THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
SLATE RIVER TRIBUTARY CULVERT REPLACEMENT
HIGHWAY 61
TOWNSHIP OF BLAKE, THUNDER BAY DISTRICT
G.W.P. 6305-14-00; SITE NO. 48W-195/C

GEOCRES No. 52A-222

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 Slate River Tributary Culvert on Highway 61, located in the Township of Blake, Thunder Bay District.

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, under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0017.

A preliminary foundation investigation carried out at this site for the replacement culvert was documented in the report titled "Foundation Investigation and Preliminary Design Report, Slate River Tributary Culvert Replacement, Highway 61, Township of Blake, Thunder Bay District", prepared by DST Consulting Engineers Inc. (DST), dated November 17, 2015; Geocres No. 52A-194. The information presented in the above report was reviewed and incorporated in the current report, as appropriate.

2. SITE DESCRIPTION

The culvert site is located on Highway 61 approximately 1.8 km north of Highway 608 in the Township of Blake, Thunder Bay District, Ontario. A tributary of the Slate River flows from west to east at the culvert location.

According to MTO Plan E-441-61-4 for the crossing at Slate River Tributary and Highway 61 (Site No. 48W-195/C), the existing culvert is a cast in place box structure with a width of 7.0 m and a height of 2.1 m. The total length of the culvert is 25.5 m with approximately 2 m of fill above the culvert.

Residential and agricultural properties are present in the vicinity of the culvert site. Naturally low-lying, swampy areas are present near the inlet and outlet of the culvert, with vegetation consisting of tall grass and shrubs with occasional trees. Local topography is of low relief with no evident bedrock outcrops. Photographs of the culvert and surrounding area are presented in Appendix C.

The site lies within the physiographical region known as the Animikie Basin of the Southern Province, which is characterized by sedimentary rock of the Rove Formation. According to Ontario Geological Survey (OGS) data, the bedrock at this site generally consists of black shale, siltstone and greywacke. The bedrock is overlain by glaciolacustrine and quiet basin deposits of the Pleistocene age consisting of silts and clays with minor sands.

3. INVESTIGATION PROCEDURES

The current site investigation and field testing for this project were carried out between March 18 and 22, 2016. A total of three boreholes, denoted as SL-1 to SL-3, were advanced to depths ranging from 9.8 m to 15.8 m below the existing grade. A Dynamic Cone Penetration Test (DCPT) was carried out below the sampled portion of Boreholes SL-1 to a cone refusal depth of 22.4 m below the existing grade (Elev. 204.2). Details of the borehole depths and completion are summarized in Table 3.1 below.

The locations of the boreholes from the previous and current investigation are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix D.

Table 3.1 – Borehole Completion Details

Borehole	Drilling Depth / Base of Hole Elevation (m)	Completion Details
SL-1	15.8 / 210.8	Borehole backfilled with bentonite holeplug from 15.8 m to 0.1 m then asphalt cold patch to surface.
SL-2	9.8 / 214.3	Borehole backfilled with bentonite holeplug from 9.8 m to the ground surface.
SL-3	9.8 / 214.3	Borehole backfilled with bentonite holeplug from 9.8 m to the ground surface.

Borehole SL-1 was advanced using a CME 750 buggy ATV drill rig in combination with hollow stem augers to advance the borehole to the target depth. Boreholes SL-2 and SL-3 were advanced to the target depth using a tripod drilling rig in combination with NW casing/wash boring techniques. 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). Field vane shear testing using an MTO "N" size vane was carried out in very soft to soft cohesive soils.

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 open boreholes were observed during and upon completion of the drilling operations.

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 gradation analysis and Atterberg Limits testing, and the results of this testing program are summarized on the Record of Borehole sheets in Appendix A and shown on the figures included in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A for details of the encountered soil stratigraphy. A stratigraphic profile is presented on the "Borehole Locations and Soil Strata" drawing in Appendix D. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations.

The borehole logs from the previous foundation investigation (Geocres 52A-194) are presented in Appendix E and are generally consistent with the results of the current investigation.

The subsurface stratigraphy encountered below the existing embankment fill at the site generally consists of an upper firm silty clay deposit with organic matter underlain by a lower stiff silty clay. The boreholes at the culvert inlet and outlet were advanced from the surface of the water in swampy areas adjacent to the river tributary. At the culvert inlet, the upper silty clay was encountered from the swamp bed surface. At the culvert outlet, the lower silty clay is overlain by sand fill which was encountered from the swamp bed surface. More detailed descriptions of the individual strata are presented below.

5.1 Asphalt

Borehole SL-1 was advanced from the top of the road embankment and encountered 125 mm of asphalt.

5.2 Sand to Gravelly Sand Fill

Granular embankment fill was encountered below the asphalt in Borehole SL-1 and below 0.6 m of water in Borehole SL-3 near the culvert outlet. The fill consists of sand, trace gravel to gravelly, and trace to some silt. Occasional cobbles were encountered in the fill. Organic materials were observed intermixed in the fill in Borehole SL-2, indicating that displacement or subexcavation of organic materials below the water level may have occurred during highway construction.

The thickness of the granular fill in the roadway embankment (Borehole SL-1) was 4.0 m, with the base at a depth of 4.1 m (Elev. 222.5). In Borehole SL-2, the fill was 3.5 m thick with a lower boundary at 4.1 m depth (Elev. 220.0).

SPT ‘N’ values recorded in the embankment fill decreased with depth from 77 to 2 blows per 0.3 m of penetration, indicating a very dense to very loose relative density. The ‘N’ value of 77 blows for 0.3 m penetration is probably indicative of frozen ground conditions however. In Borehole SL-2, ‘N’ values ranged from 1 to 8 blows per 0.3 m, indicating a very loose to loose condition. One value of 50 blows for 0.125 m of penetration was probably obtained on a cobble. Moisture contents ranged from 5 to 22%, locally up to 63% near the stream base in Borehole SL-2.

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

Gravel %	12 to 21
Sand %	62 to 69
Silt & Clay %	17 to 19

5.3 Silty Clay with Organics

A layer of brown to dark brown silty clay with organics was encountered below 0.6 m of water in Borehole SL-2 near the culvert inlet and underlying the fill in Borehole SL-1. The upper silty clay layer contained some sand and organic matter. The thickness of the silty clay layer ranged from 1.5 m to 2.4 m, with a base depth of 3.0 and 5.6 m (Elev. 221.1 and 221.0).

SPT 'N' values recorded in the upper silty clay varied between 3 and 5 blows per 0.3 m of penetration, indicating a soft to firm consistency. Natural moisture contents ranged from 33 to 48%.

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

Gravel %	0
Sand %	20
Silt %	56
Clay %	24

5.4 Silty Clay

A deep deposit of silty clay described variously as grey, reddish brown and brown was encountered below the upper silty clay in Boreholes SL-1 and SL-2, and below the sand fill in Borehole SL-3. All boreholes were terminated in the lower silty clay at depths ranging from 9.8 to 15.8 m (Elev. 214.3 to 210.8).

SPT 'N' values recorded in the silty clay varied between 2 and 8 blows per 0.3 m of penetration. The vane shear tests (VST) measured in-situ undrained shear strengths ranging from 70 to 90 kPa, with one value greater than 100 kPa. Based on the SPT and VST data, the consistency of the lower silty clay is typically stiff. Natural moisture contents ranged from 24 to 63%, with typical values between 39% and 48%.

The sensitivity of the lower silty clay, calculated as a ratio of undisturbed strength to remoulded strength, ranged from 2 to 3, suggesting that the lower silty clay is of normal sensitivity.

The results of grain size analyses conducted on samples of the lower silty clay are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B3 and B4 of Appendix B. The results are summarized as follows:

Gravel %	0
Sand %	0
Silt %	25 to 50
Clay %	50 to 75

The results of Atterberg Limits tests conducted on samples of the lower silty clay are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B5 of Appendix B. The results are summarized as follows:

Plasticity Index	17 to 45
Liquid Limit	39 to 75

The results of the Atterberg Limits testing indicate the layer to be of intermediate to high plasticity with group symbol CI to CH.

5.5 Groundwater Conditions

The groundwater level in Borehole SL-1 was measured at a depth of 5.0 m (Elev. 221.6) upon completion of drilling.

Boreholes SL-2 and SL-3 were located at the toe of the embankment slope in areas covered by water. The depth of water at the borehole locations was approximately 0.6m.

The water level in the tributary of Slate River was shown on MTO Plan E-441-61-4 to be at Elev. 224.4 on June 13, 2014. The water level in the stream and groundwater levels are expected to fluctuate seasonally and subject to precipitation patterns, and may vary from the levels noted.

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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 and topographic plans provided by Hatch.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated a buggy ATV CME-750 hi-torque drill rig and portable tripod drill rig to carry out the drilling, sampling and in-situ testing operations for the boreholes at this site.

The drilling and sampling operations in the field were supervised on a full time basis by Ms. Eckie Siu of Thurber. Geotechnical lab testing was carried out by Thurber's MTO-approved laboratory. Overall supervision of the field program was conducted by Mr. Stephane Loranger, CET.

