THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
EVERETT CREEK CULVERT REPLACEMENT
HIGHWAY 11, TOWNSHIP OF EMO
RAINY RIVER DISTRICT, ONTARIO
GWP 6902-12-00, SITE NO. 45-138/C
Geocres Number: 52C-048

Report to

Hatch

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the proposed replacement of the existing Everett Creek Culvert located on Highway 11 in the Township of Emo in the Rainy River District, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the site, and based on the data obtained, to provide a borehole location plan, record of borehole sheets, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to Hatch (formerly Hatch Mott MacDonald), under the Ministry of Transportation Ontario (MTO) Agreement Number 6013-E-0027-007.

A previous foundation investigation was carried out at this site and documented in a report titled "Foundation Investigation Report, Everett Creek Culvert Replacement, Highway 11, Township of Lash, Rainy River District, Agreement No. 6013-E-0023, Assignment No.2, Site No. 45-138/C, Geocres No. 52C-037", dated September 19, 2014, prepared by DST Consulting Engineers Inc. Following review of this report, additional field investigation was recommended and conducted by Thurber, the results of which are documented in this report. The borehole information and borehole location plan from the previous investigation are reproduced in Appendix D for information purposes.

2 SITE DESCRIPTION

The project site is located on Highway 11, 140 m west of Off Lake Road in the Township of Emo, Geographic Township of Lash, in the Rainy River District, Ontario.

The existing culvert carrying Everett Creek under Highway 11 is a cast-in-place reinforced concrete box structure approximately 4.3 m in width, 3.4 m in height and 49.7 m in length. The Everett Creek flows from the north to the south in a direction approximately perpendicular to the highway. The highway embankment is estimated to be between 7.0 and 9.0 m in height with as much as 7 m of earth fill cover above the culvert.

The culvert was built in the 1930s and extended in the late 1960s. The existing condition of the culvert was documented in an MTO Structure Inspection report dated February 7, 2014 for an inspection carried out on July 26, 2013, and summarized in a Structural Replacement Options Study dated November 5, 2015 prepared by Hatch. The north end of the culvert (inlet) was reported to have settled by more than a metre, the inlet extension had separated from the original culvert, and the top slab had failed. The inlet area is covered by timber debris, and scour/erosion has occurred around and above the culvert inlet, as well as behind the wing walls. In addition, three major cracks were reported in the walls and ceiling inside the culvert, apparently under the roadbed.

The land surrounding the site is relatively flat to gently undulating, with a mixture of agricultural lands, woodlands, and occasional commercial/residential properties. The village of Emo is located to the east, and Rainy River is located approximately 280 m to the south. Vegetation on the embankment slopes consists of grass, brush and trees. Photographs of the culvert and surrounding area are presented in Appendix C.

The site lies within the Canadian Shield, which is characterized by Pre-Cambrian igneous and metamorphic bedrock. According to Canadian Geological Survey (CGS) data, the bedrock at this site generally consists of massive to foliated granodiorite and granite of the Wabigoon Subprovince of the Superior Province. The bedrock is overlain by glaciolacustrine deep-water clay and silt deposits of the Pleistocene age.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out on December 14 and 15, 2015, and on January 25 and 26, 2016, when a total of three boreholes, denoted as EC-01, EC-02 and EC-04 were advanced at the culvert site. Borehole EC-01 and EC-04 were drilled to depths of 6.1 m and 12.8 m near the inlet and outlet of the culvert (at the north and south toes of the embankment), respectively. Borehole EC-02 was advanced to a depth of 25 m from the top of the embankment. Details of the borehole locations, drilling depths and completion details are summarized in Table 3.1 below.

Table 3.1 – Borehole Summary

Location	Boreholes	Drilling Depth/ Base of Hole Elevation(m)	Completion Details
Culvert Inlet	EC-01	6.1 / 319.7	Borehole backfilled with cuttings and bentonite to surface.
Top of Embankment	EC-02	25.0 / 310.8	Borehole backfilled with bentonite to 0.3 m then concrete to surface.
Culvert Outlet	EC-04	12.8 /318.0	Borehole backfilled with bentonite to 0.3 m then cuttings to surface.

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

Boreholes EC-02 and EC-04 were advanced using a track-mounted CME-45 drill rig in combination with hollow stem augers and wash boring techniques. Borehole EC-01 was advanced using portable tripod equipment. Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

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

Groundwater conditions in the boreholes were observed during the drilling operations. However, due to the use of water during drilling, the water levels do not reflect the groundwater conditions in the boreholes.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets included in Appendix A. Selected samples were also subjected to grain size distribution analysis and Atterberg Limits testing, and the results of this testing program are summarized on the Record of Borehole sheets in Appendix A and are shown on the figures included 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 in these sheets and on the "Borehole Locations and Soil Strata" drawings in Appendix G. An overall description of the stratigraphy based on the present investigation is given in the following paragraphs. The factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions. It should be noted that the subsurface conditions may vary beyond the borehole locations.

In summary, the soil stratigraphy encountered at the site consists of silty clay embankment fill overlying a thick deposit of silty clay extending to the depths investigated in the boreholes. The silty clay was encountered to depths ranging from 6.1 m to 25 m corresponding to Elev. 319.7 and Elev. 310.8, respectively. Descriptions of the individual strata are presented below.

5.1 Pavement Structure

Borehole EC-02 drilled from the shoulder of the highway embankment encountered a pavement structure consisting of 125 mm of asphalt underlain by a road base fill. The fill was classified as sand and gravel with some silt, trace clay and occasional cobbles. The fill was 1.4 m thick and extended to 1.5 m depth (Elev. 334.3).

An SPT 'N' value of 33 blows per 0.3 m penetration was recorded in the sand and gravel fill, indicating a dense relative density.

A moisture content of 10% was measured in the granular fill.

5.2 Silty Clay Fill

Embankment fill was encountered below the pavement structure in Borehole EC-02. The fill material extended to 10.4 m depth (Elev. 325.4), and consisted of silty clay with some sand, trace gravel, trace organic matter (rootlets), and occasional gravel lenses. Wood fragments were noted in the lower portion of the fill. The fill was grey and brown in colour to approximately 7 m depth and then became dark brown.

SPT 'N' values recorded in the silty clay fill ranged from 0 (weight of rod or weight of hammer) to 6 blows per 0.3 m penetration, indicating a very soft to firm consistency.

The results of a grain size analysis conducted on a fill sample are provided on the Record of Borehole sheet in Appendix A, and are illustrated in Figure B1 of Appendix B. The results are summarized as follows:

Gravel	0%
Sand	19%
Silt	33%
Clay	48%

Moisture contents of the cohesive fill ranged from 13% to 30%.

5.3 Sand and Gravel

A 0.3 m thick layer of sand and gravel with a boulder was encountered below the silty clay fill in Borehole EC-02 at a depth of 10.4 m. Coring methods were used to penetrate the boulder. The deposit extended to 10.7 m depth (Elev. 325.1), and probably represents the original creek channel base.

5.4 Sandy Silt

Borehole EC-01 drilled near the inlet of the creek encountered approximately 0.9 m of sandy silt material presumably placed by creek waters during flooding. The sandy silt contained some clay, some gravel and woody debris. The underside of the silty sand layer was encountered at Elev. 324.9.

5.5 Silty Clay

Underlying the sandy silt in Borehole EC-01, the sand and gravel in Borehole EC-02, and extending from the ground surface in Borehole EC-04 is a deposit of native silty clay with trace gravel and trace to some sand. Trace organic matter was noted in the upper zone of the deposit in Borehole EC-04. The silty clay was typically grey in colour, although the upper 3.8 m of the silty clay in Borehole EC-04 was mottled brown and grey. The boreholes were terminated in the silty clay at depths ranging from 6.1 m in Borehole EC-01 to 25.0 m in Borehole EC-02, corresponding to Elev. 319.7 and Elev. 310.8, respectively.

SPT 'N' values recorded in the silty clay ranged from 0 (weight of rod or weight of hammer) to 26 blows for 0.3 m penetration, however, typically ranging from 4 to 7 blows for 0.3 m penetration. The lowest SPT "N" values ranging from 0 to 1 were obtained in the upper 3.8 m zone of the silty clay in Borehole EC-04. Field vane shear tests (VST) measured in-situ undrained shear strengths ranging from 68 kPa to 100 kPa. Based on the SPT and VST data, the consistency of the silty clay varied from firm to stiff.

The results of grain size analyses conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B2 and B3 of Appendix B. The results are summarized as follows:

Gravel	0%
Sand	0% to 15%
Silt	27 to 40%
Clay	47 to 73%

The results of Atterberg Limits tests conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B4 of Appendix B. The results indicate that the deposit has plastic limits ranging from 20 to 27 and liquid limits ranging from 47 to 54, suggesting medium to high plasticity. Plasticity indices, determined as the difference between the plastic limit and liquid limit, ranged from 21 to 29. Natural moisture contents of the silty clay ranged from 21 to 52%, with typical values between 25 % and 35%.

