



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION REPORT  
SHAMROCK LAKE CENTRE CULVERT REPLACEMENT  
HIGHWAY 11  
THUNDER BAY DISTRICT, ONTARIO**

**G.W.P. No. 6910-12-00, W.P. No. 6910-12-00, SITE No. 48C-338/C**

**GEOCRES Number: 52H-39**

**Report**

**to**

**HATCH**

Date: August 25, 2016  
File: 13639



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**GEOCRES NUMBER: 52H-39**

## **1. INTRODUCTION**

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Shamrock Lake Centre Culvert on Highway 11, located north of Nipigon, Thunder Bay District, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert location and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by Hatch to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-001.

A previous foundation investigation carried out at this site was documented in the report titled "Foundation Investigation Report, Shamrock Lake Culvert Centre, Highway 11, Unsurveyed Territory, Thunder Bay District", prepared by DST Consulting Engineers Inc. (DST), dated March 17, 2015; Geocres No. 52H-25. Reference should be made to the DST report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile, record of borehole sheets and laboratory test results. It should be noted that DST is solely responsible for the subsurface information provided in the Foundation Investigation Report. The Record of Borehole sheets from the DST report have been enclosed in Appendix C of this report for reference, and the subsurface information presented in the DST report was incorporated in the current report, as appropriate.

## **2. SITE DESCRIPTION**

The site is located on Highway 11, approximately 31.5 km north of Highway 11/17, in unsurveyed territory north of Nipigon, Thunder Bay District, Ontario. The culvert allows an unnamed creek to



flow from southeast to northwest under Highway 11 to Shamrock Lake. Highway 11 generally runs in a southwest-northeast direction at the culvert site.

The Terms of Reference indicates that the existing structure is a 76 m long, 4.9 m span by 2.0 m high, concrete rigid frame, open footing culvert, with a height of fill of 16 m. An Ontario Structure Inspection Manual (OSIM) report prepared in 2014 notes severe spalled concrete, exposed rebar, 19 vertical cracks on the culvert walls, large areas of delamination, and that the structure was considered to be in overall poor condition.

The grade level of Highway 11 at the existing culvert is at an approximate Elevation of 293 m.

Naturally low-lying areas are present near the inlet and outlet of the culvert, with vegetation consisting of grass, shrubs and frequent trees. The general area along Highway 11 is bounded by a bedrock plain on the southeast side at elevations greater than 400 m, and an outwash plain with lakes and swampy lowlands on the northeast side with an approximate Elevation of 274 m at Shamrock Lake.

Photographs in Appendix E show the general nature of the site and the existing culvert.

Based on published geological information, the culvert lies within an area of glaciofluvial outwash deposits of sand and gravel, and is bounded by bedrock plains to the northwest and southeast, and talus (rubble) immediately adjacent to the southeast side of the highway. The bedrock at the site consists of undifferentiated metasedimentary rocks, with igneous and metamorphic rock at the bedrock plains in the area.

### **3. INVESTIGATION PROCEDURES**

The borehole investigation and field testing program for this project was carried out from June 8 to 9, 2016, and consisted of drilling and sampling two (2) boreholes, designated as Boreholes 16-03 and 16-04. Borehole 16-03 was located near the culvert inlet and Borehole 16-04 was located near the culvert outlet. Both boreholes were advanced near the base of the highway embankment.

Utility clearances were obtained prior to the start of drilling. The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 14 was used for the boreholes. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.



A portable tripod drill rig was used to advance Borehole 16-03 using NW casing and wash boring techniques, and a track-mounted CME 45 drill rig was used to advance Borehole 16-04 using hollow stem augers. The boreholes were advanced to depths of 8.5 m and 12.8 m respectively. Borehole 16-03 was extended beyond 8.5 m depth by conducting a Dynamic Cone Penetration Test (DCPT) to a depth of 11.0 m. In both boreholes, soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT).

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

Groundwater conditions were observed in the open boreholes throughout the drilling operations and in a temporary standpipe piezometer installed in Borehole 16-04. The standpipe piezometer consisted of a 19 mm diameter PVC pipe, with a slotted screen. The boreholes were backfilled on completion of drilling and the temporary standpipe piezometer was decommissioned in general accordance with Ontario Regulation 903 at the end of the field investigation.

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

**Table 3.1 – Borehole Completion Details**

<b>Borehole Number</b>	<b>Borehole Depth / Base Elevation (m)</b>	<b>Piezometer Tip Depth / Elevation (m)</b>	<b>Completion Details</b>
16-03	8.5 / 266.5	None installed	Bentonite holeplug from 8.5 m to ground surface.
16-04	12.8 / 262.7	12.2 / 263.3	Filter sand to 10.4 m, bentonite holeplug to 9.4 m, bentonite holeplug and cuttings to ground surface.

The previous investigation by DST included four (4) boreholes, numbered BH1 to BH4, which were each drilled through the existing highway embankment to depths of 25.0 m each. The borehole locations were referenced to the MTO station numbering system, and the ground surface elevations were established relative to a temporary local benchmark. Based on topographic information provided by Hatch, the ground surface elevations at the borehole locations have been referenced to Geodetic Datum as shown in Table 3.2. The approximate locations of the DST boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.