Ms. Deanna Pizycki, EIT, interpreted the data and prepared the report. 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.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This report presents interpretation of the geotechnical data provided in the factual report, as well as discussions and geotechnical design recommendations for the replacement of the Slate River Tributary Culvert on Highway 61 in the Township of Blake, District of Thunder Bay, Ontario.

Information on the existing culvert site was obtained from the MTO Plan E-441-61-4, titled "Crossing at Slate River Tributary and Highway 61", dated August 2014, presenting survey data collected in June 2014. The existing culvert is a concrete box with a span of 7.0 m, a height of 2.1 m, and a total length of 25.5 m. The MTO survey plan indicates the top of obvert at approximately Elev. 224.7 at both inlet and outlet, and the culvert invert at Elev. 222.6. The finish road grade at the culvert location was shown at approximate Elev. 226.7, which indicates a fill cover of approximately 2 m above the culvert.

Based on the preliminary General Arrangement drawings provided by HATCH, the existing concrete box culvert will be removed and replaced by a wider box culvert on the same alignment. The base of the replacement culvert will be at Elev. 221.7 or approximately 0.9 m below the existing culvert base. No grade raise is planned.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the current investigation. The existing subsurface information collected for the preliminary design of the culvert replacement (Geocres No. 52A-194, Appendix E) has been reviewed and incorporated in this report, where appropriate.

The interpretation and recommendations presented in this Design Report are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purpose or by any other party including the construction or design-build contractor. The contractor must make their own interpretation of the factual data presented in the Investigation Report (Part 1) as to the potential effects on equipment selection, construction methods and scheduling. Where comments are made on construction, they are provided only to highlight those aspects which could affect the design of the project

8. CULVERT DESIGN

8.1 General

In general, the subsurface stratigraphy encountered below the existing embankment fill at the culvert site consisted of a thick layer of firm to stiff silty clay that contains some organic matter in the upper 1.5 to 2.4 m. A 3.5 m thick layer of sand fill was encountered below the streambed near the culvert outlet. The water level in the Slate River was shown at Elev. 224.4 on Drawing E-441-61-4 on June 13, 2014.

The existing culvert consists of a reinforced concrete box.

8.2 Culvert Alternatives

Culvert alternatives that were considered for the culvert replacement at this site are listed below:

- Precast concrete box culvert (closed)
- Open footing concrete culvert
- Corrugated steel pipe (CSP) culvert

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is provided in Appendix F.

Given the subsurface conditions at the site, replacement of the existing box culvert with a new precast concrete box culvert is the preferred alternative from a geotechnical perspective. A CSP culvert (or multiple CSPs) could also be considered. Use of an open footing culvert is not recommended in view of the increased depth of excavation and dewatering effort required to construct spread footings, as well as the potential for differential settlement of footings constructed over silty clay and sand fill containing organic material.

Foundation recommendations for the design of the concrete box culvert and CSP culvert replacement options are presented in the sections below.

8.3 Concrete Box Culvert

Preliminary General Arrangement drawings for four box culvert alternatives indicate that the replacement box structure will comprise either a 7.2 m span single cell, a 3.6 m span twin cell, a 9.0 m span single cell, or a 4.5 m span twin cell structure. The height will be 2.7 m, and the length will be 25.0 to 27.0 m. The base of the culvert will be placed at approximate Elev. 221.7. A 600 mm thick layer of river stone will be placed within the box culvert.

Based on the borehole information, the subgrade at the level of the culvert base will consist of firm native silty clay with organics, locally loose sand fill at the outlet, underlain by stiff silty clay. The silty clay and fill subgrade is considered suitable for support of a replacement box culvert.

In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements should be provided on the approved subgrade under the base of the box culvert, as per OPSS 422 and OPSD 803.010. The bedding material should be placed in the dry as soon as practical following subgrade inspection and approval. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. Suggested wording for an NSSP in this regard is provided in Appendix G.

The factored geotechnical resistance at the Ultimate Limit State (ULS) and the geotechnical resistance at Serviceability Limit State (SLS) for a box culvert founded on bedding placed on the silty clay and sand fill at or below Elev. 221.4 as described above can be assumed as follows:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Resistance at SLS (≤ 25 mm settlement) of 130 kPa

The Factored Geotechnical Resistance at ULS and Geotechnical Resistance at SLS were estimated adopting geotechnical resistance factors of 0.5 and 0.8 for ultimate and serviceability limit states, respectively for a “typical” degree of the site understanding, as per CHBDC 2014.

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

Resistance to lateral forces / sliding resistance between precast concrete and the underlying soil should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for stiff silty clay. Sliding resistance between the concrete slabs and the underlying Granular A material should be calculated assuming an ultimate coefficient of friction of 0.5.

Preparation of the culvert subgrade should include removal of any highly organic soils or other unsuitable materials remaining after excavation to the subgrade level. In the event that subexcavation is required, the width of the subexcavation 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 subexcavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements compacted in accordance with OPSS.PROV 501. Subgrade preparation must be carried out in the dry.

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

8.4 CSP Culvert

Replacement of the box culvert with CSP culverts on the same or adjacent alignment may be considered for this site. Based on the borehole information, the subgrade at the level of the culvert base will consist of firm native silty clay with organics, locally loose sand fill at the outlet, underlain by stiff silty clay. The silty clay and fill subgrade is considered suitable for support of a CSP culvert.

If this alternative is selected, the CSP(s) should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements as per OPSD 802.014. The bedding material should be placed in the dry as soon as practical following inspection and approval.

Preparation of the culvert subgrade should include removal of any organic soils or other unsuitable materials remaining after excavation to the subgrade level. In the event that subexcavation is required, the subexcavated area should be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements compacted in accordance with OPSS.PROV 501. Subgrade preparation must be carried out in the dry. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

It is anticipated that the subgrade soils within the culvert footprint will not be subjected to additional loading due to culvert replacement. In order to accommodate the hydraulic requirements, multiple pipes may be required.

8.5 Frost Treatment

The design depth of frost penetration at this site is 2.2 m. The base of all footings, if employed, must be provided with a minimum of 2.2 m of earth cover as protection against frost action. The frost cover requirement does not apply to the base of a box culvert or CSP.

Frost treatment should be as per OPSD 803.010 for a box culvert, and as per OPSD 803.030 or 803.031 as applicable for a pipe culvert. A frost taper is not required where the excavation backfill consists of non-frost susceptible granular material similar to the existing sand embankment fill.

9. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the 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.PROV 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. 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.PROV 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:

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

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 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.

Table 9.1 - Lateral Earth Pressure Coefficients (K)

Loading Condition	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		Existing Sand Fill $\phi = 30°$; $\gamma = 20$ kN/m^3	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At-rest (Restrained Wall)	0.43	-	0.47	-	0.50	-
Passive	3.7	-	3.3	-	3.0	-

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

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. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC 2014. Active pressures should be used for any wingwalls or unrestrained walls. For rigid structures such as concrete box culverts, at-rest earth pressures should be used for design.

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 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.

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.

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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 0.035 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 (KAE) and passive (KPE) 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	Sand Fill $\phi = 30°$ $\gamma = 20$ kN/m^3
Active (K_{AE})*	0.28	0.31	0.33
Passive (K_{PE})	3.7	3.2	2.9
At Rest (K_{OE})**	0.44	0.49	0.52

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

The site is underlain by a firm to stiff silty clay and very loose to loose sand fill. In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

11. EMBANKMENT RECONSTRUCTION

The existing Highway 61 embankment is approximately 4 m in height at the culvert location. No grade raise is anticipated.

No evidence of deep-seated instability was noted, and the embankment slopes appear to be performing satisfactorily. 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 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.

Provided that the granular material is placed and compacted as specified and at the slope inclination not steeper than 2H:1V for the granular fill embankment, it is anticipated that the embankment slopes will remain stable.

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. WINGWALLS

It is understood that retained soil system (RSS) wingwalls will be constructed at the outlet and potentially the inlet to the replacement culvert. The RSS walls will have a height of 4.7 m (from top of wall cap to underside of levelling pad) and extend laterally approximately 3.0 m from the culvert wall.

Based on the borehole data, it is recommended that the RSS walls be founded on the native silty clay or sand fill at Elev. 221.5 or lower. A factored geotechnical resistance at the Ultimate Limit State (ULS) of 150 kPa and a geotechnical resistance at Serviceability Limit State (SLS) of 100 kPa is recommended for design of the RSS constructed at this level. The SLS resistance may be increased to 120 kPa by subexcavating to Elev. 219.3 and placing the RSS on a 1.5 m thick pad of Granular A compacted in accordance with OPSS.PROV 501.

The SLS value is based on an estimated foundation settlement of 30 to 40 mm under the RSS and embankment loading. The capability of the RSS wall to accommodate this magnitude of settlement must be confirmed with the RSS supplier.

The Factored Geotechnical Resistance at ULS and Geotechnical Resistance at SLS were estimated adopting geotechnical resistance factors of 0.5 and 0.8 for ultimate and serviceability limit states, respectively for a “typical” degree of the site understanding, as per CHBDC 2014.