5.6 Water Levels

Water levels in the boreholes were measured upon completion of drilling operations. Since water was used to advance the boreholes, the measured water levels do not reflect prevailing groundwater levels at the site.

It is anticipated that the groundwater level will be governed by the water level in the creek. The preliminary GA drawing indicates a water level in Everett Creek at Elev. 328.52 on June 5, 2013. This level is noted to represent flooding conditions.

The water level in the creek and groundwater levels are expected to fluctuate seasonally and subject to precipitation patterns, and therefore may vary from the levels presented above.

6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by Hatch.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated a track-mounted CME-45 hi-torque drill rig and portable tripod drilling equipment to carry out the drilling, sampling and in-situ testing operations.

The drilling and sampling operations were supervised in the field on a full time basis by Mr. Zane Burk of Thurber. Overall supervision of the field program was conducted by Mr. Stephane Loranger, CET.

Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory.

The report was prepared by Ms. Anna Piascik, P.Eng., and reviewed by Mr. Murray Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations for the design of the replacement culvert carrying Everett Creek under Highway 11 in the Rainy River District.

The existing Everett Creek culvert is a cast-in-place reinforced concrete box structure approximately 4.3 m in width, 3.4 m in height and 49.7 m in length. The Highway 11 embankment is estimated to be between 7.0 and 9.0 m in height with approximately 7 m of earth fill cover above the culvert. The north end of the culvert (inlet) has settled by more than a metre, the inlet extension has separated from the original culvert, and the top slab has failed. The inlet area is covered by timber debris, and scour/erosion has occurred around and above the culvert inlet, as well as behind the wing walls. In addition, three major cracks were reported in the walls and ceiling inside the culvert. Replacement of the culvert and slope repair are therefore required.

The discussion and recommendations presented in this report are based on information provided by Hatch on preliminary General Arrangement drawings dated October 2015 and March 2016, and on the factual data obtained during the course of this investigation.

The recommendations are intended to provide the designer with sufficient information to assess feasible foundation alternatives and to carry out the design of the foundations for the replacement culvert.

8 CULVERT FOUNDATIONS

The preliminary General Arrangement drawings present two alternatives for the culvert replacement, namely:

- Corrugated steel plate (CSP) arch culvert
- Precast concrete panels on sheet pile abutments.

Both types of replacement culvert will be installed along the same alignment as the existing culvert, and roadway protection will be required to enable staged construction. A temporary modular bridge may be installed as an alternative to the extensive protection system required for installation of the CSP arch option.

Recommendations for design and installation of a CSP arch culvert as well as a culvert comprising concrete panels on sheet pile abutments are presented below.

A comparison of the advantages and disadvantages of the culvert types is presented in Appendix E. Use of a pre-cast box culvert was also considered, however this design option has not been carried forward in view of the performance of the existing box culvert and the creek diversion/dewatering requirements for installation of this culvert type.

8.1 CSP Arch Culvert

The preliminary General Arrangement drawing indicates that the replacement CSP arch culvert will have a span of 8.3 m, a rise of 3.1 m, and a length of 41.3 m. The soil cover on the top of the arch crown will be approximately 6 m thick. The streambed will fall from Elev. 326.0 at the inlet to Elev. 324.6 at the outlet, and be provided with a 500 mm thick layer of rock protection.

Based on the borehole information, the subgrade at the level of the culvert base will consist of native firm to stiff silty clay. Considering the low geotechnical resistance available in the silty clay, the culvert span, and the height of cover above the culvert, supporting the arch culvert on spread footings is not considered practical.

A system of driven steel H-piles developing resistance through shaft friction is recommended to support the culvert loads at this site. A suitable bearing stratum for development of appreciable end-bearing resistance was not encountered within the exploration depth of 25 m.

8.1.1 Axial Resistance of Driven Piles

The pile cut-off level is expected to be near Elev. 325. The geotechnical resistances recommended for HP 310x110 and HP 310x79 piles driven to selected tip elevations are presented in Table 8.1.

The recommended pile tip elevation is considered approximate and the actual tip elevation required to develop the design resistance will need to be confirmed by pile monitoring during installation.

The SLS values are based on a vertical pile settlement of 25 mm.

Oversize materials (e.g. greater than 75 mm nominal diameter) should not be used for any new fill through which the piles will be driven.

Table 8.1 – Geotechnical Resistance and Reaction for Driven Piles

Pile Section	Pile Length (m)	Pile Tip Elevation	Factored Geotechnical Resistance at ULS (kN) per pile	Geotechnical Reaction at SLS (kN) per pile
HP310x110	10	315	227	189
	15	310	340	283
	20	305	446	372
HP310x79	10	315	222	185
	15	310	332	277
	20	305	436	363

8.1.2 Pile Installation

Pile installation should be in accordance with OPSS 903.

Pile driving at both abutments should be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance should be specified by the designer. The Hiley formula need not be used until the piles are within 3.0 m of the design pile tip elevation. The appropriate pile driving note is "Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of "R" kN per pile. "R" should have a minimum value of twice the design load at ULS, but should not exceed the ultimate pile capacity.

If the proposed culvert design requires that the deviation at the top of the pile be limited to a tight tolerance, a driving template or other means may be required to achieve the specified maximum deviation.

Pile tip protection is not required and should not be used for driven H-piles developing resistance through shaft friction at this site.

8.1.3 Lateral Pile Resistance

The geotechnical lateral resistance acting on a pile in cohesive soils may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

$$k_s = 67\ S_u / D \quad (kN/m^3)$$

$$p_{ult} = 9\ S_u \quad (kPa)$$

Where S_u = undrained shear strength of the soil (kPa)
= 60 kPa for native silty clay

D = pile width or diameter in metres.

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

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The spring constant, K_s, for analysis may be obtained from the expression:

$$K_s = k_s \, L \, D \text{ (kN/m)},$$

where k_s = coefficient of horizontal subgrade reaction (kN/m^3),
D = pile width (m), and
L = length (m) of the pile segment or element used in the analysis.

The ultimate lateral resistance, P_{ult}, may be obtained from the expression, $P_{ult} = p_{ult} \, L \, D$. This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

The modulus of subgrade reaction and ultimate lateral resistance may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 8.2. Intermediate values may be obtained by linear interpolation.

Table 8.2 – Subgrade Reaction Reduction Factors for Pile Spacing

Condition	Pile Spacing, Centre to Centre	Reduction Factor
Pile group oriented ***perpendicular*** to direction of loading	4D	1.0
	1D	0.5
Pile group oriented ***parallel*** to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

In the case of conventional abutments, i.e. not integral type, horizontal loads may be resisted by means of battered piles.

8.2 Precast Concrete Panels Supported on Sheet Pile Abutments

A culvert consisting of two parallel sheet pile walls capped with precast concrete panels is considered feasible at this site. The sheet piles will provide containment and resistance to lateral earth pressures from the embankment fill.

The preliminary General Arrangement drawing indicates that the sheet pile culvert will have a span of 8.5 m, an opening height of about 9 m, and a cover of 1.5 m to the roadway surface. The sheet pile abutment will extend for a length of 33.8 m (excluding wing walls), of which 21 m length will be capped by precast deck panels.

8.2.1 Axial Resistance of Sheet Piles

Driven steel sheet piles will develop resistance to vertical loads through frictional resistance along the sides of the sheet piles within the native firm to stiff silty clay. A suitable bearing stratum for development of appreciable end-bearing resistance was not encountered within the exploration depth of 25 m.

The factored geotechnical resistances at ULS (per metre width of sheet pile) and geotechnical reactions at SLS recommended for EZ-88 and AZ36-700N sheet pile sections driven to selected depths into the native silty clay are presented in the table below. The pile lengths assume a top of sheet pile at Elev. 334.5 and a native clay surface at Elev. 325.

Table 8.3 – Estimated Axial Resistances of Steel Sheet Piles

Sheet Pile Section	Pile Length (m)	Pile Toe Elevation	Factored ULS Resistance (kN) per meter width	SLS Resistance (kN) per meter width
EZ-88	19.5	315	368	307
	20.5	314	414	345
	24.5	310	597	497
AZ36-700N	19.5	315	411	342
	24.5	310	664	553

The SLS values are based on a vertical pile settlement of 25 mm at the base of the embankment fill. Elastic compression of the pile will be in addition to this settlement.

8.2.2 Pile Installation

Pile installation should be in accordance with OPSS 903.

Sheet piles should be driven to the specified elevation noted in Table 8.3. The appropriate pile driving note is “Sheet piles to be driven to El. ___”. An additional note should be included to indicate that installation of permanent sheet pile walls by vibratory equipment is not permitted.

Tip protection should not be used for sheet piles at this site as the load bearing sheet piles will derive vertical resistance almost entirely from shaft friction.

Design of the permanent sheet pile walls must consider environmental conditions such as road salts or fluctuating water levels that may cause long term corrosion and reduce the service life of the structure.