**Table 3.2 – DST Borehole Elevations**

Borehole Number	Ground Surface Elevation	
	Assumed Local Datum (m)	Geodetic Datum (m)
BH1	99.9	292.5
BH2	100.0	292.6
BH3	99.8	292.4
BH4	99.9	292.5

#### **4. LABORATORY TESTING**

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

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing native soil, and a sample of the surface water from the creek upstream of the existing culvert were collected. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

#### **5. DESCRIPTION OF SUBSURFACE CONDITIONS**

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

In general, the subsurface conditions encountered in the boreholes from the current and previous investigations consisted of asphalt pavement overlying granular fill and embankment fill, which was in turn underlain by native soil consisting of sand and silty sand. Topsoil and peat were also



noted at the locations where there was no fill. Descriptions of the individual strata are presented below.

### 5.1 Asphalt

Boreholes BH1 and BH2 were drilled through the existing asphalt shoulder on Highway 11. The asphalt thickness measured in the boreholes ranged from 85 to 100 mm.

### 5.2 Fill

Underlying the asphalt in Boreholes BH1 and BH2, and at the ground surface of Boreholes BH3 and BH4, which were drilled through the highway shoulders, a 0.1 to 0.4 m thick layer of granular fill consisting of sand and crushed gravel was encountered.

A sand embankment fill containing trace to some gravel, trace to some silt, and trace cobbles was encountered below the granular fill in Boreholes BH1 to BH4. The sand fill ranged in thickness from 19.4 to 19.6 m, and extended to depths ranging from 19.8 to 19.9 m (Elev. 272.6 to 272.8 m). SPT 'N' values within the sand fill ranged from 4 to 33 blows per 0.3 m penetration, indicating a loose to dense relative density.

The measured moisture content of the fill generally ranged from 4% to 28%, with the exception of one sample in BH1, where the presence of organic material in the fill resulted in a moisture content of 41%. The results of grain size analyses conducted on samples of the fill are presented on the DST Record of Borehole sheets included in Appendix C, and are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0 to 25
Sand	39 to 95
Silt and Clay	4 to 61

### 5.3 Topsoil and Peat

A 150 mm thick layer of sandy topsoil with rootlets and wood fibres was encountered at the ground surface in Borehole 16-04.

A 0.6 m thick layer of peat with rootlets and wood fibres was encountered at the ground surface in Borehole 16-03. The base of the peat layer was at Elev. 274.4 m. An SPT 'N' value of 4 blows



per 0.3 m penetration was recorded in the peat, indicating a soft state. A moisture content of 55% was measured in the peat.

The topsoil and peat thickness may vary in other areas of the site and this limited data should not be relied upon for estimating stripping quantities.

#### **5.4 Sand**

A native deposit of sand was encountered below the embankment fill, topsoil and peat layers in all of the boreholes at the site. Boreholes 16-04 and BH1 to BH4 were terminated in the sand at depths ranging from 12.8 to 25.0 m (Elev. 262.7 to 267.6 m). The thickness of the sand was 6.6 m in Borehole 16-03, with the base of the sand at a depth of 7.2 m (Elev. 267.8 m). The sand was brown to grey in colour and contained trace to some gravel and trace to some silt. Occasional wood fragments of 0.1 to 0.3 m in thickness were also encountered within the sand in Borehole 16-04, indicating the possible presence of alluvium. A silty sand layer was also encountered within the sand deposit in Borehole 16-04, as described in Section 5.5.

SPT 'N' values within the sand ranged from 4 to 33 blows per 0.3 m penetration, indicating a loose to dense relative density. The measured moisture content of the sand generally ranged from 8% to 30%, with the exception of zones where wood fragments were encountered. The moisture content in these zones ranged from 88% to 252%. The results of grain size distribution analyses conducted on selected samples of the sand are presented on the Record of Borehole sheets included in Appendices A and C and are summarized in the following table. The results from the Thurber boreholes are presented on Figure B1 in Appendix B.

<b>Soil Particle</b>	<b>Percentage (%)</b>
Gravel	0 to 17
Sand	75 to 97
Silt and Clay	1 to 18

#### **5.5 Silty Sand**

A 3.7 m thick silty sand layer containing trace clay was encountered within the sand deposit in Borehole 16-04. The base of the silty sand layer was encountered at a depth of 7.8 m (Elev. 267.7 m). Borehole 16-03 was terminated at 8.5 m depth (Elev. 266.5 m) in a silty sand layer underlying the sand deposit. A Dynamic Cone Penetration Test was conducted at the base of Borehole 16-03, where cone refusal of greater than 100 blows per 0.3 m penetration was encountered at a depth of 11.0 m (Elev. 264.0 m).





SPT 'N' values within the silty sand ranged from 13 to 29 blows per 0.3 m of penetration, indicating a compact relative density. Measured moisture contents within the silty sand deposit ranged between 19% and 41%.

The results of grain size distribution analyses conducted on selected samples of the silty sand are presented on the Record of Borehole sheets included in Appendix A and on Figure B2 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	63 to 74
Silt	23 to 34
Clay	3

## 5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes and temporary standpipe piezometer upon completion of drilling. The groundwater levels measured in the open boreholes and in the piezometer are summarized in Table 5.1 below. Groundwater levels reported in the DST report are also included.