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

Resistance to lateral forces / sliding resistance should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for stiff silty clay. Sliding resistance between the levelling pad and the underlying granular material should be calculated assuming an ultimate coefficient of friction of 0.5.

Preparation of the wall subgrade should be carried out as per the culvert subgrade. In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided on the approved subgrade prior to construction of the wing walls. The bedding material should be placed in the dry as soon as practical following subgrade inspection and approval. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

13. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet, as well as for the RSS wingwalls. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

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

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

14. EXCAVATION AND GROUNDWATER CONTROL

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

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 silty clay and sand fill at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Any surficial alluvial materials should also be classified as Type 4 soils.

The water level in the tributary was reported to be Elev. 224.4 on June 13, 2014, which is 3.0 m above the anticipated excavation level for placement of the granular bedding layer below the culvert base. Considering the high water level, the general marsh setting, and the presence of cohesionless sand fill below the streambed, it is anticipated that a dewatering system comprising stream diversion measures and cofferdam construction will be required to enable culvert installation in the dry. The use of an interlocking steel sheetpile enclosure along with sump pumping from within the enclosure is expected to be suitable.

Construction must be carried out in the dry. Dewatering during construction should be effective to maintain the water level below the final subgrade level throughout construction. Design of the dewatering system and selection of equipment and methodology for culvert installation is the responsibility of the Contractor. The Contract Documents should contain a NSSP advising the Contractor of the groundwater levels at this site that may impact foundation construction. Suggested wording for an NSSP in this regards is provided in Appendix G.

Reference should be made to OPSS 517 and OPSS 518 for dewatering requirements and control of water from dewatering.

Roadway protection will be required during construction staging to maintain traffic on Highway 61. Roadway protection should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. From a foundations viewpoint, use of vibratory equipment to install and remove roadway protection may be permitted. 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.

15. CONSTRUCTION CONCERNS

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

- The water level in the stream may fluctuate and be at a higher elevation at the time of construction than indicated in the report. Further, water levels may fluctuate during the construction period. All work should be scheduled to avoid flooding conditions.
- The thickness and depth of excessively soft streambed deposits may vary at locations away from the boreholes.
- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the cofferdam and temporary

roadway protection system. The Contractor should be prepared to remove or otherwise penetrate these obstructions.

- 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 the report were carried out by Ms. A. Piascik, P.Eng. The report was reviewed by Mr. M. 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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Associate, Senior Foundation Engineer

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Review Principal, Designated MTO Contact

THURBER

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.

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			

Ministry of Transportation
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THURBER

RECORD OF BOREHOLE No SL-1

METRIC

GWP# 6305-14-00	LOCATION Slate River Tributary Culvert N 5 348 607.7 E 343 102.2	ORIGINATED BY ES
HWY 61	BOREHOLE TYPE Hollow Stem Augers/DCPT	COMPILED BY MFA
DATUM Geodetic	DATE 2016.03.18 - 2016.03.18	CHECKED BY DJP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
226.6	GROUND SURFACE
0.0	**ASPHALT:** (125mm)
0.1	**SAND**, trace gravel to gravelly, trace to some silt, occasional cobbles Very Loose to Very Dense Brown Moist to Wet (FILL)
222.5 / 4.1	Silty **CLAY**, some sand, some organics Firm Dark Brown Moist
221.0 / 5.6	Silty **CLAY**, trace sand Stiff Grey

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	GS		
1	SS	77	21 62 17 (SI+CL)
2	SS	17	
3	SS	6	
4	SS	2	
5	SS	5	
6	SS	3	0 0 25 75
7	SS	3	
8	SS	2	

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (226, 225, 224, 223, 222, 221, 220, 219, 218, 217); 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.

Field vane readings: >100 (approx. elev. 219.5); 2.4 (approx. elev. 218.0).

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

ONTMT4S 10088.GPJ 2015TEMPLATE(MTO).GDT 7/4/16

RECORD OF BOREHOLE No SL-1

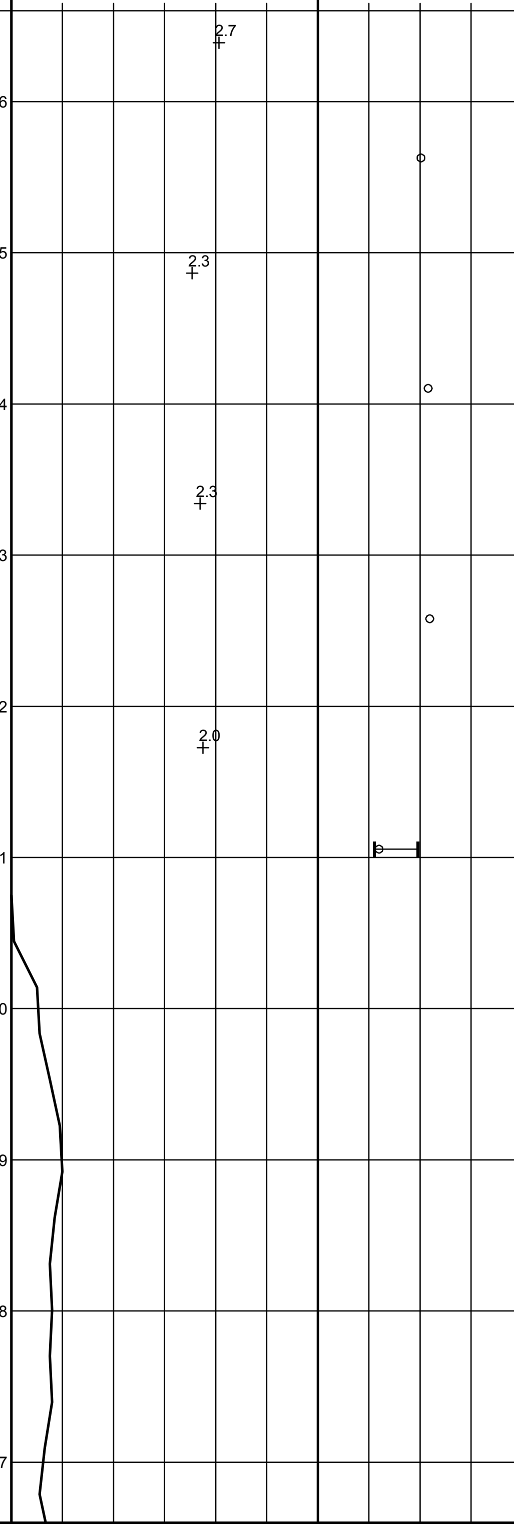
METRIC

GWP# 6305-14-00	LOCATION Slate River Tributary Culvert N 5 348 607.7 E 343 102.2		ORIGINATED BY ES
HWY 61	BOREHOLE TYPE Hollow Stem Augers/DCPT		COMPILED BY MFA
DATUM Geodetic	DATE 2016.03.18 - 2016.03.18		CHECKED BY DJP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		hatched					216	
			9	SS	3			0 0 45 55
							215	
			10	SS	3		214	
							213	
			11	SS	4			
							212	
			12	SS	6		211	0 0 50 50
210.8 / 15.8	End of sampling at 15.8m, begin DCPT						210	
							209	
							208	
							207	

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



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+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No SL-1

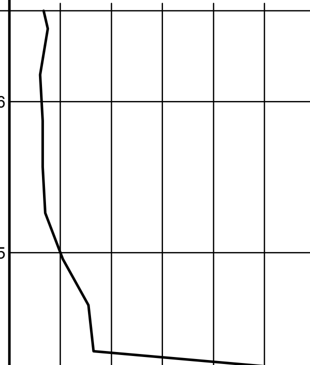
METRIC

GWP# 6305-14-00 | LOCATION Slate River Tributary Culvert N 5 348 607.7 E 343 102.2 | ORIGINATED BY ES

HWY 61 | BOREHOLE TYPE Hollow Stem Augers/DCPT | COMPILED BY MFA

DATUM Geodetic | DATE 2016.03.18 - 2016.03.18 | CHECKED BY DJP

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	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)	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 From Previous Page										
							206				
							205				
204.2 / 22.4	END OF DCPT AT 22.4m UPON CONE REFUSAL. WATER LEVEL AT 5.0m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.										



+ 3, × 3: Numbers refer to Sensitivity

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

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Ontario

THURBER

RECORD OF BOREHOLE No SL-2

METRIC

GWP# 6305-14-00 LOCATION Slate River Tributary Culvert N 5 348 594.0 E 343 085.6 ORIGINATED BY ES

HWY 61 BOREHOLE TYPE Tripod COMPILED BY MFA

DATUM Geodetic DATE 2016.03.21 - 2016.03.21 CHECKED BY DJP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
224.1	GROUND SURFACE									
0.0	**WATER**				224					
223.5 / 0.6	Silty **CLAY**, some sand, some organics (rootlets) Firm Brown Frozen (top 0.3m)	1	SS	3	223	○				
		2	SS	5		○				
		3	SS	3	222	○				
	becoming dark brown at 2.4m	4	SS	3		○	0	20	56	24
221.1 / 3.0	Silty **CLAY**, trace sand Stiff Reddish Brown	5	SS	5	221	○				
		6	SS	5	220	○				
		7	SS	8	219	├─○┤	0	0	47	53
		8	SS	6	218 / 217	○				
	becoming grey at 7.8m	9	SS	5	216	○	0	0	49	51
		10	SS	4	215	○				
214.3 / 9.8	END OF BOREHOLE AT 9.8m.									