The sheet piles will be driven through the embankment fill. It should be recognized that fill materials including embankment fills are heterogeneous in nature and may contain obstructions such as wood, boulders or rock fill. If such obstructions are encountered at the proposed location of the sheet pile walls, they will have to be removed to facilitate sheet pile installation. Suggested text for an NSSP is included in Appendix F.

8.2.3 Lateral Resistance of Sheet Pile Wall

The depth of penetration of the sheet piles will be governed not only by the axial resistance/capacity, but also by the lateral pressure imposed by the soils retained behind the sheet piles.

The ultimate lateral resistance of a steel sheet pile wall may be assessed using the expression presented in Section 9 and the following earth pressure coefficients:

Table 8.4 – Soil Parameters for Lateral Sheet Pile Resistance

Soil Unit	Elevation (m)		γ′ (kN/m³)	K_a	K_o	K_p
	Top	Bottom				
Sand and Gravel Fill	335.8	334.3	21	0.33	0.5	3.0
Silty Clay Fill - above water level	334.3	328.5	19	0.44	0.61	2.28
Silty Clay Fill - below water level	328.5	325.0	9	0.44	0.61	2.28
Silty Clay	325.0	311.0	9	0.41	0.58	2.46

For soil-spring analysis, the spring constant, K_s, may be obtained by the expression $K_s = k_s L$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3) and L is the length (m) of the pile segment or element used in the analysis. For the firm to stiff silty clay at the site, a k_s value of 3,000 kN/m^2 is recommended for analysis. This value may be assumed to be constant with depth.

To maintain the computed passive resistance, protection must be provided in front of the sheet piles to prevent material loss due to creek erosion.

8.3 Recommended Foundation

From a geotechnical perspective, a steel sheet pile wall culvert is the preferred culvert type for this site in view of the deep excavation and extensive roadway protection required to install a CSP arch culvert.

8.4 Frost Cover

The design depth of frost penetration at this site is 2.2 m. The base of pile caps, if employed, should be provided with a minimum of 2.2 m of earth cover as protection against frost action. As an alternative, provision of insulation (EPS foam) could be considered to compensate for the soil cover and to minimize the frost action.

Frost treatment at the culvert should be placed in accordance with OPSD 803.010.

8.5 Downdrag

As installation of a larger culvert at this site will result in a decreased loading on the embankment subgrade, downdrag on the piles is not considered to be an issue.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to an arch culvert should consist of granular material conforming to OPSS Granular A or Granular B Type II specifications. Backfill should be placed and compacted in accordance with OPSS 501 and OPSS 902.

The backfill should be placed in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be within 500 mm on both sides of the culvert at all times. The precast concrete cap panels must be in place prior to backfilling. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction equipment to be used adjacent to culverts should be restricted in accordance with OPSS 501.

In general, earth pressures acting on the culvert walls may be assumed to impose a triangular distribution governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC 2014, Clause 6.12, but generally are given by the expression:

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

where:

- p = horizontal pressure on the wall at depth h (kPa)
- K = earth pressure coefficient (see Table 9.1)
- γ = bulk unit weight of retained soil (see Table 9.1)
- 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 and wingwalls are dependent on the material used as backfill and the inclination of the ground surface behind the wall. Recommended values are shown in Table 9.1.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. In the case of a strutted sheet pile wall (ie., with concrete cap), the triangular pressure distribution may underestimate the pressures near the struts, as at-rest pressures may develop due to the restraint of the strut. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC. Active pressures should be used for any wingwalls or unrestrained walls.

Table 9.1 – Earth Pressure Coefficients for Granular Backfill (K)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8\ kN/m^3$		OPSS Granular B Type I $\phi = 32°, \gamma = 21.2\ kN/m^3$	
	Horizontal Surface	Sloping Surface behind Wall (2H:1V)	Horizontal Surface	Sloping Surface behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

* Use submerged unit weight below groundwater level.

For the at-rest condition, all soil above a horizontal surface behind the wall should be treated as a surcharge load.

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 wall.

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

The design of the culvert should incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill, or alternatively the culvert walls should be designed to withstand the potential build-up of hydrostatic pressures behind the walls.

10 SEISMIC CONSIDERATIONS

Based on the undrained shear strength of the silty clay fill and underlying silty clay, Site Class E (soft soil) should be assumed to evaluate the seismic site response, as per Table 4.1, Clause 4.4.3.2 of the CHBDC 2014.

The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.038 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 10.1 may be used:

Table 10.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or Granular B Type II $\phi = 35°$ $\gamma = 22.8$ kN/m^3	OPSS Granular B Type I $\phi = 32°$ $\gamma = 21.2$ kN/m^3	Silty Clay Fill $\phi = 23°$ $\gamma = 19$ kN/m^3	Native Silty Clay $\phi = 25°$ $\gamma = 19$ kN/m^3
Active (K_{AE})*	0.28	0.31	0.45	0.42
Passive (K_{PE})	3.7	3.2	2.29	2.47
At Rest (K_{OE})**	0.44	0.49	0.65	0.62

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

The cohesive soils underlying this site are not considered to be prone to liquefaction. Liquefaction is therefore not a concern at this site.

11 EMBANKMENT RESTORATION

The existing highway embankment is up to 9 m in height at the culvert location. Failure of the north end of the culvert along with scour and erosion around and above the culvert inlet and wing walls has resulted in surficial failures on the north embankment slope. At the time of the site investigation, the failure scarp extended to within about 2 m of the embankment crest. No evidence of deep-seated instability was noted, and the south slope of the embankment appears to be performing satisfactorily.

The replacement culvert will encompass the majority of the failed embankment area, and therefore the area of erosion and instability will be removed during new culvert installation. Provided that the embankment is reconstructed at the same slope inclination as the existing embankment (but not steeper than 2H:1V) and suitable erosion protection measures are incorporated, the restored embankment slope is expected to be stable.

As the roadway grade will not be raised and installation of a new larger culvert should impart a net unloading of the embankment subgrade, 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.

Embankment restoration should be carried out in accordance with OPSS.PROV 206. In general, surface vegetation, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from within the embankment footprint prior to placement of new fill.

12 SCOUR AND EROSION CONTROL

Erosion protection should be provided for the creek bed, in the culvert inlet/outlet areas and on any embankment slope that may be affected by the creek flow. Design of the erosion protection measures should consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which creek flow 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.

13 EXCAVATION AND GROUNDWATER CONTROL

The excavation and backfilling should be carried out in accordance with OPSS 902.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the silty clay fill and native silty clay may be classified as Type 3 soils.

Excavation for construction of pile caps, if employed, is expected to extend to the approximate level of the channel base. In view of the cohesive, relatively impermeable nature of the silty clay on site, excavation and dewatering for pile cap construction should be relatively straightforward provided the work is carried out when creek water levels are lowest to minimize the volume of water to be handled. In general, retaining the existing box culvert during construction, placing earth dikes or sandbags to prevent creek water from entering the excavations, and pumping from within the excavation should be adequate. Concentrated seepage should be expected from any previously disturbed zones or from former creek channel (sand and gravel) deposits.

Construction during high water levels is not recommended. It is noted that the surveyed water level in the creek was Elev. 328.5 on June 5, 2013, which is above the top of the existing box culvert. We understand that this level is controlled by the lake level downstream. Construction during high water levels would require an extensive cofferdam system to isolate the excavation area from the creek to permit construction in the dry.

Selection of the equipment and methodology to excavate for pile cap construction and prepare the channel base is the responsibility of the Contractor. The Contract Documents should contain a NSSP advising the Contractor of the potential high groundwater levels, existing debris and possible cobbles and boulders at this site that may impact foundation construction. Suggested wording for an NSSP in this regards is provided in Appendix F.

Roadway protection will be required during construction staging to facilitate traffic operations on Highway 11. Roadway protection should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. The design of roadway protection is the responsibility of the Contractor, and all shoring should be designed by a Professional Engineer experienced in such designs.

14 TEMPORARY MODULAR BRIDGE

We understand that installation of a temporary modular bridge may be considered to carry traffic as an alternative to staged construction of a CSP arch culvert. It is anticipated that the temporary bridge would be supported on sleeper slabs/footings placed on the existing granular material overlying the silty clay fill embankment. Based on the borehole information, the existing granular material is approximately 1.5 m thick.

A factored geotechnical resistance at ULS of 120 kPa and a geotechnical reaction of 80 kPa is recommended to evaluate the feasibility of supporting the modular bridge on the existing fill embankment, assuming a 2.5 by 3.5 m footing placed at the surface of the roadway granular material. The resistance/reaction values will need to be reviewed when the loading and footing dimensions are established. If the available resistance is inadequate, consideration may be given to construction of a thicker granular pad under the footings or supporting the bridge on driven piles developing shaft resistance in the native silty clay.