**Table 5.1 – Groundwater Measurements**

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-03	June 9, 2016	0.5	274.5	Open borehole
16-04	June 9, 2016	1.5	274.0	Standpipe piezometer
	June 10, 2016	1.5	274.0	
	June 11, 2016	1.5	274.0	
	June 12, 2016	1.5	274.0	
BH1	October 20, 2014	19.8	272.7	Reported by DST
BH2	October 20, 2014	18.3	274.3	Reported by DST
BH3	October 20, 2014	18.3	274.2	Reported by DST
BH4	October 20, 2014	19.8	272.8	Reported by DST

A water level measurement near the outlet of the creek was reported on the drawings provided by Hatch, which indicate a creek level at Elevation 274.35 m on May 8, 2013. The groundwater level should be assumed to reflect the local creek water level. The groundwater levels above are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In



particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

## 6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native sand from Borehole 16-04, and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Units (Water)	Test Results	
			16-04, SS#2, 2.5'-4.5'	Shamrock Lake Centre
			(Sand)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	10	0.39
Sulphate	µg/g	mg/L	2.0	1.6
pH	No unit	No unit	7.33 – 8.09	7.36
Electrical Conductivity	µS/cm	µS/cm	87	47
Resistivity	Ohms.cm	MOhms.cm	11500	21400
Redox Potential	mV	mV	273	197

## 7. MISCELLANEOUS

Thurber obtained subsurface 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.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. George Azzopardi of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical laboratory testing was carried out by SGS Canada Inc. Interpretation of the field data and



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

Thurber Engineering Ltd.



Mark Farrant, P.Eng.

Project Manager, Geotechnical Engineer



P.K. Chatterji, P.Eng.

Review Principal, Designated MTO Contact

Client: Hatch

File No.: 13639

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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 <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

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



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

### 5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level  
 Shear Strength Determination by Pocket Penetrometer

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

# UNIFIED SOILS CLASSIFICATION

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

# RECORD OF BOREHOLE No 16-03

1 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 458 967.3 E 222 487.6 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Tripod/NW Casing/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.09 - 2016.06.09 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR  SA  SI  CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20   40   60   80   100								
275.0	GROUND SURFACE															
0.0	<b>PEAT</b> , some rootlets, occasional wood fibres Soft Brown Wet  <b>SAND</b> , trace gravel, trace silt Compact Brown Wet		1	SS	4											
274.4																
0.6																
			2	SS	11											
			3	SS	12											
			4	SS	15											
			5	SS	17											
			6	SS	18											
			7	SS	15											
267.8																
7.2	Silty <b>SAND</b> , trace clay Compact Brown Wet															
			8	SS	29											
266.5																
8.5	End of sampling at 8.5m and start DCPT															

Continued Next Page

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

RECORD OF BOREHOLE No 16-03

2 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 458 967.3 E 222 487.6 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Tripod/NW Casing/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.09 - 2016.06.09 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  NATURAL MOISTURE CONTENT  LIQUID LIMIT	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								20 40 60 80 100							W P W W L			
	Continued From Previous Page																	
264.0																		
11.0	END OF BOREHOLE AT 11.0m UPON DCPT REFUSAL. BOREHOLE OPEN AND WATER LEVEL AT 0.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																	

ONTMT4S 13639-MTO.GPJ 2015TEMPLATE(MTO).GDT 7/14/16



# RECORD OF BOREHOLE No 16-04

1 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 459 024.7 E 222 435.8 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.08 - 2016.06.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
275.5	GROUND SURFACE							20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>				
0.0	TOPSOIL, sandy, some rootlets and wood fibres: (150mm)		1	SS	4		275												
0.2	SAND, trace silt, occasional rootlets and wood fibres Loose Brown Dry		2	SS	6		274												
	Wood fragments (log) from 1.5m to 1.8m Becoming Wet		3	SS	15		273												
			4	SS	4		272												
	Wood fragments (log) from 3.1m to 3.2m		5	SS	4		271												
271.4	Silty SAND, trace clay Compact Brown Wet		6	SS	14		270												
4.1			7	SS	13		269												
							268												
267.7	SAND, trace to some gravel, trace to some silt Compact to Dense Brown Wet		8	SS	29		267												
7.8			9	SS	31		266												

Continued Next Page

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

# RECORD OF BOREHOLE No 16-04

2 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 459 024.7 E 222 435.8 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.08 - 2016.06.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page							20	40	60	80	100					
			10	SS	26		265										
							264										
262.7			11	SS	30		263										14 80 6 (SI+CL)
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE OPEN TO 12.2m AND WATER LEVEL AT 1.5m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2016.06.09 1.5 274.0 2016.06.10 1.5 274.0 2016.06.11 1.5 274.0 2016.06.12 1.5 274.0 2016.06.12 Decommissioned																

