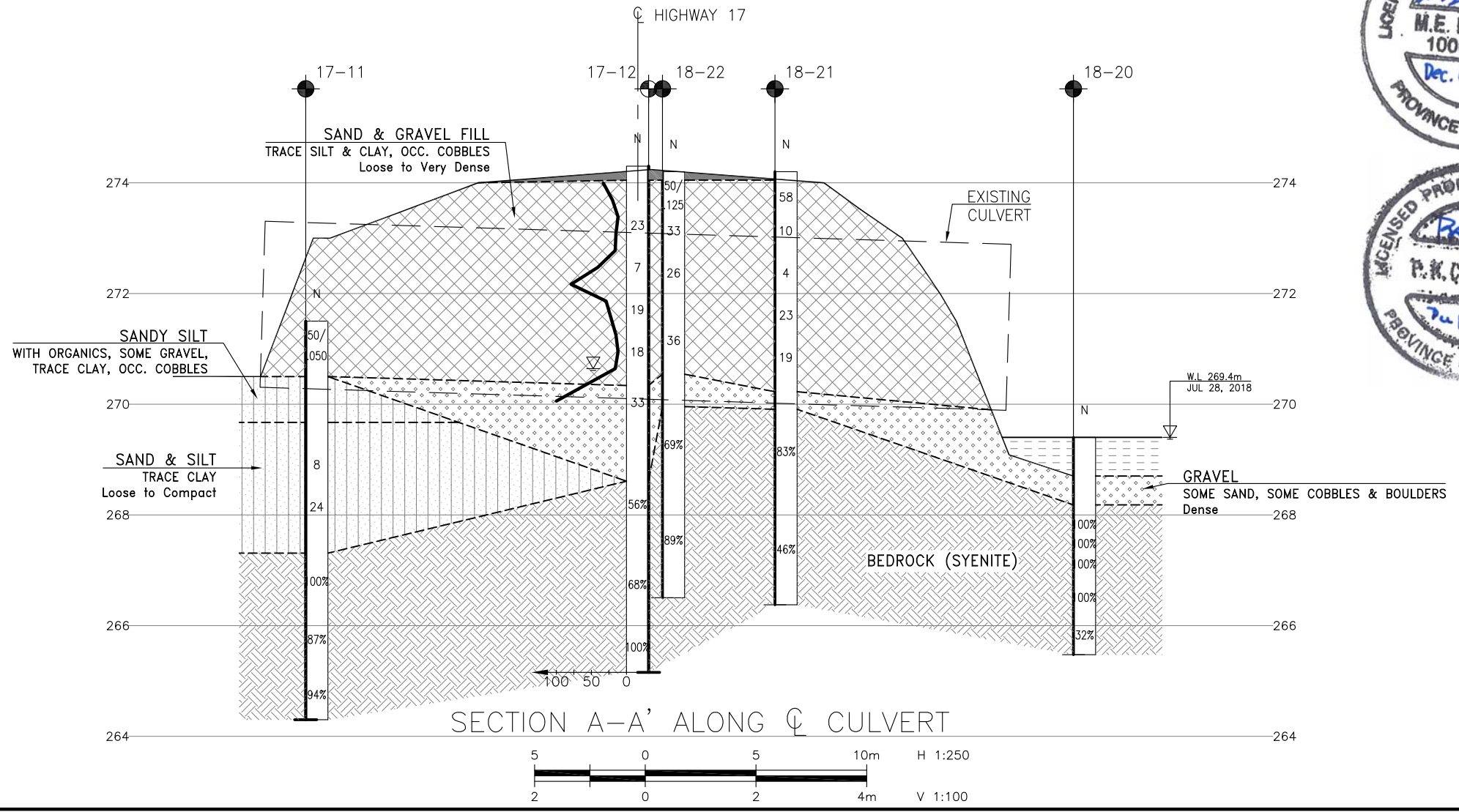
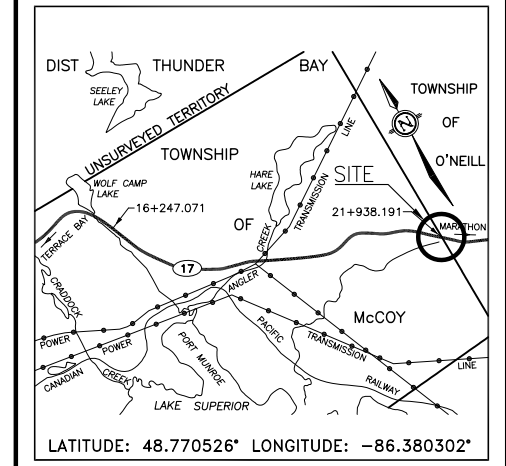
CONT No
WP No 6812-14-01