The front edge of the sleeper slab/footings should be positioned a minimum distance of 3 m from the crest of the excavation, assuming a 2H:1V temporary excavation slope.

15 CONSTRUCTION CONCERNS

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

- The thickness and depth to the base of the existing fill and any soft streambed deposits may vary at locations away from the boreholes.
- Cobbles and other obstructions may be present within or at the base of the embankment fill. These materials may interfere with excavation or installation of piles and roadway protection systems. The Contractor should be prepared to remove or otherwise penetrate these obstructions.
- A suitable dewatering system should be employed to enable construction in the dry.
- Water levels in the creek may fluctuate during construction, and work should be scheduled to avoid flooding conditions resulting from downstream lake levels.
- 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. The design and safety of any temporary works is the responsibility of the Contractor.

16 CLOSURE

Engineering analysis and preparation of this foundation design report was carried out by Ms. Anna Piascik, P.Eng., and the report was reviewed by Mr. Murray Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

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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

C_{pen} 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.

<u>UNIFIED SOILS CLASSIFICATION</u>

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			

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RECORD OF BOREHOLE No EC-01

METRIC

W.P. ______ LOCATION Everett Creek Culvert, Site 45-138/C N 5 388 824.5 E 242 075.1 ORIGINATED BY TS

HWY 11 BOREHOLE TYPE Tripod / Wash Boring COMPILED BY MFA

DATUM Geodetic DATE 2016.01.25 - 2016.01.25 CHECKED BY AMP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
325.8	GROUND SURFACE												
0.0	Sandy **SILT**, some clay, some gravel, some organics (woody debris) Loose Grey Wet						325						
324.9 / 0.9	Silty **CLAY**, some sand, trace gravel Stiff to Very Stiff Grey Moist												
			1	SS	15		324	o		0	13	36	51
							323						
			2	SS	10			o					
			3	SS	22		322	o					
			4	SS	12		321	o					
			5	SS	26		320	o					
319.7 / 6.1	END OF BOREHOLE AT 6.1m. BOREHOLE BACKFILLED WITH CUTTINGS AND BENTONITE TO SURFACE.												

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

REMARKS & GRAIN SIZE DISTRIBUTION (%)

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 10203.GPJ 2015TEMPLATE(MTO).GDT 3/15/16

RECORD OF BOREHOLE No EC-02

METRIC

W.P.		ORIGINATED BY	ZRB
HWY	11	COMPILED BY	AN
DATUM	Geodetic	CHECKED BY	AMP
LOCATION	Everett Creek Culvert, Site 45-138/C N 5 388 803.1 E 242 059.3		
BOREHOLE TYPE	NW Casing / Wash Boring		
DATE	2015.12.14 - 2015.12.14		

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS: GR	SA	SI	CL
335.8	GROUND SURFACE								
0.0	**ASPHALT:** (125mm)								
0.1	**SAND** and **GRAVEL**, some silt, trace clay, occasional cobbles Dense Grey Moist (FILL)	1	SS	33	~4				
334.3 / 1.5	Silty **CLAY**, some sand, trace gravel, trace organics (rootlets), occasional gravel lenses Soft to Firm Grey and Brown (FILL)	2	SS	6	~6				
		3	SS	4	~28				
	Frequent brown silt seams	4	SS	4	~30	0	19	33	48
		5	SS	0	~30				
	Dark brown below 7.0m	6	SS	3	~20				
	Some gravel, occasional wood fragments	7	SS	5	~28				

Elevation scale: 335, 334, 333, 332, 331, 330, 329, 328, 327, 326

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No EC-02

METRIC

W.P. ______ LOCATION Everett Creek Culvert, Site 45-138/C N 5 388 803.1 E 242 059.3 ORIGINATED BY ZRB

HWY 11 BOREHOLE TYPE NW Casing / Wash Boring COMPILED BY AN

DATUM Geodetic DATE 2015.12.14 - 2015.12.14 CHECKED BY AMP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
325.4 / 10.4	**SAND** and **GRAVEL** and 300mm boulder					Cored through boulder
325.1 / 10.7	Silty **CLAY**, some sand, trace gravel Firm to Stiff Grey Moist				325	
		8	SS	6		0 15 33 52
					324	
		9	SS	7		
					323	
					322	
		10	SS	5		
					321	
		11	SS	5		0 15 35 50
					320	
					319	
		12	SS	5		
					318	
		13	SS	3		
					317	
					316	

Shear strength annotation near elevation 318: 4.0

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity. 20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No EC-02

METRIC

W.P. ______ LOCATION Everett Creek Culvert, Site 45-138/C N 5 388 803.1 E 242 059.3 ORIGINATED BY ZRB

HWY 11 BOREHOLE TYPE NW Casing / Wash Boring COMPILED BY AN

DATUM Geodetic DATE 2015.12.14 - 2015.12.14 CHECKED BY AMP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
	Continued From Previous Page													
			14	SS	7						0	14	29	57
							315							
			15	SS	4									
							314							
							313							
			16	SS	7									
							312							
			17	SS	7									
310.8							311							
25.0	END OF BOREHOLE AT 25.0m. BOREHOLE BACKFILLED WITH BENTONITE TO 0.3m, THEN CONCRETE TO SURFACE.													

Legend: PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. Scale 20 40 60 80 100.

+3, ×3: Numbers refer to Sensitivity

20 / 15 / 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 10203.GPJ 2015TEMPLATE(MTO).GDT 3/15/16

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RECORD OF BOREHOLE No EC-04

METRIC

W.P. ______ LOCATION Everett Creek Culvert, Site 45-138/C N 5 388 780.9 E 242 044.6 ORIGINATED BY ZRB

HWY 11 BOREHOLE TYPE NW Casing / Wash Boring COMPILED BY AN

DATUM Geodetic DATE 2015.12.15 - 2015.12.15 CHECKED BY AMP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
330.8	GROUND SURFACE							
0.0	Silty **CLAY**, trace to some sand, occasional sand lenses, trace gravel, trace organics (grass, wood fragments) in the upper 1.5m zone Very Soft to Firm Mottled Brown and Grey Moist to Wet	1	GS					
					330			
		1	SS	4				0 13 40 47
		2	SS	1	329			
		3	SS	1	328			
		4	SS	0				0 0 27 73
327.0 3.8	Silty **CLAY**, trace to some sand, trace gravel Firm to Stiff Grey Moist				327	+ 5.0		
		5	SS	6	326			
					325			
		6	SS	6	324	+ 4.0		
		7	SS	3	323			
					322			
		8	SS	4	321			0 13 39 48

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No EC-04

METRIC

W.P.		LOCATION	Everett Creek Culvert, Site 45-138/C N 5 388 780.9 E 242 044.6	ORIGINATED BY	ZRB
HWY	11	BOREHOLE TYPE	NW Casing / Wash Boring	COMPILED BY	AN
DATUM	Geodetic	DATE	2015.12.15 - 2015.12.15	CHECKED BY	AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m 3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page	▨						4.0 +			
		▨					320				
		▨	9	SS	5				○		
		▨					319				
318.0		▨	10	SS	4				○		
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE BACKFILLED WITH BENTONITE TO 0.3m, THEN CUTTINGS TO SURFACE.						318				