Column headings: 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/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

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

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Ontario

THURBER

RECORD OF BOREHOLE No SL-2

METRIC

GWP# 6305-14-00	LOCATION Slate River Tributary Culvert N 5 348 594.0 E 343 085.6	ORIGINATED BY ES
HWY 61	BOREHOLE TYPE Tripod	COMPILED BY MFA
DATUM Geodetic	DATE 2016.03.21 - 2016.03.21	CHECKED BY DJP

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/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	*					
	Continued From Previous Page										
	WATER LEVEL AT SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.										

+ 3 , × 3 : Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No SL-3

METRIC

GWP#	6305-14-00	LOCATION	Slate River Tributary Culvert N 5 348 610.6 E 343 112.0	ORIGINATED BY	ES
HWY	61	BOREHOLE TYPE	Tripod	COMPILED BY	MFA
DATUM	Geodetic	DATE	2016.03.22 - 2016.03.22	CHECKED BY	DJP

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT	GR	SA	SI	CL
224.1	GROUND SURFACE									
0.0 / 223.5	**WATER**				224					
0.6	**SAND**, trace gravel to gravelly, some silt, with organics (rootlets, wood, peat) Very Loose to Loose Dark Grey Wet (FILL)	1	SS	1		○				
					223					
		2	SS	3		○				
		3	SS	4	222	○				
		4	SS	8		○	12	69	15	4
	probable cobble	5	SS	50/0.125	221	○				
		1	GS			○				
220.0					220					
4.1	Silty **CLAY**, trace sand Stiff Reddish Brown	2	GS			○				
		6	SS	5		├○┤	0	0	48	52
					219					
	becoming brown at 6.1m				218					
		7	SS	5		○				
					217					
		8	SS	4		├○┤	0	0	50	50
					216					
					215					
		9	SS	5		○				
214.3 / 9.8	END OF BOREHOLE AT 9.8m.									

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); 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/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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+ ³, × ³: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No SL-3

METRIC

GWP#	6305-14-00	LOCATION	Slate River Tributary Culvert N 5 348 610.6 E 343 112.0	ORIGINATED BY	ES
HWY	61	BOREHOLE TYPE	Tripod	COMPILED BY	MFA
DATUM	Geodetic	DATE	2016.03.22 - 2016.03.22	CHECKED BY	DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O 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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	*					
	Continued From Previous Page										
	WATER LEVEL AT SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

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

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Appendix B

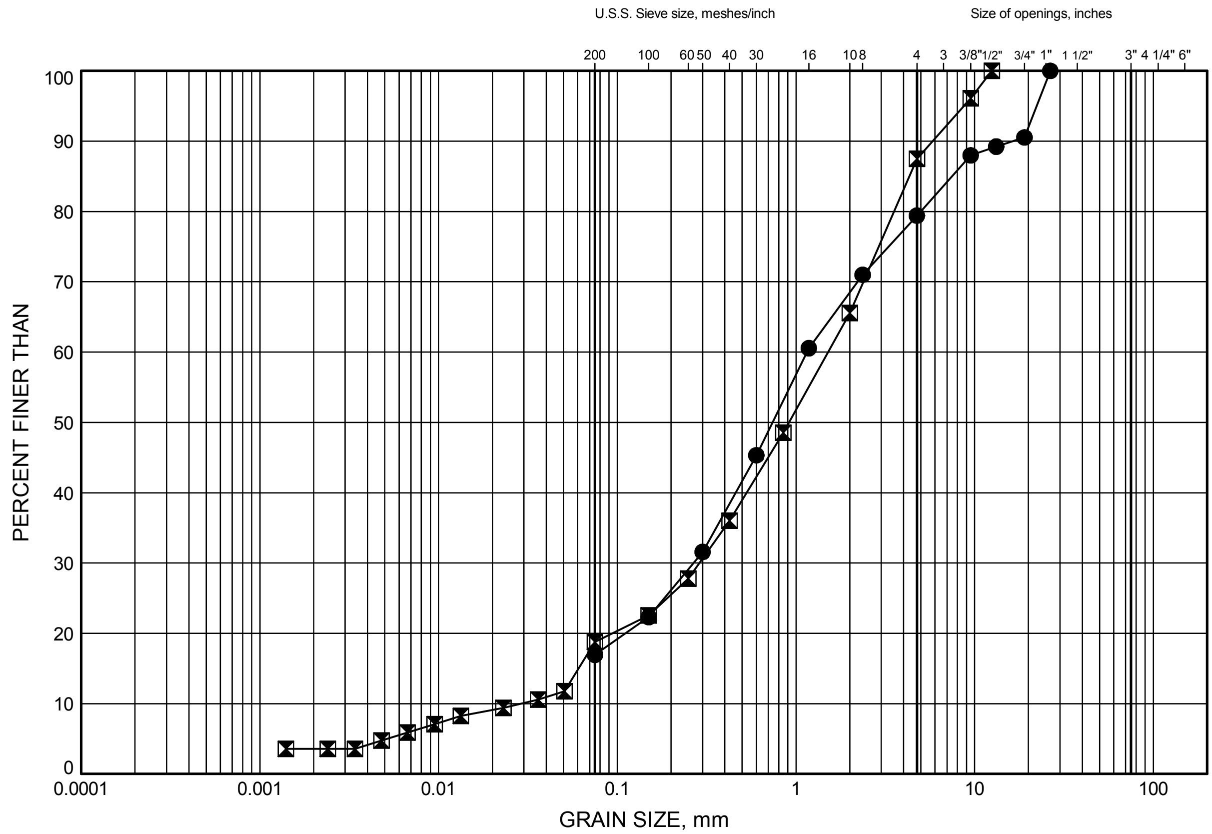
Laboratory Test Results

Slate River Tributary Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B1

Sand FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-1	1.07	225.53
⧗	SL-3	2.74	221.36

Date July 2016

GWP# 6305-14-00

THURBER

Prep'd MFA

Chkd. DJP

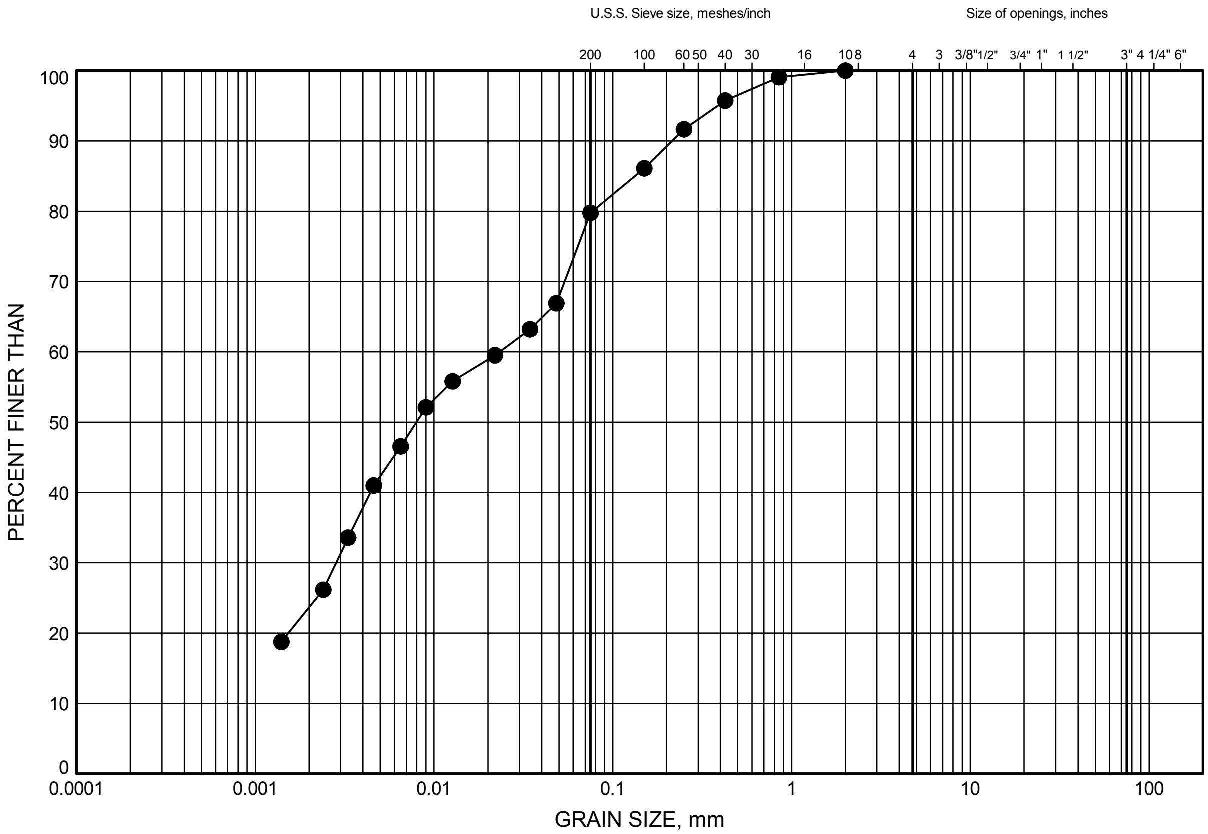
GRAIN SIZE DISTRIBUTION - THURBER 10088.GPJ 7/4/16