HIGHWAY 17
 ANGLER CREEK TRIBUTARY
 CULVERT REPLACEMENT
 BOREHOLE LOCATIONS AND SOIL STRATA

HATCH



THURBER ENGINEERING LTD.



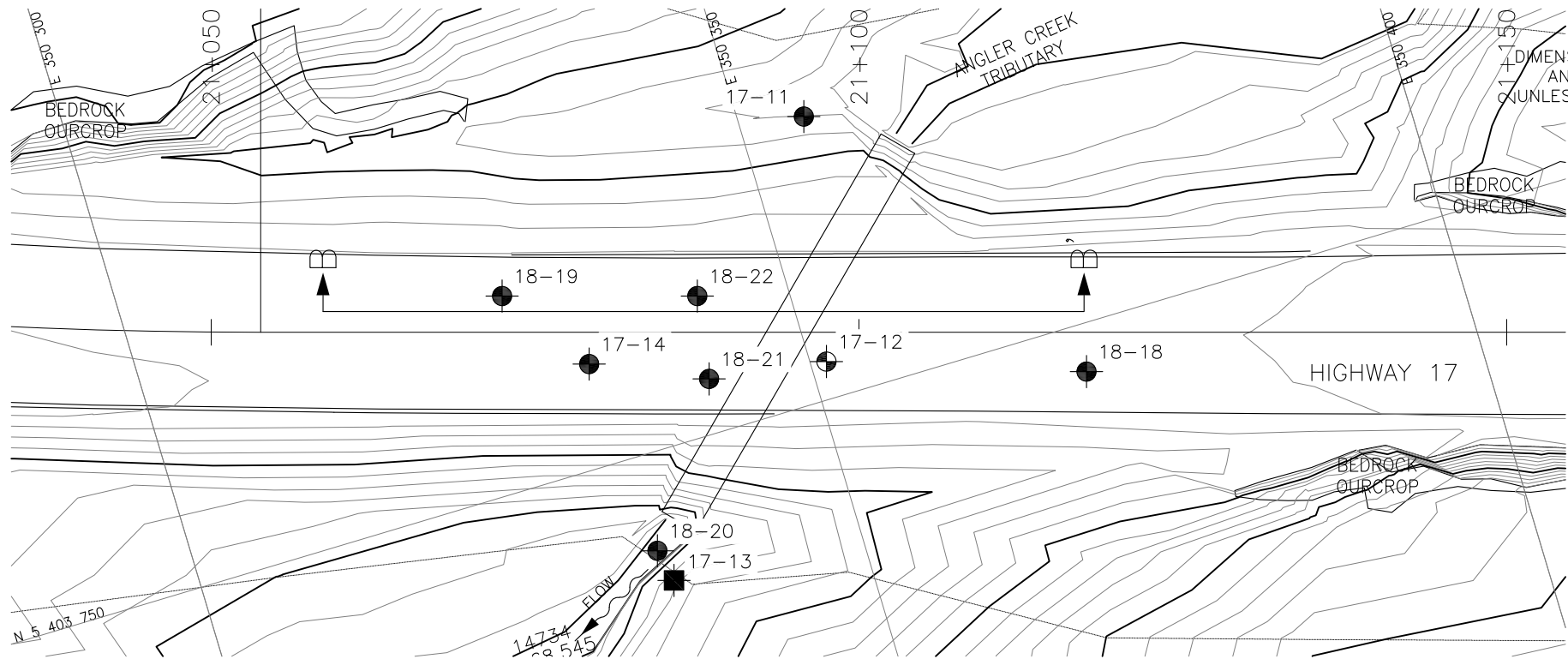
A circular professional engineer seal for the Province of Ontario. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. In the center, the name "P. K. CHATTERJEE" is printed. Handwritten in blue ink over the seal are the signature "P. K. Chatterjee" and the date "July 18/18".

-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.