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

Laboratory Test Results

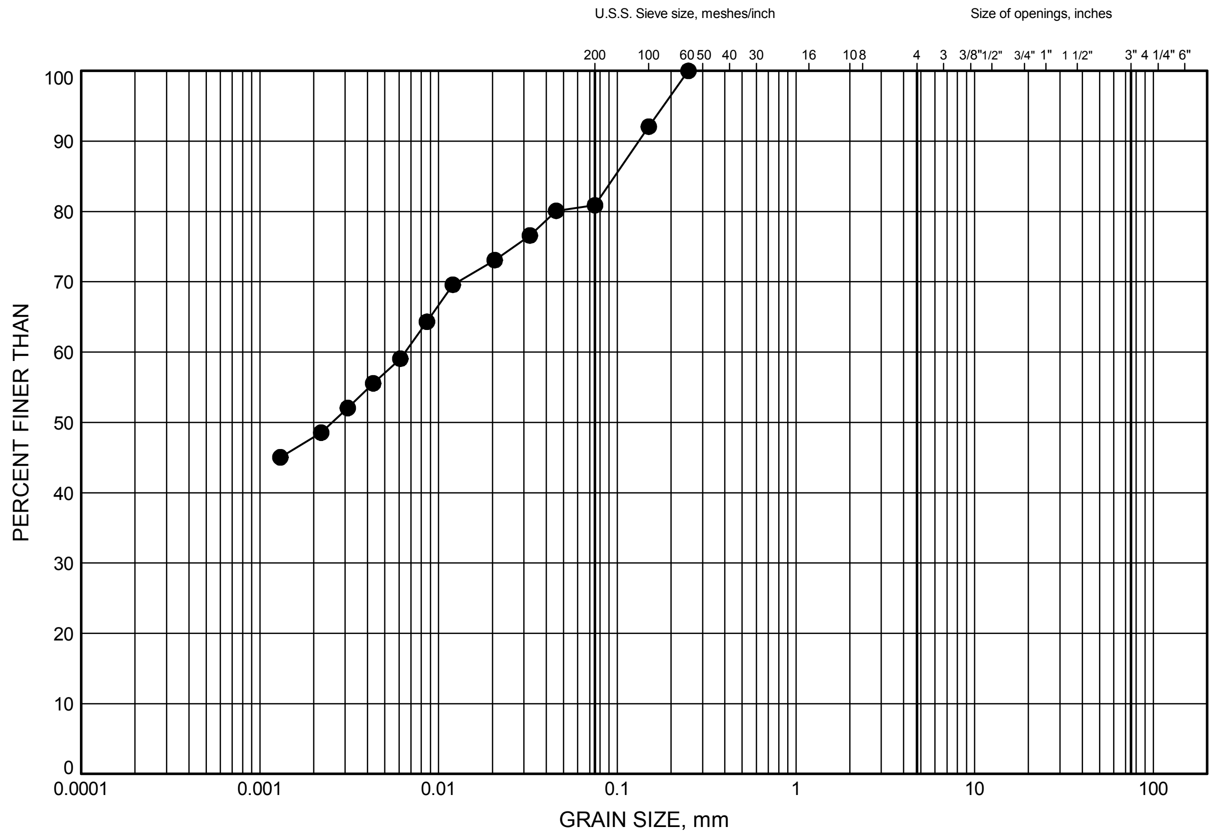
THURBER

Everett Creek Culvert, Site 45-138/C

GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	EC-02	4.88	330.92

Date March 2016

W.P.

THURBER

Prep'd MFA

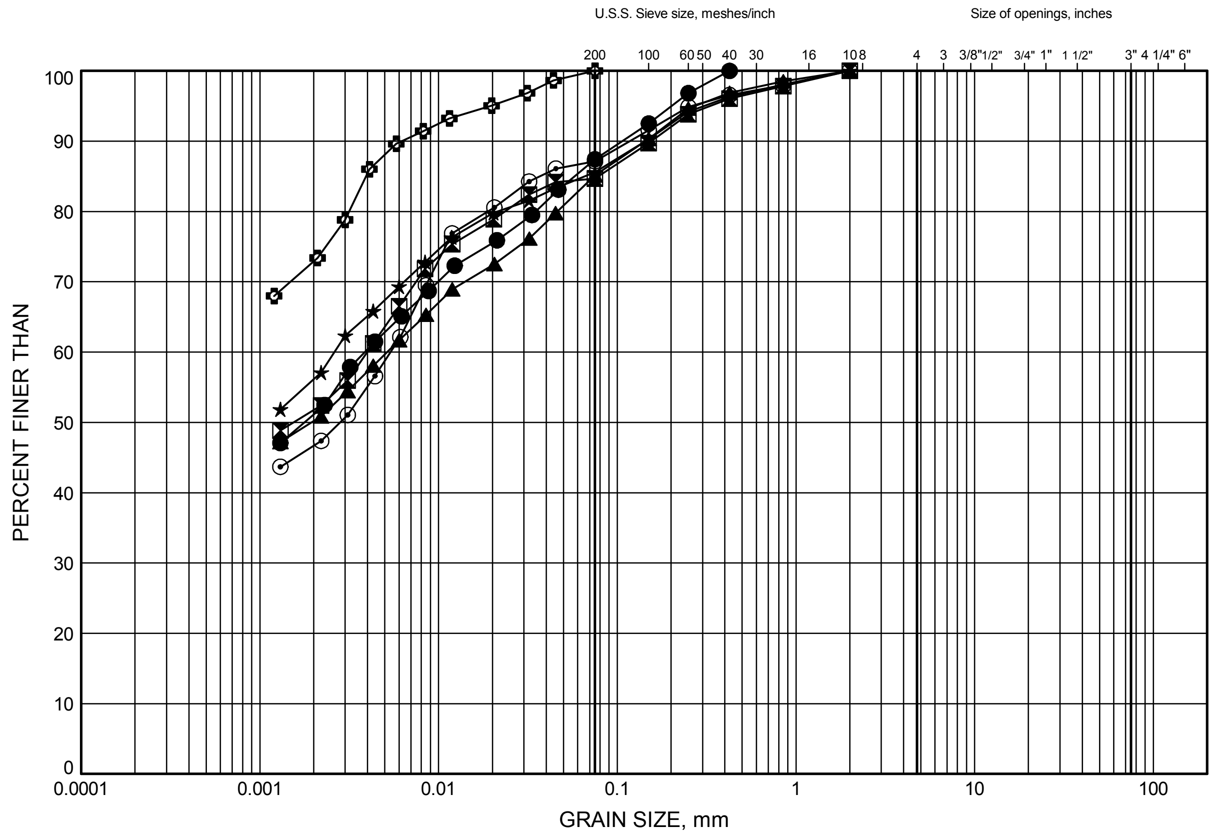
Chkd. AMP

Everett Creek Culvert, Site 45-138/C

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	EC-01	1.83	323.97
⧗	EC-02	10.97	324.83
▲	EC-02	15.54	320.26
★	EC-02	20.12	315.68
⊙	EC-04	1.07	329.73
✪	EC-04	3.35	327.45

Date March 2016

W.P.

THURBER

Prep'd MFA

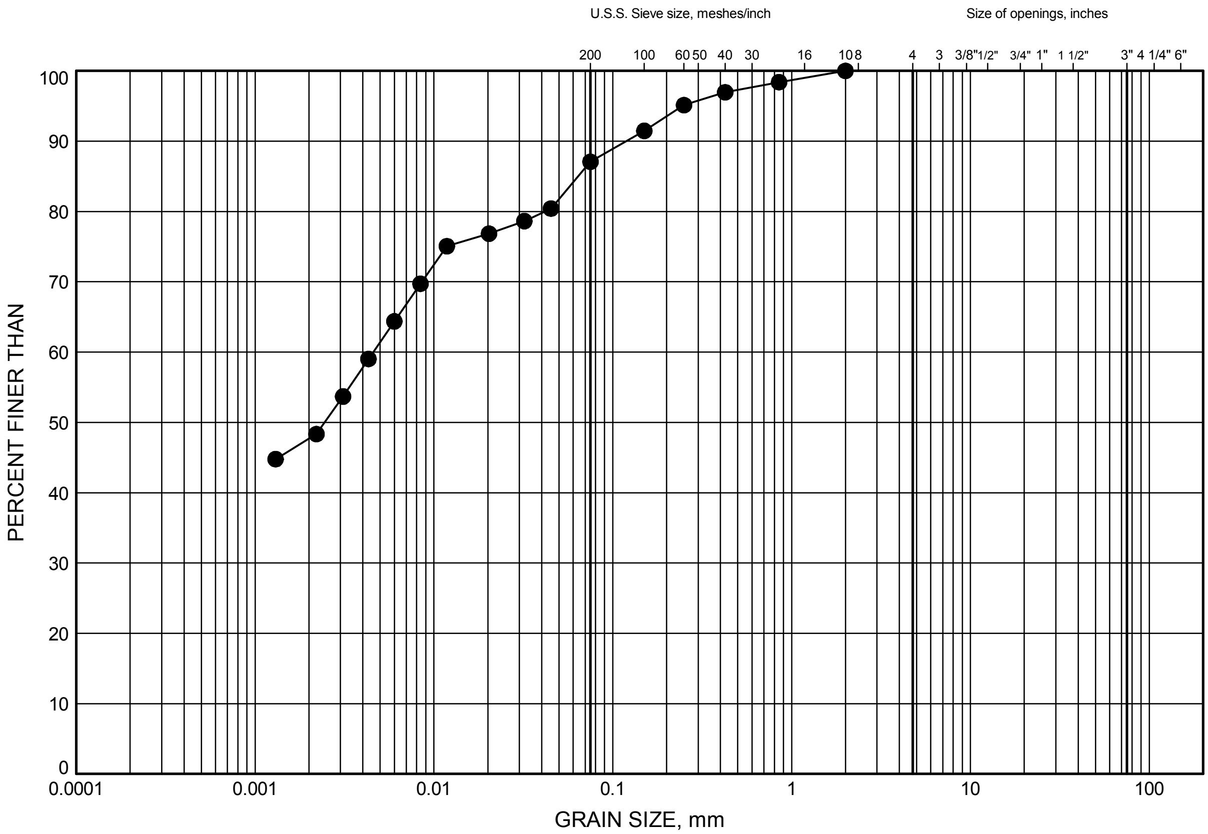
Chkd. AMP

Everett Creek Culvert, Site 45-138/C

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	EC-04	9.45	321.35

Date March 2016

W.P.