Slate River Tributary Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

Upper Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-2	2.74	221.36

Date July 2016

GWP# 6305-14-00

THURBER

Prep'd MFA

Chkd. DJP

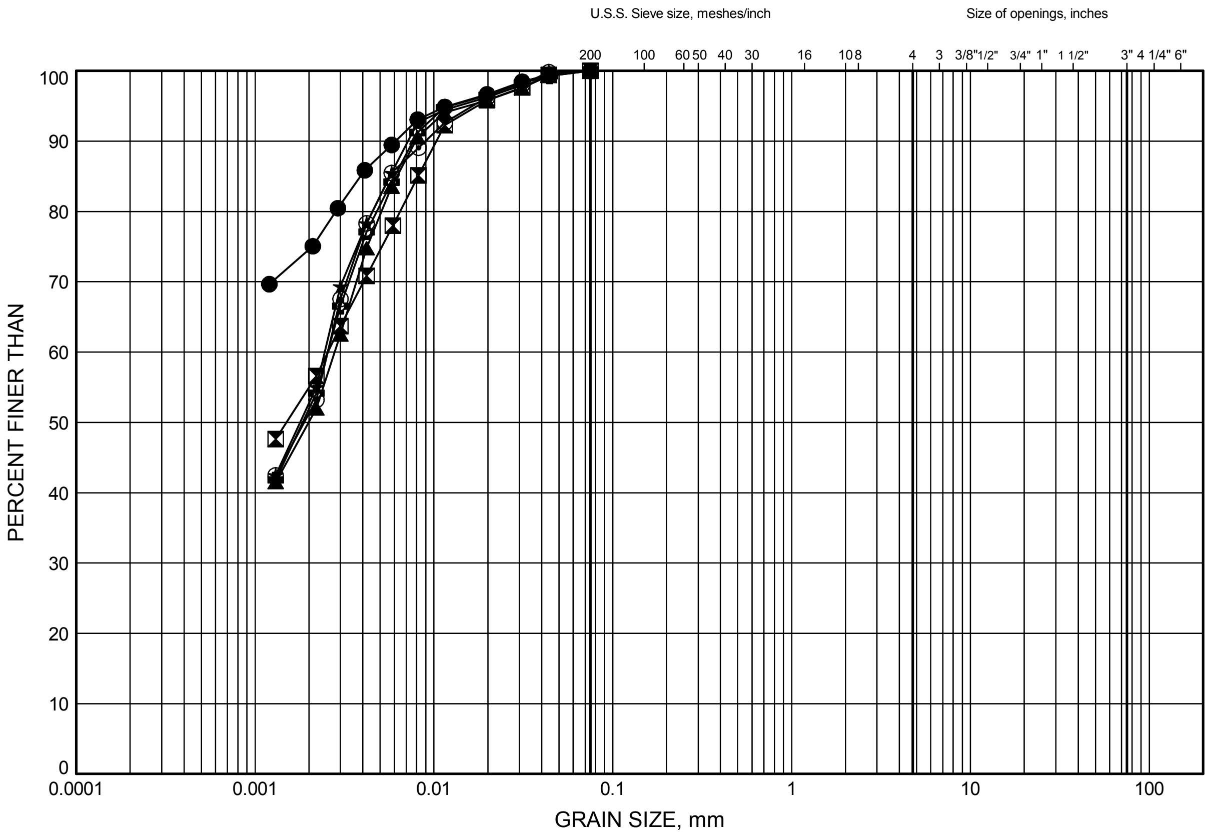
GRAIN SIZE DISTRIBUTION - THURBER 10088.GPJ 7/4/16

Slate River Tributary Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B3

Lower Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-1	6.40	220.20
⧗	SL-1	10.97	215.63
▲	SL-1	15.54	211.06
★	SL-2	4.88	219.22
⊙	SL-2	7.92	216.18
✪	SL-3	4.88	219.22

Date July 2016

GWP# 6305-14-00

THURBER

Prep'd MFA

Chkd. DJP

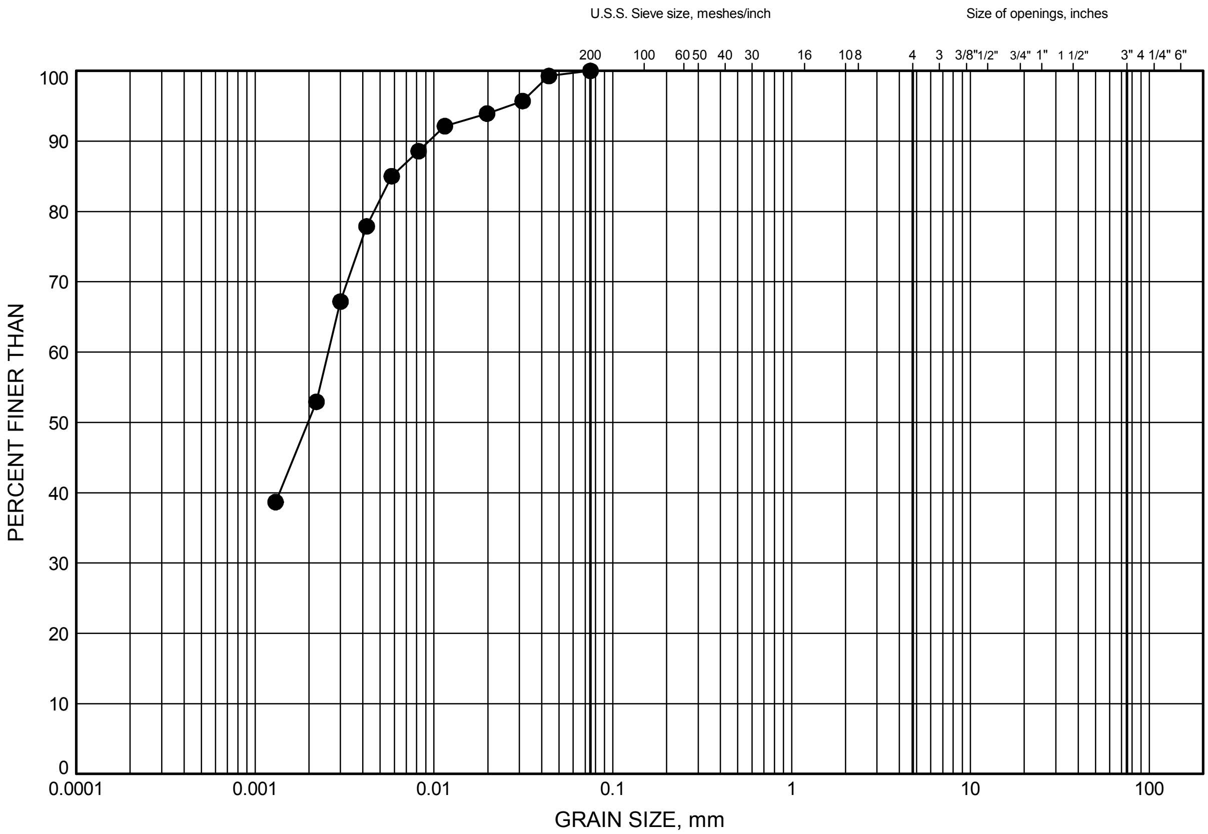
GRAIN SIZE DISTRIBUTION - THURBER 10088.GPJ 7/4/16