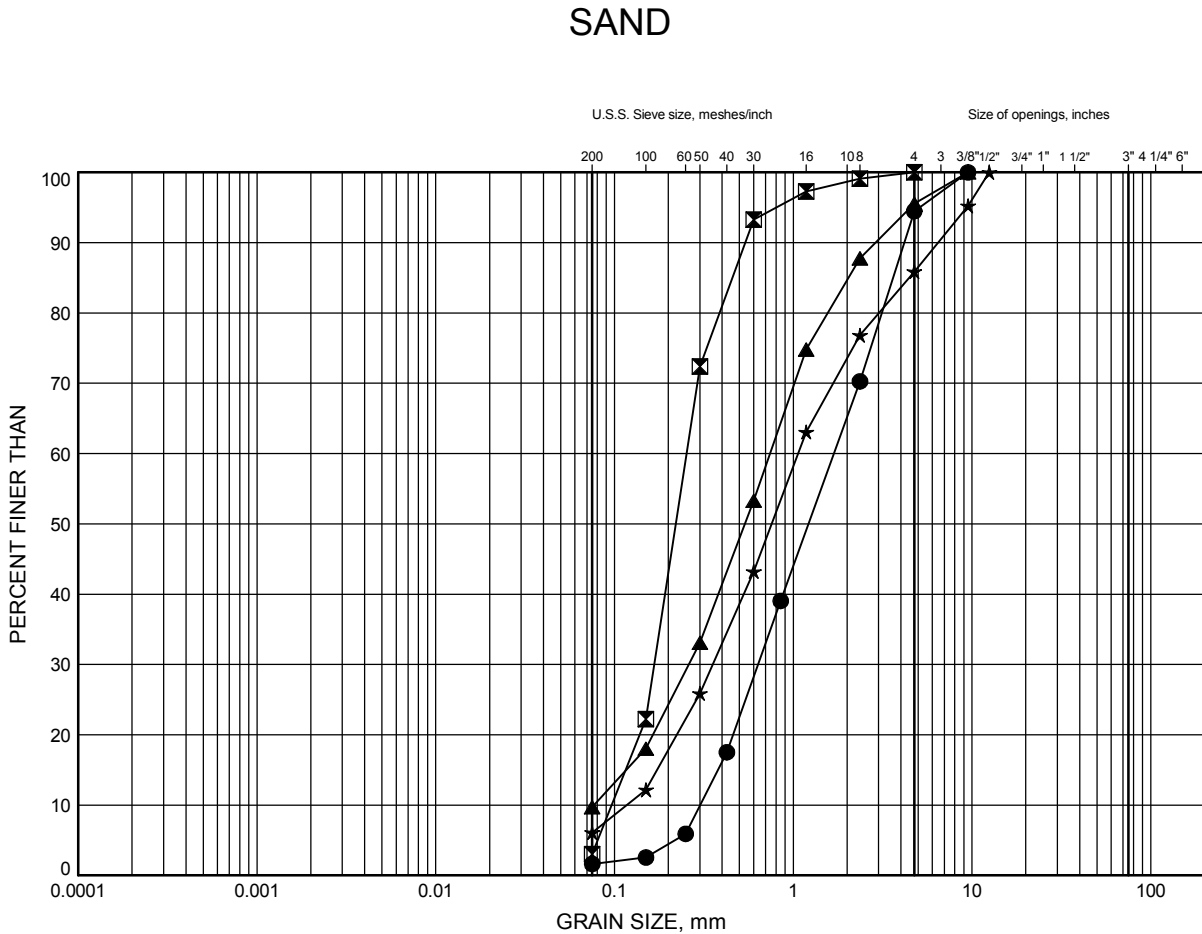
## **Appendix B**

### **Geotechnical and Analytical Laboratory Test Results**

# Shamrock Lake Centre Culvert Replacement

## GRAIN SIZE DISTRIBUTION

FIGURE B1



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	1.07	273.93
⊠	16-03	2.59	272.41
▲	16-04	9.45	266.05
★	16-04	12.50	263.00