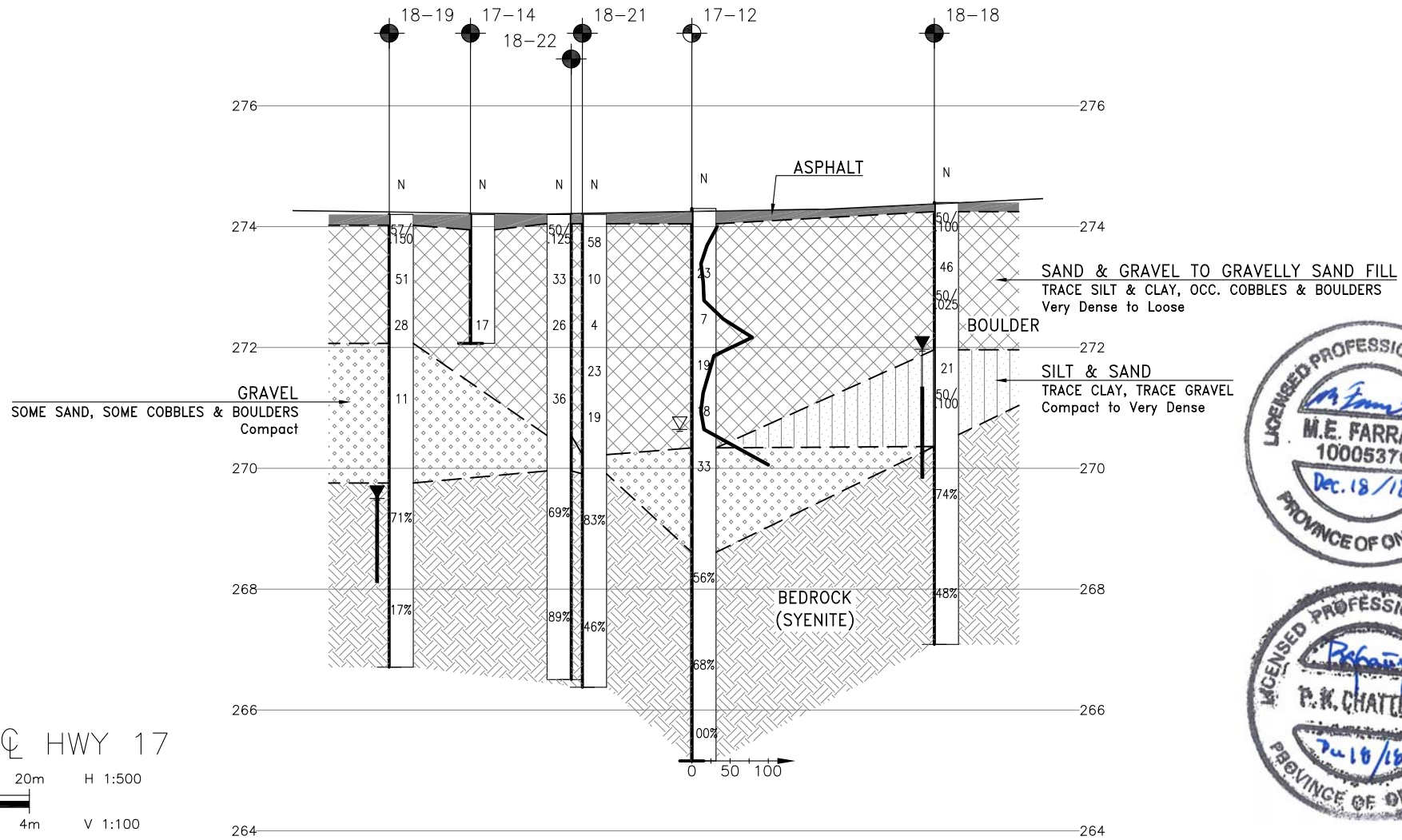
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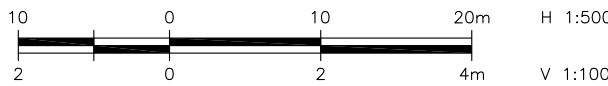
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