Slate River Tributary Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B4

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-3	7.92	216.18

Date July 2016

GWP# 6305-14-00

THURBER

Prep'd MFA

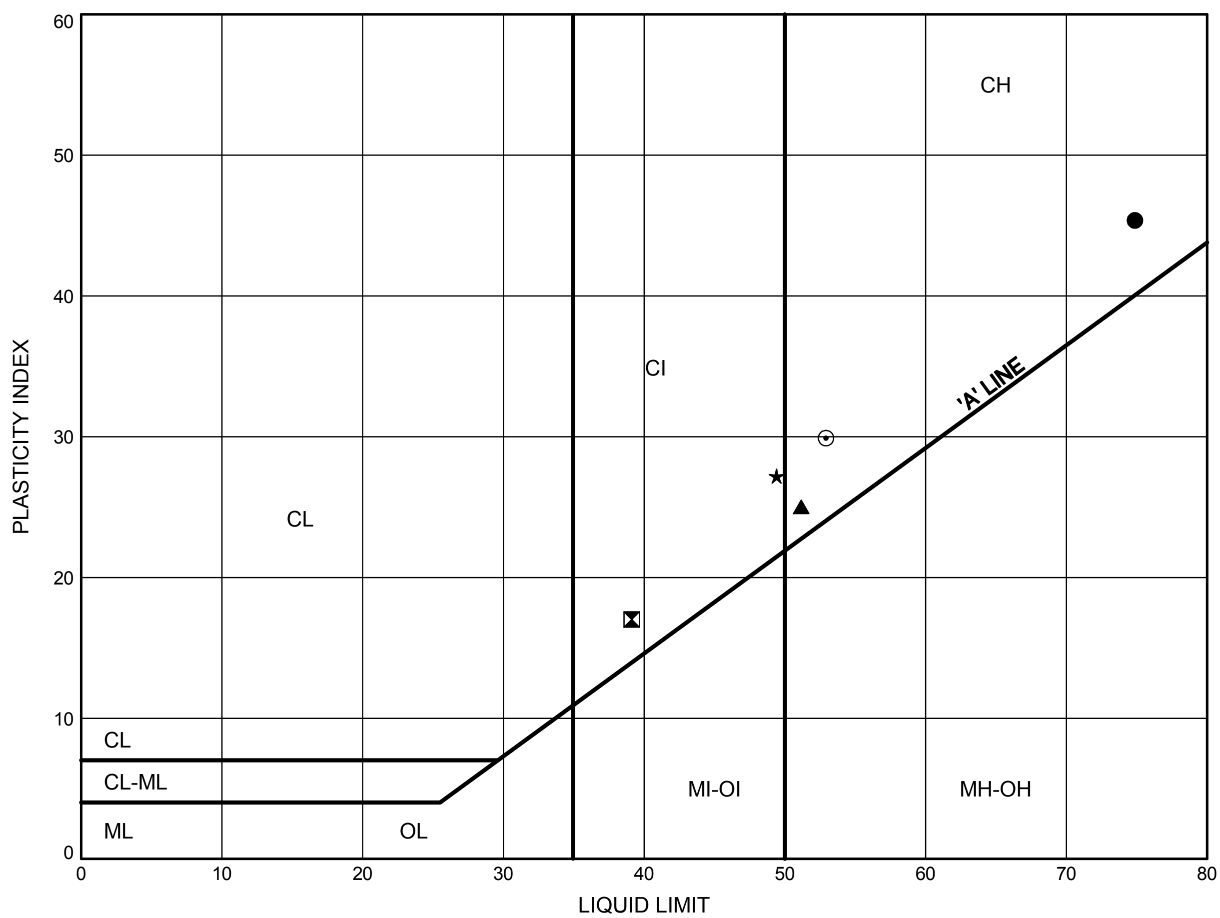
Chkd. DJP

Slate River Tributary Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-1	6.40	220.20
⧗	SL-1	15.54	211.06
▲	SL-2	4.88	219.22
★	SL-3	4.88	219.22
⊙	SL-3	7.92	216.18

THURBALT 10088.GPJ 7/4/16

Date July 2016

GWP# 6305-14-00

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Prep'd MFA

Chkd. DJP

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Appendix C

Selected Site Photographs

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Photograph 1: Drilling Borehole SL-1, Looking South

Photograph 2: Culvert Inlet, Looking Northwest

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Photograph 3: Culvert Outlet, Looking Southeast

Photograph 4: Looking Northeast from Culvert

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Appendix D

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

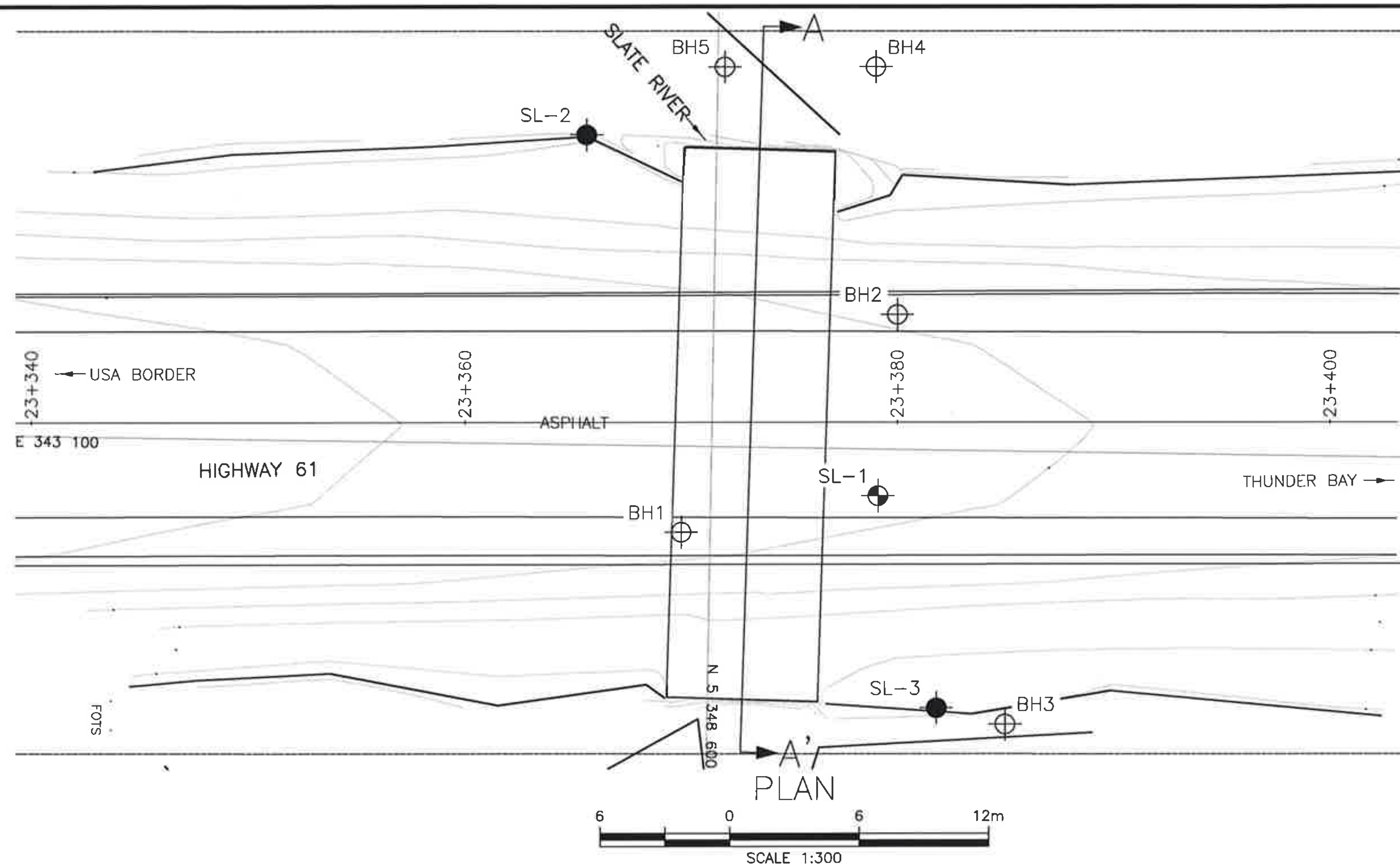
CONT No 2016–6249
GWP No 6304–14–00

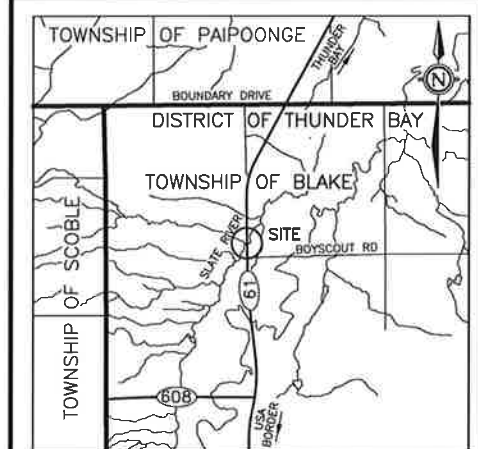
HIGHWAY 61
SLATE RIVER
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 17

HATCH

THURBER ENGINEERING LTD.