THURBER

Prep'd MFA

Chkd. AMP

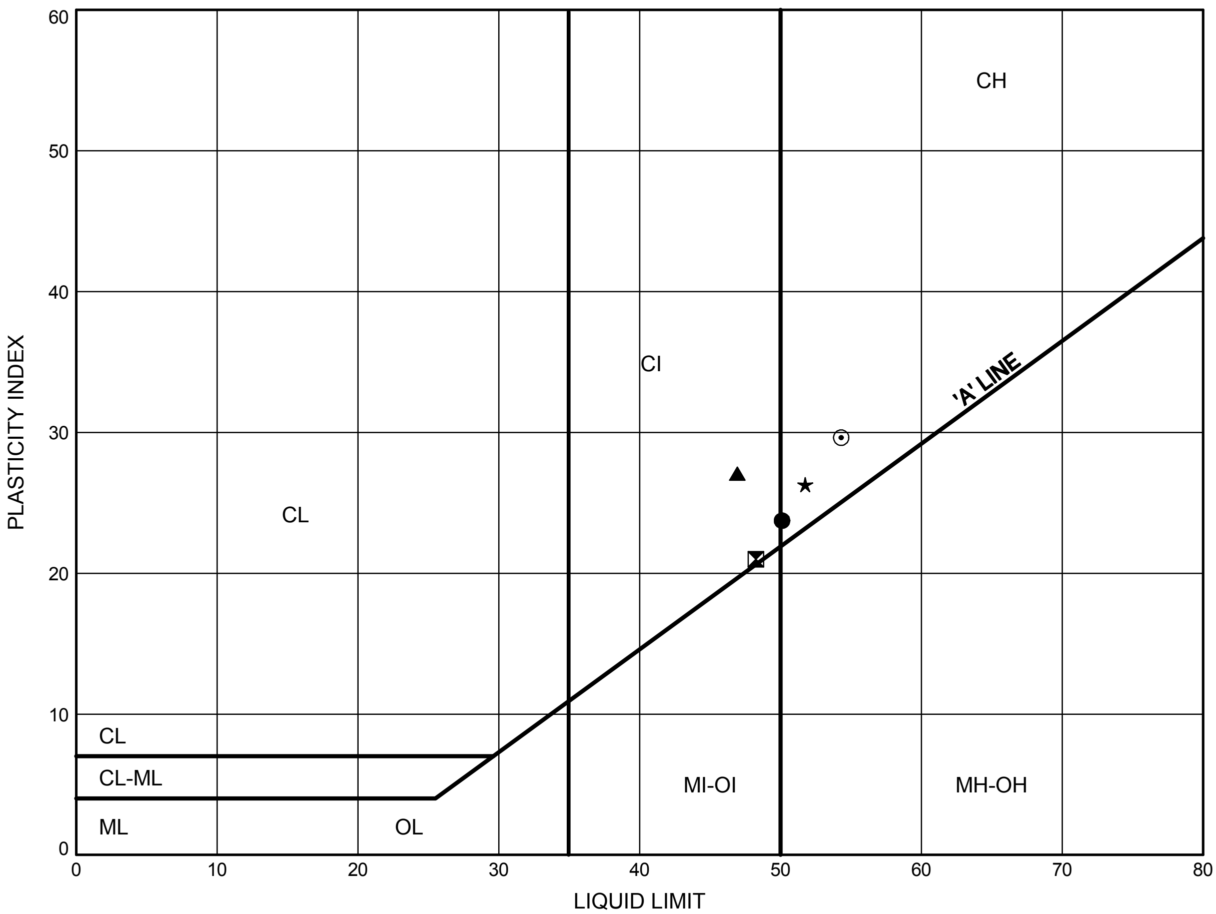
GRAIN SIZE DISTRIBUTION - THURBER 10203.GPJ 3/15/16

Everett Creek Culvert, Site 45-138/C

ATTERBERG LIMITS TEST RESULTS

FIGURE B4

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	EC-02	10.97	324.83
⊠	EC-02	15.54	320.26
▲	EC-02	20.12	315.68
★	EC-04	3.35	327.45
⊙	EC-04	9.45	321.35

THURBALT 10203.GPJ 3/15/16

Date March 2016

W.P.

THURBER

Prep'd MFA

Chkd. AMP

Appendix C

Site Photographs

Photograph 1 – North side of Highway 11 embankment at Everett Creek, looking east

Photograph 2 – South side of Highway 11 embankment at Everett Creek, looking west

Photograph 3 – Everett Creek Culvert Inlet (north end)

Photograph 4 – Debris, scour and erosion at the north end of the culvert

Photograph 5 – North embankment slope in December 2015, from the top of slope

Photograph 6 – North embankment slope failure above the culvert location

Photograph 7 – Culvert outlet, at the time of field investigation

Photograph 8 – South embankment slope at the culvert location

Appendix D

Borehole Logs and Location Plan from Previous Investigation

RECORD OF BOREHOLE No BH1

METRIC

W.P. 6013-E-0023 LOCATION EVERETT CREEK CULVERT - STA 10+ 008 5 m, LT ORIGINATED BY JOE

DIST HWY HWY 11 BOREHOLE TYPE HOLLOW STEM AUGER (80 mm ID) COMPILED BY MD

DATUM LOCAL DATE 2014 05 04 CHECKED BY DB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
99.6	GROUND SURFACE				
99.0 / 0.0	ASPHALT - 130 mm				
99.4 / 0.1	FILL - SAND AND CRUSHED GRAVEL, trace silt, brown	1	AS		35 49 (13)
98.8 / 0.8	FILL-SAND- trace gravel, some silt	2	SS	18	
98.1 / 1.5	CLAY - Silty, trace sand, trace gravel, trace organics, brown/grey, stiff to very stiff	3	SS	10	
		4	SS	7	Groundwater at 2.9 m
		5	SS	26	
		6	SS	4	
		7	SS	7	
		8	SS	7	
		9	SS	8	
		10	SS	7	
90.3 / 9.3	SAND - some silt, trace organics, black	11	SS	9	
90.0 / 9.6	CLAY - Silty, trace sand, trace gravel, trace organics, grey		SS	50/50	
88.9 / 10.7	Auger Refusal - End of Borehole				

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (99 to 89); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE □ QUICK TRIAXIAL × LAB VANE 50 100 150 200 250; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-018736 EVERETT CREEK LOGS.GPJ DST_MIN.GDT 9/8/14

RECORD OF BOREHOLE No BH2

METRIC

W.P. 6013-E-0023 LOCATION EVERETT CREEK CULVERT - STA 9 + 999 5 m, RT ORIGINATED BY JOE

DIST ___ HWY HWY 11 BOREHOLE TYPE HOLLOW STEM AUGER (80 mm ID) COMPILED BY MD

DATUM LOCAL DATE 2014 05 04 CHECKED BY DB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
99.6	GROUND SURFACE				
99.5 / 0.1	Asphalt - 130 mm				
	FILL - SAND AND CRUSHED GRAVEL, trace silt, brown	1	AS		
98.9 / 0.8	FILL-SAND - with gravel, some silt, brown	2	SS	12	24 54 (16)
		3	SS	8	
97.3 / 2.3	CLAY - Silty, some sand, trace gravel, trace organics, grey, Stiff to very stiff	4	SS	4	
		5	SS	4	
		6	SS	6	
		7	SS	9	
		8	SS	7	
		9	SS	9	
		10	SS	12	
		11	SS	7	
		12	SS	8	
		13	SS	7	
		14	SS	7	
83.8		13	SS	7	
15.8	End of Borehole				

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (99, 98, 97, 96, 95, 94, 93, 92, 91, 90, 89, 88, 87, 86, 85, 84); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE □ QUICK TRIAXIAL × LAB VANE 50 100 150 200 250; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH3

METRIC

W.P. 6013-E-0023 LOCATION EVERETT CREEK CULVERT - STA 9 + 998 23 m, LT ORIGINATED BY JOE

DIST HWY HWY 11 BOREHOLE TYPE HOLLOW STEM AUGER (80 mm ID) COMPILED BY MD

DATUM LOCAL DATE 2014 05 04 CHECKED BY DB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE (50 100 150 200 250)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
92.1	GROUND SURFACE										
	Clay-silty, some sand, some gravel, organics, grey		1	AS			92				
91.1 1.0	Auger Refusal at 1.0 m										

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH4

METRIC

W.P. 6013-E-0023 LOCATION EVERETT CREEK CULVERT - STA 10 + 009 20 m, LT ORIGINATED BY JOE

DIST ___ HWY HWY 11 BOREHOLE TYPE HOLLOW STEM AUGER (80 mm ID) COMPILED BY MD

DATUM LOCAL DATE 2014 05 04 CHECKED BY DB

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
91.3	GROUND SURFACE							
91.1	TOPSOIL							
0.2	CLAY - Silty, some sand, some gravel, trace organics, grey						91	
			1	AS				
			2	AS			90	CPT 1102 kPa CPT 1447 kPa
			3	AS			89	CPT 1171 kPa CPT 1378 kPa
88.3								
3.0	End of Borehole							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE □ QUICK TRIAXIAL × LAB VANE; 50 100 150 200 250