Date July 2016  
W.P. 6910-12-00



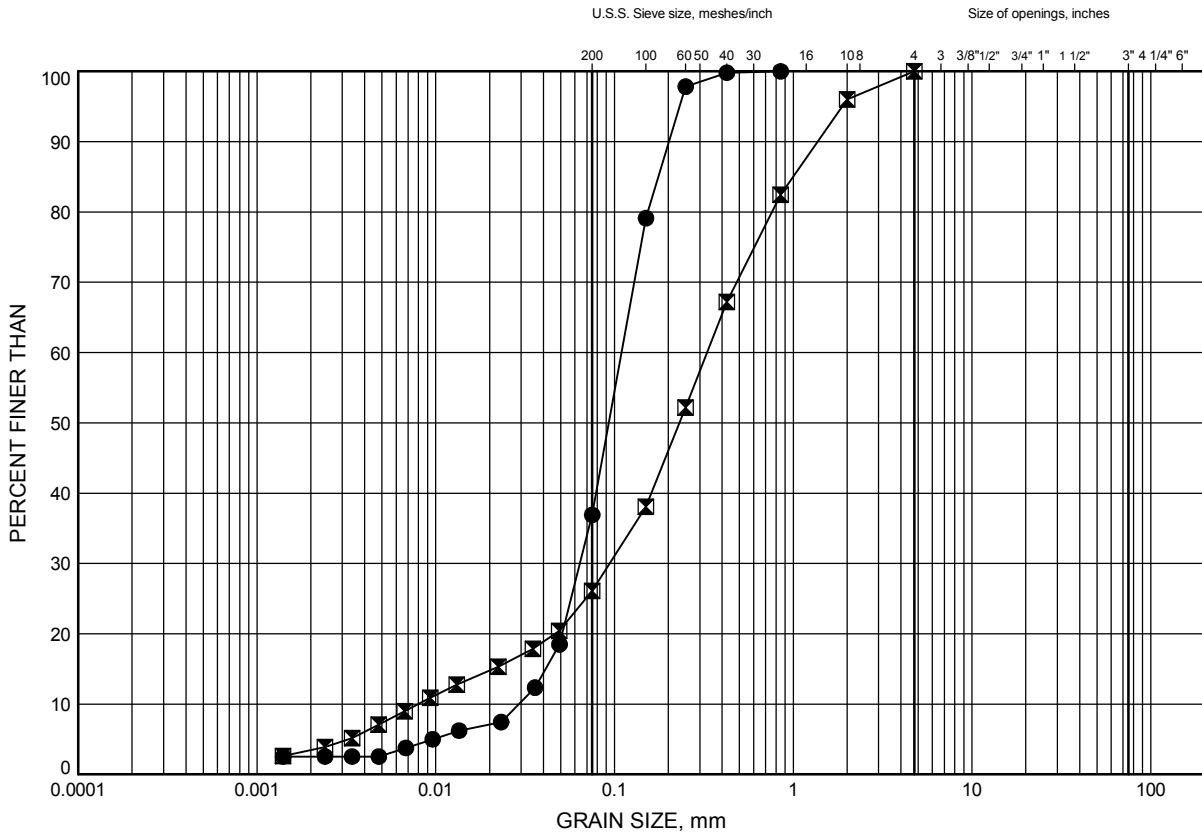
Prep'd MFA  
Chkd. MEF

# Shamrock Lake Centre Culvert Replacement

## GRAIN SIZE DISTRIBUTION

FIGURE B2

### Silty SAND



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	7.92	267.08
⊠	16-04	6.40	269.10

Date July 2016  
W.P. 6910-12-00



Prep'd MFA  
Chkd. MEF

**SGS Canada Inc.**

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

**Project : 13639****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive  
Oakville, ON  
L6H 5R7,

Phone: 905-829-8666 x 228  
Fax:

11-July-2016

**Date Rec. :** 30 June 2016  
**LR Report:** CA15745-JUN16  
**Reference:** 13639

**Copy:** #1

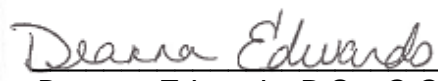
## CERTIFICATE OF ANALYSIS

### Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	6: Shamrock Lake West	7: Shamrock Lake Centre	8: Keemle Lake
Sample Date & Time						27-Jun-16 07:35	27-Jun-16 07:50	27-Jun-16 08:05
Temperature Upon Receipt [°C]	---	---	--	--	---	14.0	14.0	14.0
Corrosivity Index [none]	07-Jul-16	15:20	07-Jul-16	15:20		< 1	< 1	< 1
pH [no unit]	30-Jun-16	14:14	04-Jul-16	12:17	0.05	7.44	7.36	6.43
Conductivity [µS/cm]	30-Jun-16	14:14	04-Jul-16	12:17	2	87	47	21
Resistivity (calculated) [MOhms.cm]	07-Jul-16	14:27	07-Jul-16	14:28	---	11500	21400	48100
Redox Potential [mV]	30-Jun-16	14:34	06-Jul-16	09:05	---	206	197	201
Chloride [mg/L]	06-Jul-16	06:58	07-Jul-16	11:30	0.04	1.3	0.39	0.09
Sulphate [mg/L]	06-Jul-16	06:58	07-Jul-16	11:30	0.04	1.6	1.6	0.81
Sulphide [mg/L]	01-Jul-16	10:00	04-Jul-16	12:51	0.006	< 0.006	< 0.006	0.006

### Method Descriptions

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

  
**Deanna Edwards, B.Sc, C.Chem**  
**Project Specialist**  
**Environmental Services, Analytical**



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**Project :** 13639

**LR Report :** CA15745-JUN16

Temperature of Samples upon Receipt 14 degrees C  
Cooling Agent Present

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



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**Project :** 13639

**LR Report :** CA15745-JUN16

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
							Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
					RPD	Acceptance Criteria		Low	High		Low	High
Anions by IC - QCBatchID: DIO0054-JUL16												
Chloride	0.04	mg/L	<0.04		ND	20	103	80	120	105	75	125
Sulphate	0.04	mg/L	<0.04		ND	20	100	80	120	98	75	125
Conductivity - QCBatchID: EWL0498-JUN16												
Conductivity	2	µS/cm	< 2		0	10	97	90	110	NA		
pH - QCBatchID: EWL0498-JUN16												
pH	0.05	no unit	NA		1		97			NA		
Redox Potential - QCBatchID: EWL0500-JUN16												
Redox Potential	no	mV	NA		7	20	104	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0002-JUL16												
Sulphide	0.006	mg/L	<0.006		ND	20	7	80	120	NV	75	125



**SGS Canada Inc.**

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**Project : 13639****28-June-2016****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive  
 Oakville, ON  
 L6H 5R7,

Phone: 905-829-8666 x 228


Fax:

**Date Rec. : 21 June 2016****LR Report: CA14531-JUN16****Reference: 13639 Mark Farrant****CERTIFICATE OF ANALYSIS**

<b>Analysis</b>	<b>1: Analysis Start Date</b>	<b>2: Analysis Start Time</b>	<b>3: Analysis Approval Date</b>	<b>4: Analysis Approval Time</b>	<b>5: 16-01 SS #2, 16-04 SS #2, 16-05 SS #2, 2.5'-4.5'</b>	<b>6: 2.5'-4.5'</b>	<b>7: 2.5'-4.5'</b>
Sample Date & Time					07-Jun-16	08-Jun-16	12-Jun-16
Corrosivity Index [none]	27-Jun-16	17:00	27-Jun-16	17:00	3	3	3
pH [no unit]	22-Jun-16	10:19	22-Jun-16	11:34	7.28	7.33	5.96
Soil Redox Potential [mV]	27-Jun-16	14:03	27-Jun-16	16:53	284	273	363
Sulphide [%]	24-Jun-16	13:25	24-Jun-16	14:10	0.02	< 0.02	< 0.02
% Moisture (wet wt) [%]	24-Jun-16	07:20	24-Jun-16	14:10	73.2	82.0	88.3
pH [no unit]	42548	0.46	27-Jun-16	16:54	7.82	8.09	7.23
Chloride [µg/g]	25-Jun-16	11:33	27-Jun-16	14:22	49	10	11
Sulphate [µg/g]	25-Jun-16	11:33	27-Jun-16	14:22	61	2.0	8.8
Conductivity [uS/cm]	27-Jun-16	11:08	27-Jun-16	16:55	118	87	28
Resistivity (calculated) [Ohms.cm]	---	---	27-Jun-16	17:00	8500	11500	35700

Temperature of Samples upon receipt 12 degree C  
 Ice was added by SGS Courier

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

  
**Deanna Edwards, B.Sc, C.Chem**  
**Project Specialist**  
**Environmental Services, Analytical**

**SGS Canada Inc.**

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

**Project : 13639****LR Report : CA14531-JUN16**

### Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020	ASTM E1918
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013	
pH	ME-CA-[ENV]EWL-LAK-AN-001	SM 4500



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

**Project :** 13639

**LR Report :** CA14531-JUN16

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank		RPD		LCS / Spike Blank			Matrix Spike / Reference Material		
					1	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Anions by IC - QCBatchID: DIO0413-JUN16												
Chloride	0.4	µg/g	<0.4		1	20	101	80	120	103	75	125
Sulphate	0.4	µg/g	<0.4		2	20	96	80	120	95	75	125
Carbon/Sulphur - QCBatchID: ECS0031-JUN16												
Sulphide	0.02	%	<0.02		ND	20	100	80	120			
Conductivity - QCBatchID: EWL0419-JUN16												
Conductivity	2	uS/cm	< 2		0	10	97	90	110	NA		
pH - QCBatchID: ARD0070-JUN16												
pH	0.05	no unit			0	20	100	80	120			

## **Appendix C**

### **Factual Data from 2015 DST Foundation Investigation Report**

# RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+667, 4.5 RT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED	+ FIELD VANE						
							□ QUICK TRIAXIAL	x LAB VANE		WATER CONTENT (%)					
							20	40	60	80	100	20	40	60	
99.9	GROUND SURFACE														
98.9	ASPHALT		AS1	AS											16 74 (10)
98.2	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	9										2 65 (33)
	FILL-SAND-trace to some gravel, trace to with silt, cobbles, BROWN, Loose to Dense		SS3	SS	9										
			SS4	SS	26										
			SS5	SS	20										2 91 (7)
			SS6	SS	22										
			SS7	SS	33										
			SS8	SS	16										
			SS9	SS	17										0 88 (12)
			SS10	SS	20										
			SS11	SS	33										
			SS12	SS	23										7 84 (9)
			SS13	SS	24										
	-roots		SS14	SS	9										
			SS15	SS	6										6 86 (8)
	-Black organics		SS16	SS	4										
80.1															
19.8	SAND-trace gravel, some silt, cobbles, GREY, Compact to Dense		SS17	SS	15										
			SS18	SS	18										
			SS19	SS	33										4 84 (12)
			SS20	SS	24										
74.9															
25.0	END OF BOREHOLE														

NR = NO RECOVERY

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+674, 4.5 RT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT $w_p$	NATURAL MOISTURE CONTENT $w$	LIQUID LIMIT $w_L$	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE □ QUICK TRIAXIAL    × LAB VANE							
100.0	GROUND SURFACE														
98.9	ASPHALT		AS1	AS											
98.3	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	8										
	FILL-SAND-trace to some gravel, trace to with silt, cobbles, BROWN, Loose to Compact		SS3	SS	12		98							0 65 (35)	
			SS4	SS	21										
			SS5	SS	20										
			SS6	SS	18		96							0 39 (61)	
			SS7	SS	21										
			SS8	SS	20		94								
			SS9	SS	16		92								
			SS10	SS	29		90							8 76 (16)	
			SS11	SS	17										
			SS12	SS	19		88								
			SS13	SS	11		86								
			SS14	SS	9		84							6 80 (14)	
			SS15	SS	8										
			SS16	SS	6		82								
80.2															
19.8	SAND-some gravel, trace to some silt, GREY, Loose to Compact		SS17	SS	12		80							17 75 (8)	
			SS18	SS	9		78								
			SS19	SS	19										
			SS20	SS	23		76							0 82 (18)	
75.0															
25.0	END OF BOREHOLE														