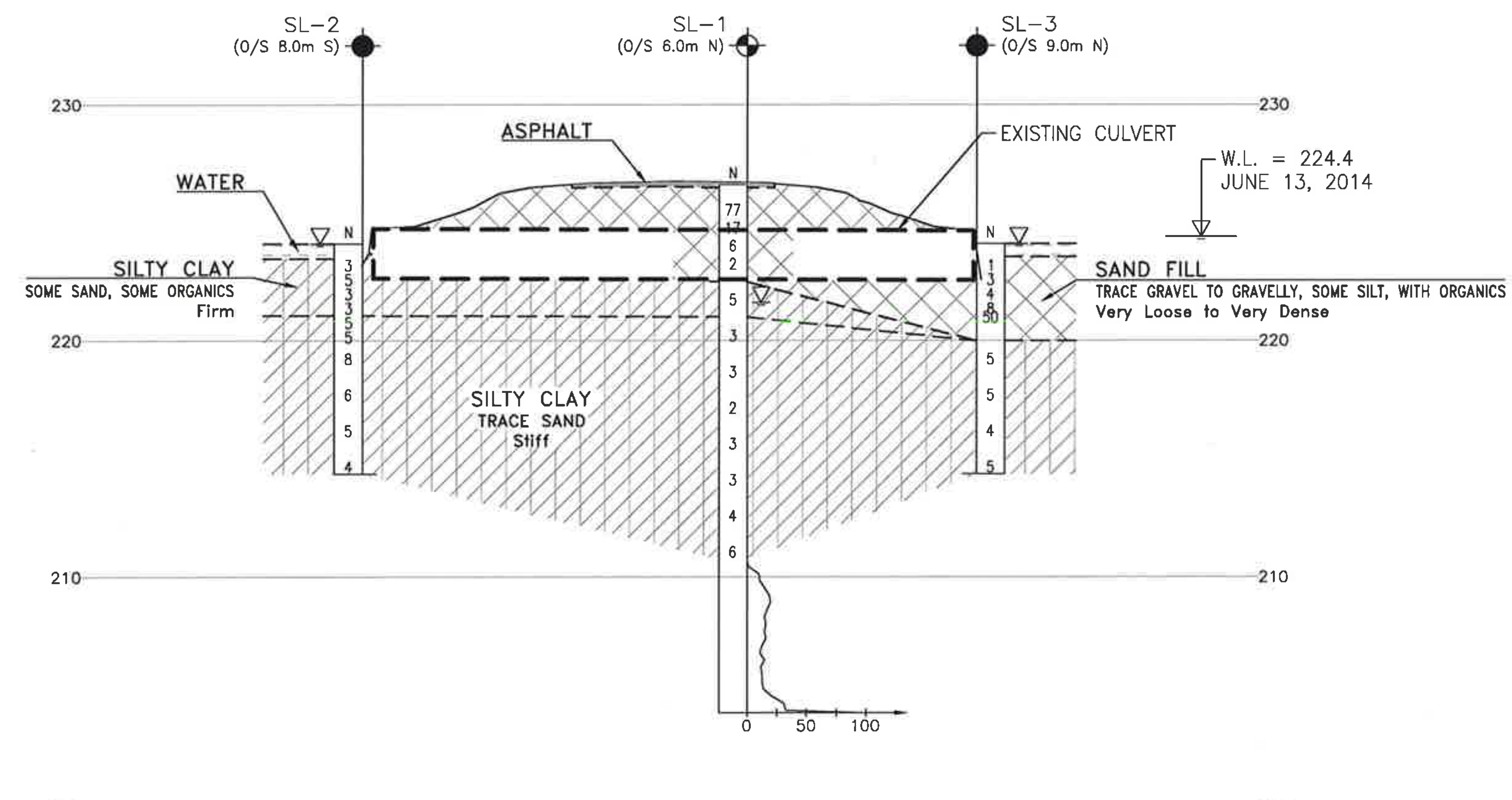


KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
⊕	Borehole by Others
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
BH1	226.6	5 348 598.7	343 104.0
BH2	226.3	5 348 608.5	343 093.7
BH3	223.8	5 348 613.8	343 112.7
BH4	223.9	5 348 607.3	343 082.3
BH5	223.9	5 348 600.3	343 082.4
SL–1	226.6	5 348 607.7	343 102.2
SL–2	224.1	5 348 594.0	343 085.6
SL–3	224.1	5 348 610.6	343 112.0



SECTION ALONG ℄ CULVERT A–A'

SCALE 1:300

-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. 52A-222

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN DJP	CHK AMP	CODE	LOAD	DATE OCT 2016	
DRAWN MFA	CHK DJP	SITE	STRUCT	DWG 2	

FILENAME: H:\Drafting\10000\10068\TED-10068-PLPR-SL.dwg
PLOTDATE: 10/25/2016 1:24 PM

THURBER

Appendix E

Borehole Data from Preliminary Foundation Report
Geocres No. 52A-194

RECORD OF BOREHOLE No BH1

1 OF 1 **METRIC**

W.P. 6013-E-0021	LOCATION Slate River Tributary Culvert STA 23+370 RT 5.1 m		ORIGINATED BY PR
DIST Thunder Bay HWY 61	BOREHOLE TYPE Hollow Stem Auger 80 mm		COMPILED BY DB
DATUM Local	DATE 2014 08 27		CHECKED BY DM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION	STRAT PLOT
101.4	GROUND SURFACE	
101.4 / 0.1	ASPHALT	
101.2 / 0.3	FILL-SAND & CRUSHED GRAVEL-Trace silt	
	FILL-SAND-some gravel, trace silt, BROWN□L□□S□ t□C□M□AC□	
96.8 / 4.6	CLAY-Silty, GREY□S□□□	
90.6 / 10.8	END OF BOREHOLE	

SAMPLES

NUMBER	TYPE	"N" VALUES
AS1	AS	
SS2	SS	5
SS3	SS	10
SS4	SS	2
SS5	SS	5
SS6	SS	7
SS7	SS	4
SS8	SS	4
SS9	SS	1
SS10	SS	3

GROUND WATER CONDITIONS: ∇ (at approx. elev. 99.2)

ELEVATION SCALE: 101, 100, 99, 98, 97, 96, 95, 94, 93, 92, 91

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

Field vane results: +6 (approx. elev. 95.8), + (approx. elev. 94.7), +6 (approx. elev. 92.8), +6 (approx. elev. 90.9)

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
18	68	(14)	

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

RECORD OF BOREHOLE No BH2

METRIC

W.P. 6013-E-0021	LOCATION Slate River Tributary Culvert STA 23+380 LT 5.0 m		ORIGINATED BY PR
DIST Thunder Bay HWY 61	BOREHOLE TYPE Hollow Stem Auger 80 mm		COMPILED BY DB
DATUM Local	DATE 2014 08 27		CHECKED BY DM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
101.1	GROUND SURFACE
101.1 / 0.1	ASPHALT
100.8 / 0.3	FILL-SAND & CRUSHED GRAVEL-Trace silt
	FILL-SAND-some gravel, trace silt, BROWN□L□□S□ □□ C□M□AC□
95.8 / 5.3	CLAY-Silty, GREY□S□□□
90.3 / 10.8	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES
AS1	AS	
SS2	SS	21
SS3	SS	8
SS4	SS	4
SS5	SS	5
SS6	SS	8
SS7	SS	7
SS8	SS	4
SS9	SS	5
SS10	SS	4
SS11	SS	2

GROUND WATER CONDITIONS: ∇ (water level at approx. elevation 99)

ELEVATION SCALE: 101, 100, 99, 98, 97, 96, 95, 94, 93, 92, 91

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

Field vane sensitivity values: 5, 10, 6.5, 7.2

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
30	55	(15)	

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-019500 SLATE RIVER.GPJ DST_MIN.GDT 11/24/14

ENCLOSURE 2

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH3

METRIC

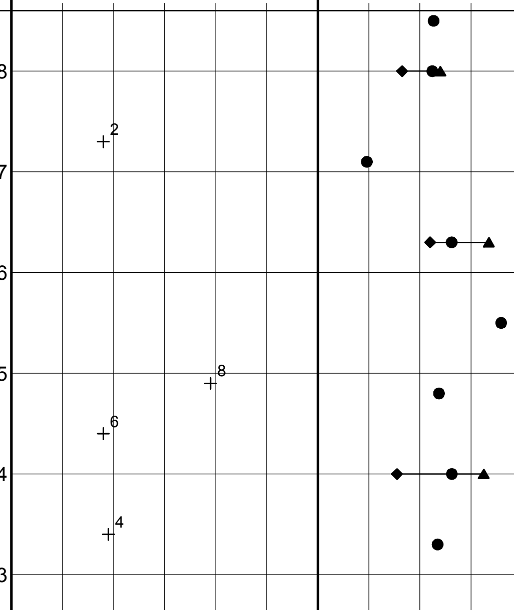
W.P. 6013-E-0021	LOCATION Slate River Tributary Culvert STA 23+385 RT 14.0 m		ORIGINATED BY PR
DIST Thunder Bay HWY 61	BOREHOLE TYPE Hollow Stem Auger 80 mm		COMPILED BY DB
DATUM Local	DATE 2014 09 05		CHECKED BY DM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
98.6	GROUND SURFACE					
98.5 / 0.1	TOPSOIL					
	SAND-organics, BLACK□□□□Y L□□S□	SS1	SS	1		
98.0 / 0.6	SILT-sandy, some clay, Very Loose	SS2	SS	3	98	0 51 31 □8
		SS3	SS	1	97	
96.3 / 2.3	CLAY-Silty, GREY/REDISH□□□□M □□ S□□□	SS4	SS	3	96	
	-Trace Organics	SS5	SS	2	95	
		SS6	SS	8	94	
		SS7	SS	3		
		SS8	SS	3	93	
92.6 / 6.0	END OF BOREHOLE					

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



NR = NO RECOVERY

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

ENCLOSURE 3

RECORD OF BOREHOLE No BH4

METRIC

W.P. 6013-E-0021	LOCATION Slate River Tributary Culvert STA 23+379 LT 16.5 m	ORIGINATED BY PR
DIST Thunder Bay HWY 61	BOREHOLE TYPE Hand Auger Hole	COMPILED BY DB
DATUM Local	DATE 2014 09 05	CHECKED BY DM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (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
98.7	GROUND SURFACE										
	WATER and ORGANICS						98				
97.2 / 1.5	SAND-some gravel						97				
96.9 / 1.8	CLAY-silty						96, 95				
94.7 / 4.0	END OF BOREHOLE										