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-018736 EVERETT CREEK LOGS.GPJ DST_MIN.GDT 9/8/14

CONT No 6013–E–0023
WP No xxx–xx–xx
SITE No 45–138/C
GEOCRES No 52C–37

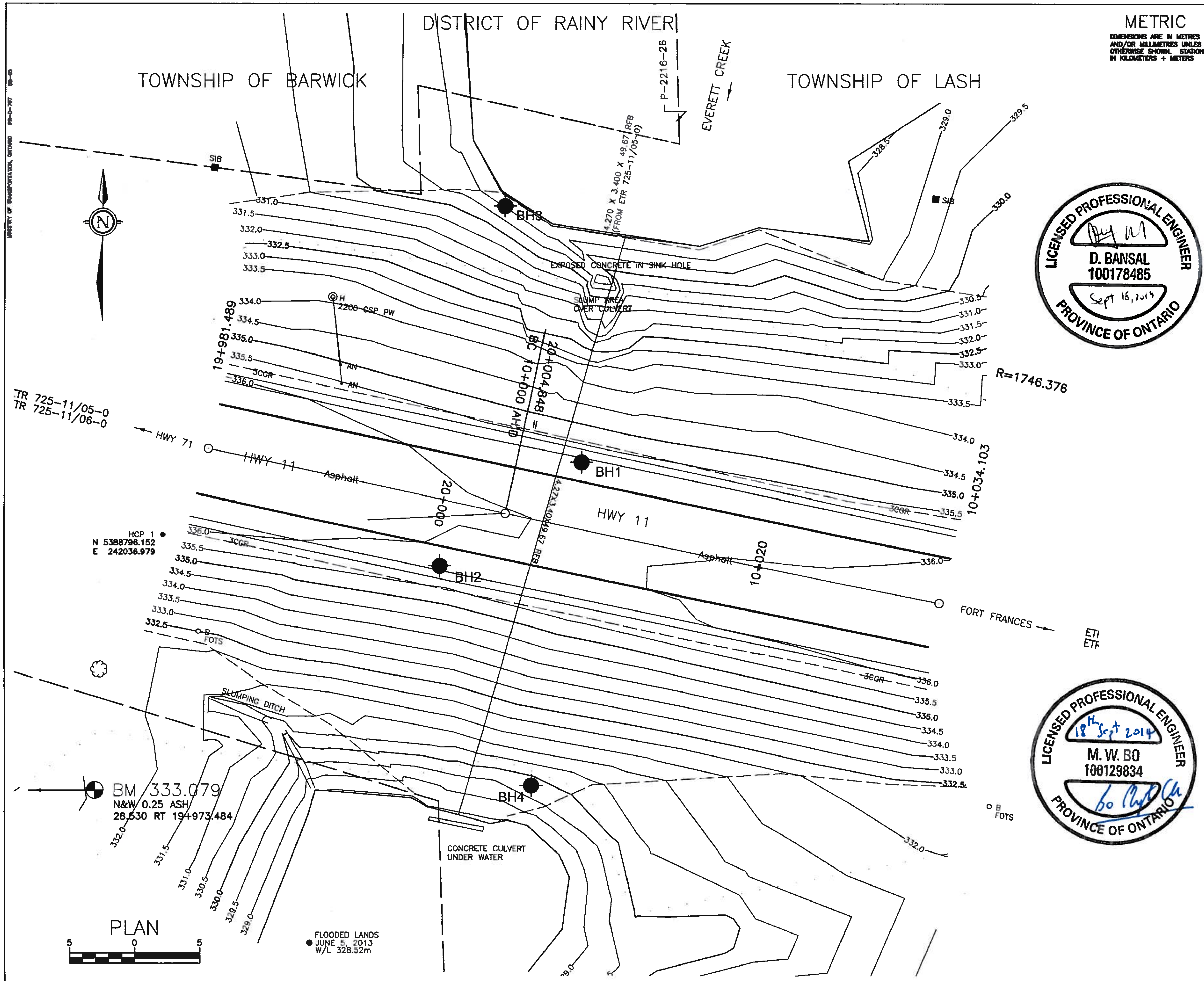
CULVERT REPLACEMENT
EVERETT CREEK CULVERT

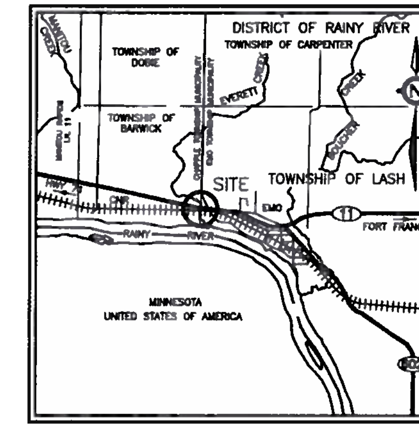
STA 9+995 TO STA 10+006

Survey 13–06 Revised

SHEET

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLES OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS





KEY PLAN

1.0 km 0 1.0 km

LICENSED PROFESSIONAL ENGINEER
D. BANSAL
100178485
Sept 15, 2014
PROVINCE OF ONTARIO

LEGEND

- Borehole
- Borehole with CPT
- Asphalt Core
- Rock Probe
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.

Fill, Organics, Topsoil, Till, Bedrock, Sand, Silt, Clay, Sand & Gravel, Boulders

No.	Elevation	Northing	Easting	Station	Offset
BH1	98.6	5388801 m N	242069 m E	10+008	5.0 m LT
BH2	99.6	5388793 m N	242058 m E	9+989	5.0 m RT
BH3	92.1	5388821 m N	242063 m E	9+998	23 m LT
BH4	91.3	5388776 m N	242065 m E	10+009	20 m RT

LICENSED PROFESSIONAL ENGINEER
18th Sept 2014
M. W. BO
100129834
PROVINCE OF ONTARIO

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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DRAWING 1

Appendix E

Comparison of Foundation Alternatives

COMPARISON OF CULVERT TYPE / FOUNDATION ALTERNATIVES

Concrete Box Culvert	Corrugated Steel Plate (CSP) Arch Culvert	Precast Concrete Slab Supported on Sheet Pile Abutments
Advantages: i. Relatively rapid installation and shorter construction time. ii. Less disturbance to subgrade soils if precast units are used. iii. Loading is spread over a larger width, hence lesser geotechnical resistance is required. iv. Typically least costly culvert type. v. Can tolerate some differential settlement.	***Advantages:*** i. Relatively rapid installation if precast footings are used. ii. May be more cost effective than cast-in-place culverts. iii. Less disturbance of creek channel.	***Advantages:*** i. Minimizes potential for disturbance of streambed. ii. Ease of construction. iii. Provides shoring and foundation elements in one operation. iv. Installation of piles could continue in freezing weather. v. Potentially minimizes volume of excavation and roadway protection requirements.
Disadvantages: i. Requires deep excavation in existing embankment. ii. Excavation to place bedding material will extend below water level. iii. Maintenance of water flow can be an issue and would require a sacrificial culvert. iv. Poor performance of existing culvert. v. Potential environmental impact on fisheries. vi. Requires lengthy traffic protection.	***Disadvantages:*** i. Requires deeper excavation for footing or pile cap construction. ii. Potentially more difficult dewatering requirements. iii. Possible inadequate geotechnical resistance available in native soils, and requirements for large size of footing or large number of piles. iv. Requires traffic protection or temporary bridge during construction.	***Disadvantages:*** i. Potential for corrosion of sheet piles. ii. Less conventional construction. iii. Strut needed for lateral support of high sheet pile walls.
NOT RECOMMENDED	**FEASIBLE**	**RECOMMENDED**

THURBER

Appendix F

List of Standard Specifications

and Suggested Wording for NSSP

1. List of OPSS and OPSD Documents Referenced in this Report

- OPSS.PROV 206
- OPSS 501
- OPSS.PROV 539
- OPSD 803.010
- OPSS.PROV 804
- OPSS 902
- OPSS 903

2. Suggested Wording for NSSP on Foundation Excavation

The Contractor is advised that the existing embankment fill and original creek channel deposits on site may contain cobbles and possibly boulders that will require handling during foundation excavation. Further, timber debris and the existing box culvert will require removal. Removal of large obstructions will require appropriate excavating equipment, and may result in areas of over-excavation requiring backfill. The work should be carried out in a manner which minimizes disturbance to the excavation base.

It is further noted that the water level in the creek may fluctuate significantly. The dewatering system used during foundation construction must anticipate potential water level variations.

Selection of the equipment and methodology to excavate and prepare the founding surface remains the responsibility of the Contractor, and should be based on his interpretation of the subsurface conditions presented in the Foundation Investigation Report as well as the surface conditions exposed at the site.