NR = NO RECOVERY

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

ENCLOSURE 2

# RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+655, 4.5 LT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+ FIELD VANE	□ QUICK TRIAXIAL	× LAB VANE						
99.8	GROUND SURFACE						20	40	60	80	100						
99.5	FILL-SAND AND CRUSHED GRAVEL			AS1	AS												25 64 (11)
0.3	FILL-SAND-trace to with gravel, trace to with silt, cobbles, BROWN, Loose to Compact			SS2	SS	7											3 71 (26)
				SS3	SS	10											
				SS4	SS	8											
				SS5	SS	5											
				SS6	SS	5											
				SS7	SS	11											
				SS8	SS	7											
				SS9	SS	22											
				SS10	SS	21											
				SS11	SS	15											

NR = NO RECOVERY +<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 3

# RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+662, 4.4 LT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20	40	60	80	100						20	40	60
99.9	GROUND SURFACE																			
99.6	FILL-SAND AND CRUSHED GRAVEL			AS1	AS												16 71 (13)			
0.4	FILL-SAND-trace to some gravel, trace to some silt, cobbles, BROWN, Loose to Dense			SS2	SS	9														
				SS3	SS	10														
				SS4	SS	8														
				SS5	SS	21														
				SS6	SS	10														
				SS7	SS	29														
				SS8	SS	29														
				SS9	SS	30														
				SS10	SS	30														
				SS11	SS	32														
				SS12	SS	10														
	SS13	SS	6																	
	SS14	SS	9																	
	SS15	SS	10																	
	SS16	SS	8																	
80.1																				
19.8	SAND-trace to some silt, trace gravel, BROWN, Loose to Compact			SS17	SS	8														
				SS18	SS	11														
				SS19	SS	15														
		SS20	SS	14																
74.9																				
25.0	END OF BOREHOLE																			

NR = NO RECOVERY

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

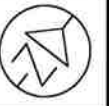


## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**

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

CONT No  
WP No 6910-12-00



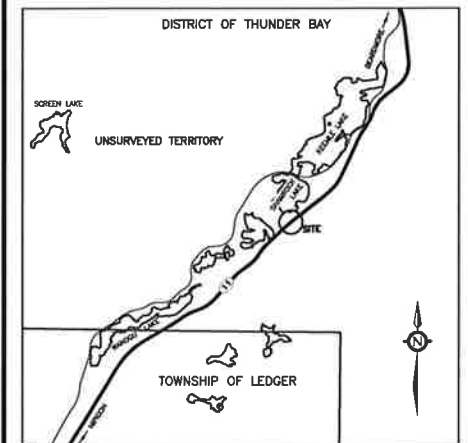
HIGHWAY 11  
SHAMROCK LAKE CENTRE  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

**HATCH**



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

◆	Borehole by Thurber (2016)
⊕	Borehole and Cone by Thurber (2016)
⊗	Borehole by DST (2014)
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
16-03	275.0	5 458 967.3	222 487.6
16-04	275.5	5 459 024.7	222 435.8
BH1	292.5	5 458 995.5	222 470.3
BH2	292.6	5 458 999.8	222 475.8
BH3	292.5	5 458 995.2	222 455.3
BH4	292.6	5 458 999.4	222 460.9