PLAN



SECTION B-B' ALONG ϕ HWY 17



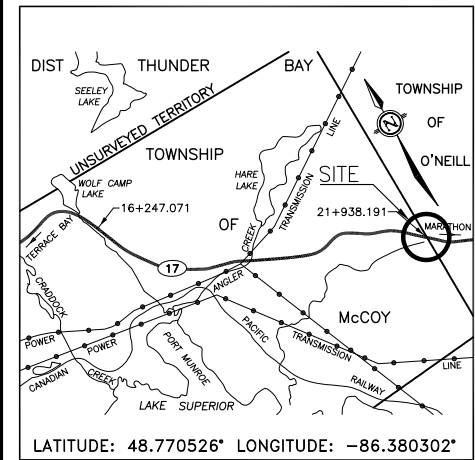
CONT No
WP No 6812-14-01

HIGHWAY 17
ANGLER CREEK TRIBUTARY
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET

HATCH



KEYPLAN

LEGEND

	Borehole
	Borehole and Cone
	Test Pit
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
17-11	271.5	5 403 771.5	350 355.0
17-12	274.3	5 403 752.9	350 351.2
17-13	269.8	5 403 740.0	350 335.1
17-14	274.2	5 403 757.9	350 333.6
18-18	274.4	5 403 746.4	350 370.2
18-19	274.2	5 403 764.9	350 328.7
18-20	269.4	5 403 742.6	350 334.5
18-21	274.2	5 403 754.2	350 342.2
18-22	274.2	5 403 760.6	350 343.1

-NOTES-

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

GEORES No.



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MEF	CHK PKC	CODE
DRAWN	AN	CHK MEF	SITE 48E-079/C/STRUCT
			LOAD
			DATE DEC 2018
			DWG 2



Appendix E

List of OPSSs and OPSDs 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 401 (Construction Specification for Trenching, Backfilling and Compacting)
- 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)
- 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)
- Special Provision No. FOUN0003 to OPSS 902 (Dewatering Structure Excavations)
- OPSS PROV 1004 (Material Specification for Aggregates – Miscellaneous)
- OPSS 1005 (Material Specification for Aggregates – Streambed Material)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS PROV 1205 (Material Specification for Clay Seal)
- OPSS 1860 (Material Specification for Geotextiles)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.014 (Flexible Pipe Embedment in Embankment)
- 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 Obstructions

Excavations and installation of cofferdams and roadway protection systems will encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheet pile installation. The Contractor

shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.

- **Suggested Text for NSSP on Dewatering**

Dewatering will be required to install the new culvert and the diversion pipe in the dry. The design of an effective dewatering system is the responsibility of the contractor. The dewatering system must be effective to lower the groundwater table at a minimum of 0.5 m below the final subgrade level to avoid basal heave and base boiling. The dewatering system is to be designed in accordance with SP FOUN0003 and OPSS.PROV. 517. A preconstruction survey is not required, thus Designer Fill-In ** in SP FOUN0003 should be "N/A". Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing systems of similar nature and scope to the required work is not required.

- **Suggested Text for NSSP on Temporary Modular Bridge**

The Contractor is responsible for the detailed design of the Temporary Modular Bridge (TMB) including, but not limited to, slope stability of the temporary excavation slope in front of the TMB abutment footings, determination of bearing capacity for the abutment footings and safe footing set back distance from the open excavation, as well as the performance of the temporary footings throughout construction. As a minimum, modular bridge footings shall be set back a minimum two (2) metres from the top of the temporary excavation. The temporary excavation slope shall be no steeper than two (2) horizontal to one (1) vertical with full dewatering to 500 mm below the final base of the temporary excavation for the duration of time when the temporary modular bridge is in use. The contractor is responsible for retaining a RAQS approved Licensed Geotechnical Engineer with a medium-complexity rating (RAQs Category – Geotechnical Structures and Embankment – Medium Complexity) to confirm all aspects of the modular bridge slope stability and foundation design. All final reports and drawings must be sealed and signed by a Professional Engineer, who shall also be a RAQS Designated Contact.



Appendix F

Slope Stability Analysis Figure

Figure 1 - Angler Creek CSP Culvert Excavation

File Name: Angler Creek LT 2m setback-3H to 1V & 1.5H to 1V-w dewatering - revised.gsz

Created By: Geoff Lay

Date: 11/05/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 0.1 m

Seismic: 0

Sand and Silt - Compact 21 kN/m³ 0 kPa 32 °

Fill 21 kN/m³ 0 kPa 33 °