SHEAR STRENGTH legend: ○ UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE

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

ON_MOT-HIGH VANES GS-TB-019500 SLATE RIVER.GPJ DST_MIN.GDT 11/24/14

ENCLOSURE 4

RECORD OF BOREHOLE No BH5

METRIC

W.P. 6013-E-0021 | LOCATION Slate River Tributary Culvert STA 23+372 LT 16.5 m | ORIGINATED BY PR

DIST Thunder Bay HWY 61 | BOREHOLE TYPE Hand Auger Hole | COMPILED BY DB

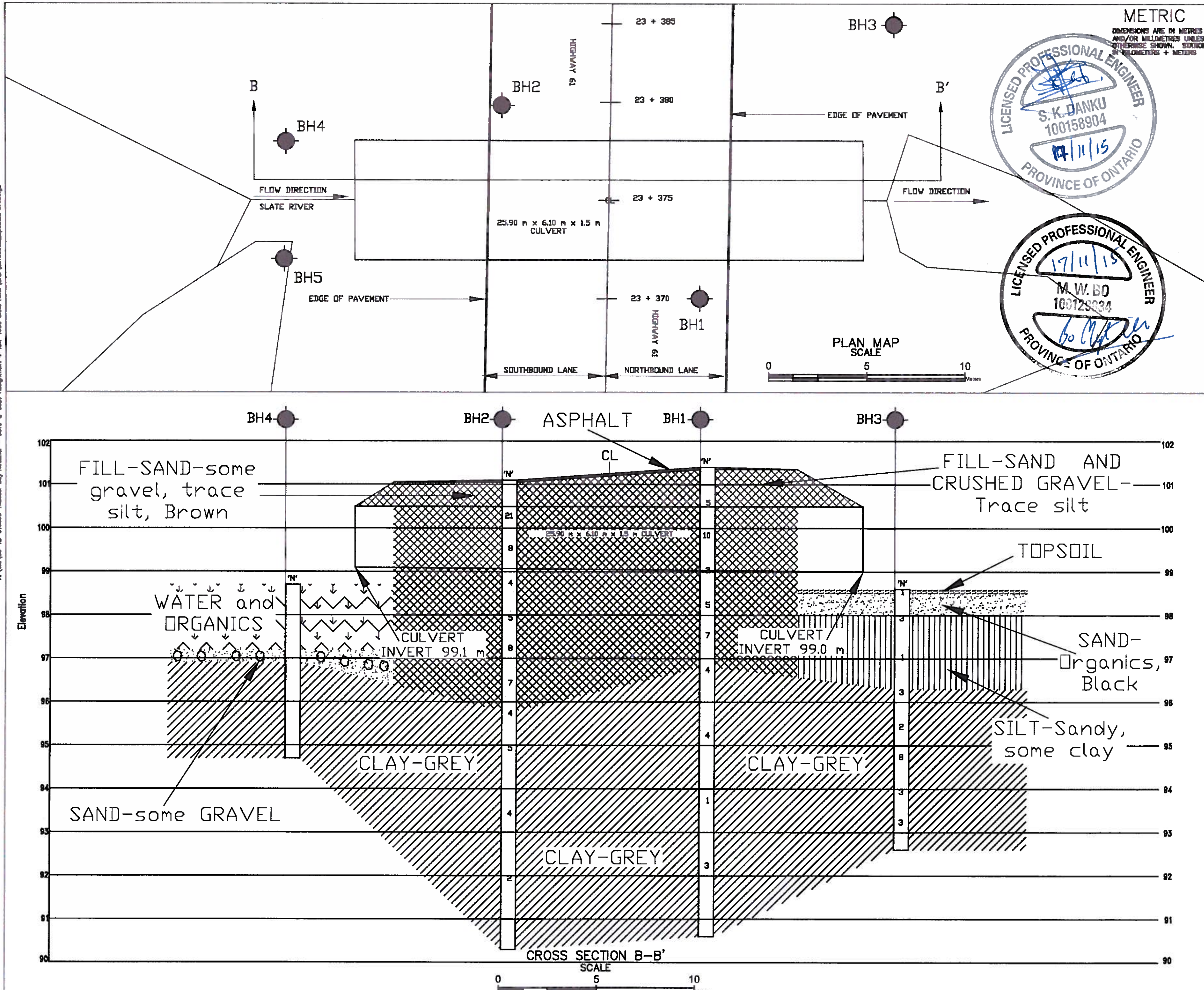
DATUM Local | DATE 2014 09 05 | CHECKED BY DM

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	TYPE	"N" VALUES	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
98.7	GROUND SURFACE										
	WATER and ORGANICS						98				
97.6 / 1.1	SAND-some gravel										
97.3 / 1.4	CLAY-silty						97				
							96				
95.1 / 3.6	END OF BOREHOLE										

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

○ 3% STRAIN AT FAILURE

ON_MOT-HIGH VANES GS-TB-019500 SLATE RIVER.GPJ DST_MIN.GDT 11/24/14

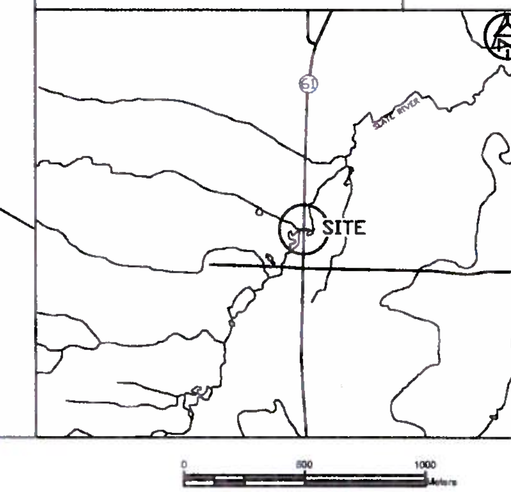


CONT	No
WP	No 6305-14-00
SITE	No 48W-195/C
GEOCRES	No 52A-194

CULVERT REPLACEMENT
SLATE RIVER CULVERT
STA 23+370 TO STA 23+385

Survey________ Revised________

SHEET



KEY MAP

LEGEND

- Borehole
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)

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

No.	Elevation	Northing	Easting	Station	Offset
BH1	101.4	5349847 m N	315704 m E	23+370	5.1 m RT
BH2	101.2	5349880 m N	315694 m E	23+380	5.0 m LT
BH3	98.6	5349862 m N	315714 m E	23+385	14.0 m RT
BH4	98.7	5349853 m N	315683 m E	23+379	16.5 m LT
BH5	-	-	-	23+372	16.5 m LT

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.

DST consulting engineers
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605 Hewitson Street
Thunder Bay, ON P7B 5V5
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Email: thunderbay@dstgroup.com

DRAWING 2

Appendix F

Comparison of Foundation Alternatives

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COMPARISON OF CULVERT TYPE / FOUNDATION ALTERNATIVES

Concrete Box Culvert	Corrugated Steel Pipe Culvert	Concrete Open Footing Culvert
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. Can tolerate some differential settlement. v. Less costly than an open footing culvert.	Advantages: i. Ease of construction. ii. Can tolerate some differential settlement. iii. Typically least costly option.	Advantages: i. Bedding material not required. ii. Potentially less disturbance of creek channel.
Disadvantages: i. Likely more costly than a CSP. ii. Excavation to place bedding material will extend below water level. iii. Potential environmental impact on fisheries.	Disadvantages: i. Steel pipes may have a shorter design life than concrete culverts. ii. Potential environmental impact on fisheries iii. Multiple pipes may be needed to meet hydraulic requirements.	Disadvantages: i. Requires deeper excavation for footing construction. ii. Potentially more difficult dewatering requirements. iii. Possible inadequate geotechnical resistance available in native soils, and requirements for large size of footing.
RECOMMENDED	**FEASIBLE**	**NOT RECOMMENDED**

Appendix G

List of Standard Specifications and Suggested Wording for NSSPs

THURBER

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

- OPSS.PROV 206
- OPSS 422
- OPSS.PROV 501
- OPSS 517
- OPSS 518
- OPSS.PROV 539
- OPSS.PROV 804
- OPSS 902
- OPSS.PROV 1010
- OPSS.PROV 1205
- OPSD 802.014
- OPSD 803.010
- OPSD 803.030
- OPSD 803.031

2. Suggested Wording for NSSP on Protection of Prepared Subgrade

Construction equipment shall not be allowed to travel on the bedding material or prepared culvert subgrade, which should be protected from disturbance during construction.

3. Suggested Wording for NSSP on Dewatering

Dewatering and stream diversion measures shall be provided by the Contractor during structure excavation and backfilling to allow the work to proceed in the dry. It is noted that the water level in the creek may fluctuate. Further, concentrated seepage should be expected from cohesionless fill and creek channel deposits at the base of the existing embankment fill.

Up to 1.5 m of peat/organics has been noted in boreholes drilled in the swamp conditions present near the culvert inlet. Installation of the culvert will require removal of the organic soils. Dewatering during construction must be effective in lowering the water level to a minimum 0.5 m below the base of the sub-excavation to facilitate removal of the peat/organics and placement of backfill.

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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.