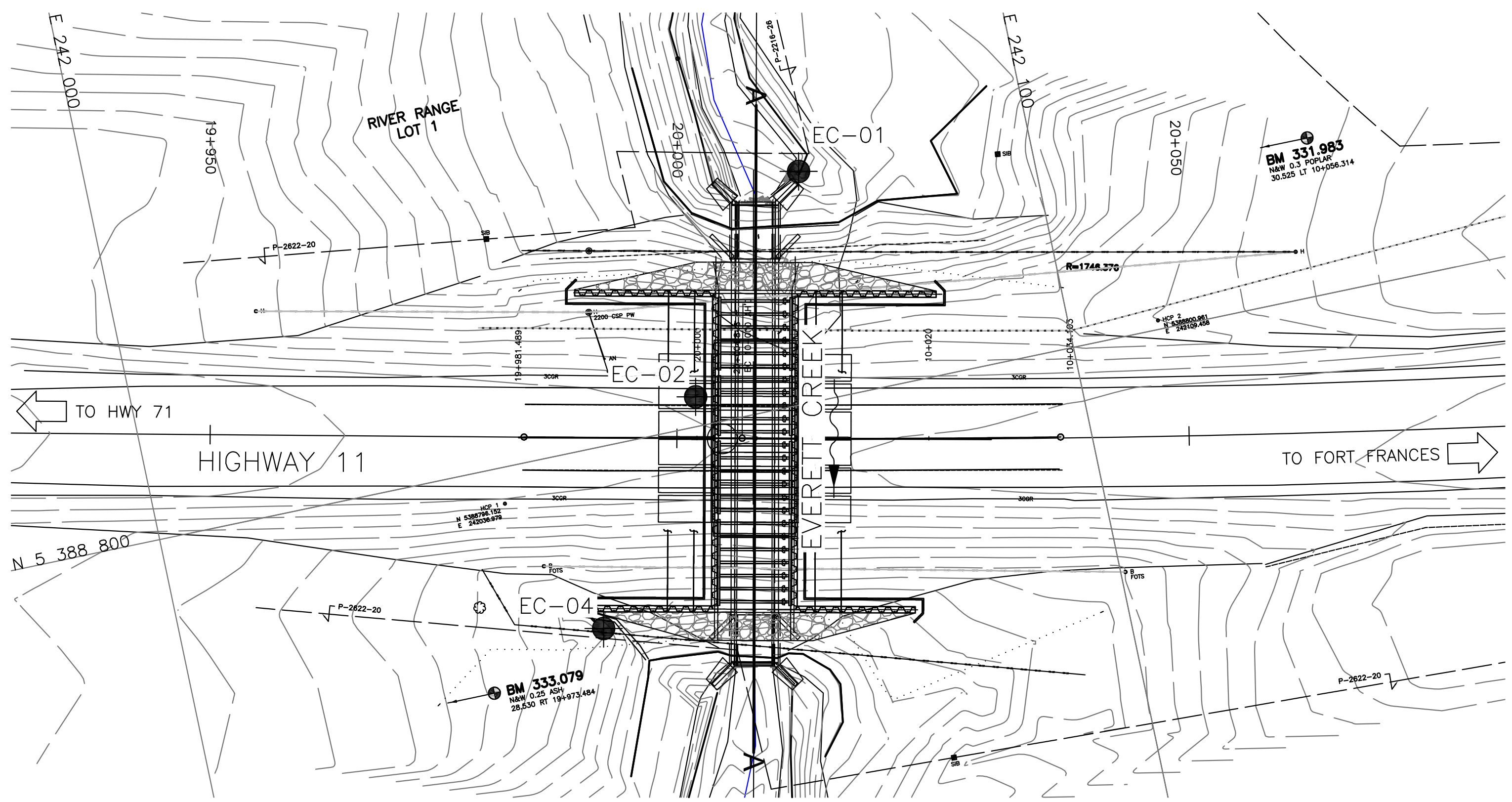
3. Suggested Text for NSSP on Installation of Steel Sheet Piles

Obstructions such as wood, boulders or rock fill may be present within the existing embankment fill. These obstructions may impede the driving of sheet piles and at some locations the sheet piles may not be able to penetrate these materials to reach the design depth of installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the piles to the design depth.

Appendix G

Borehole Locations and Soil Strata Drawing

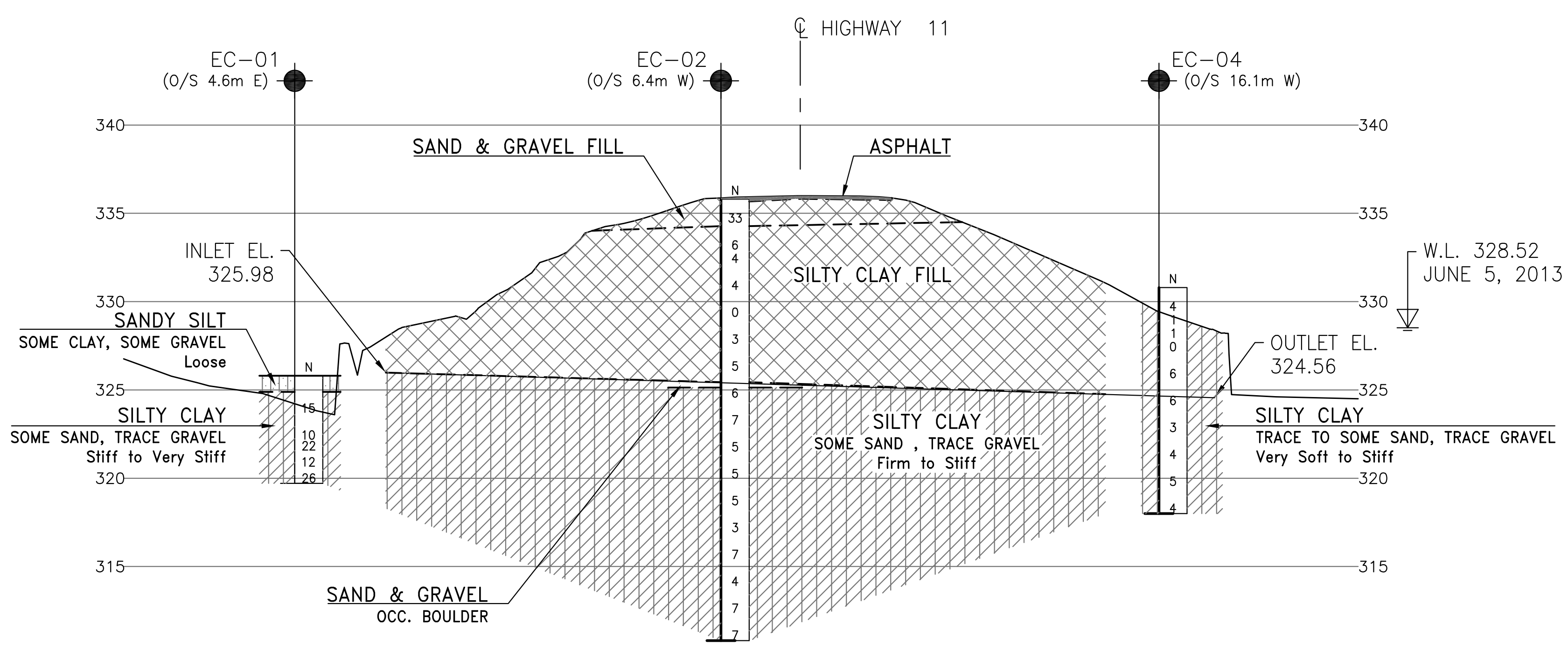
MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

16 0 16 32m

SCALE 1:800



SECTION A-A

8 0 8 16m

SCALE 1:400

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

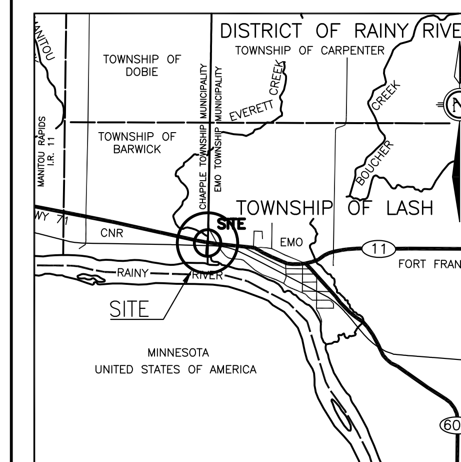
CONT No 2016-6029
GWP No 6902-12-00

HIGHWAY 11
EVERETT CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 8

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
EC-01	325.8	5 388 824.5	242 075.1
EC-02	335.8	5 388 803.1	242 059.3
EC-04	330.8	5 388 780.9	242 044.6

-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.

GEOCRES No. 52C-048

REVISIONS | DATE | BY | DESCRIPTION

DESIGN AMP	CHK PKC	CODE CAN/CSA S6/06	LOAD CL-625-ONT	DATE APR 2016
DRAWN MFA	CHK AMP	SITE 45-138/C	STRUCT	DWG 2

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