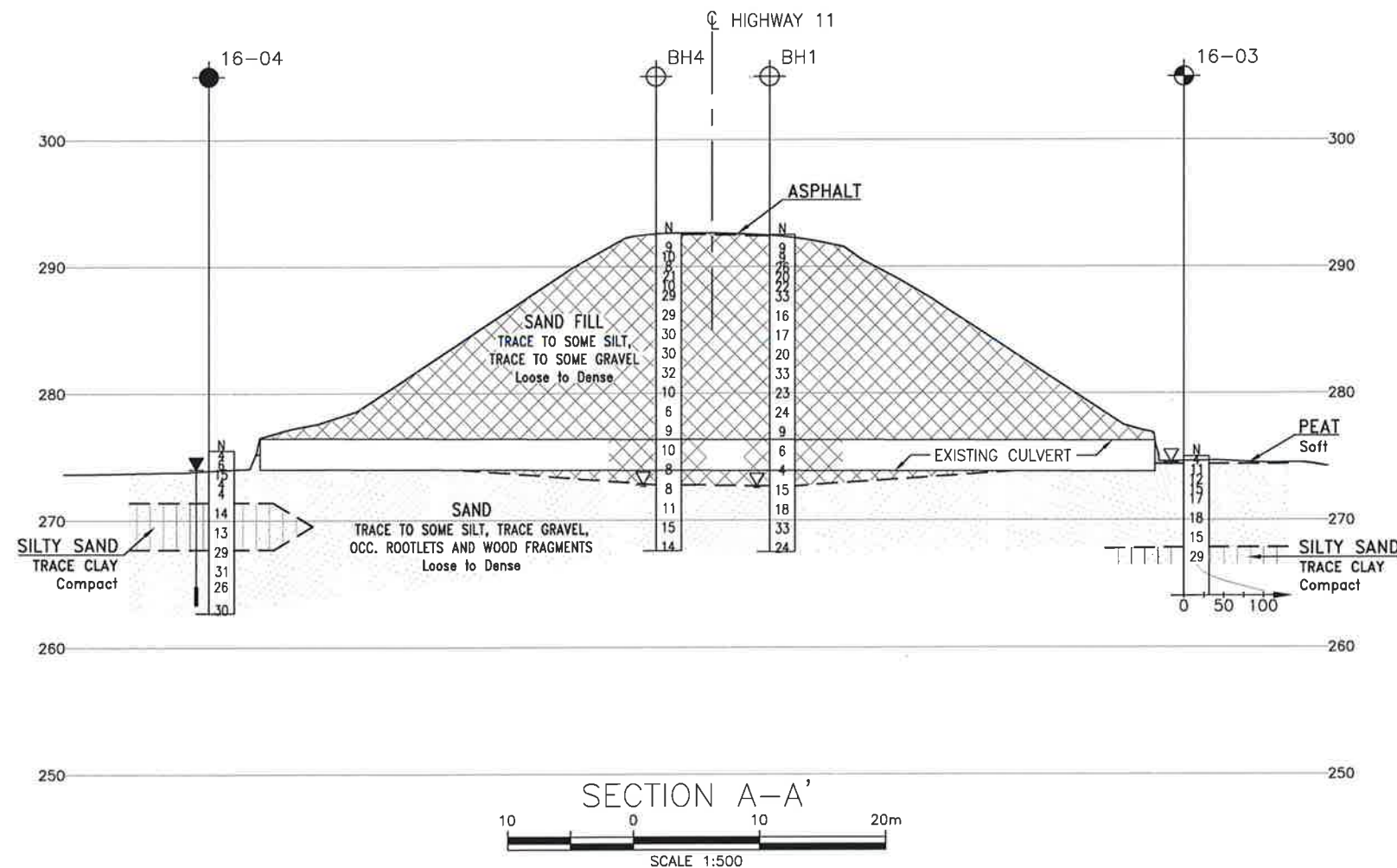
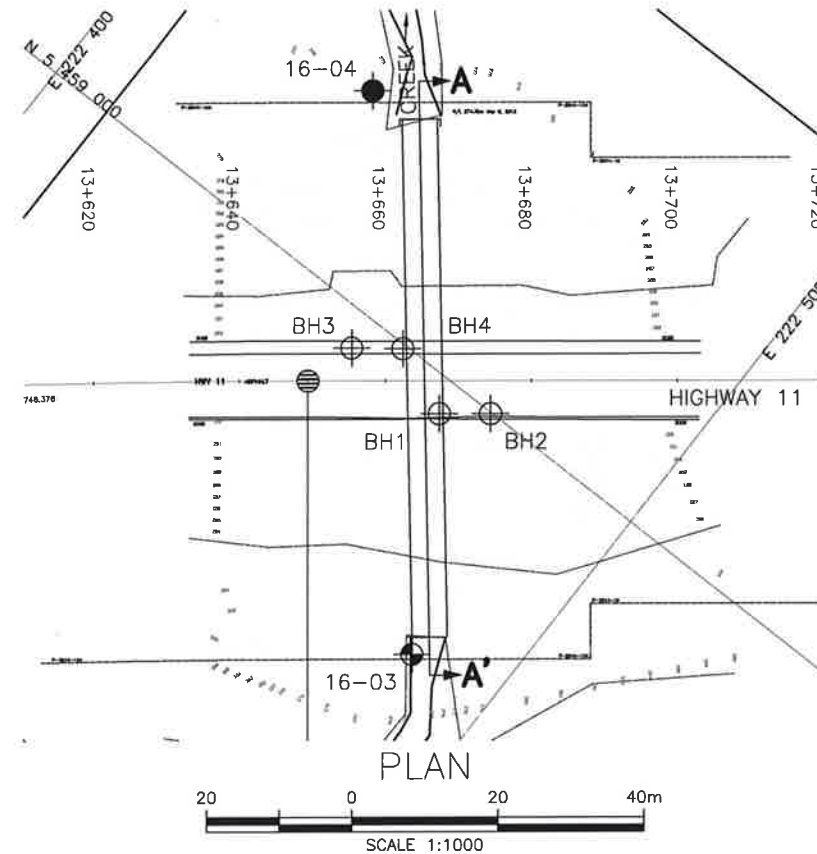
NOTES-

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

GEOCRES No. 52H-39

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MEF	CHK MRA	CODE
DRAWN	MFA	CHK MEF	SITE
			LOAD
			DATE
			AUG 2016
			STRUCT
			DWG 1

FILENAME: H:\Drafting\13000\13639\13639-PLPR-SC.dwg  
PLOTDATE: 8/24/2016 2:50 PM



## **Appendix E**

### **Site Photographs**





**Photo 1: Shamrock Lake Centre Culvert Inlet**



**Photo 2: Shamrock Lake Centre Culvert Outlet**





**Photo 3: Looking northeast along Highway 11 at Shamrock Lake Centre Culvert**



**Photo 4: Looking northeast along west side of Highway 11 embankment**



**Photo 5: Looking northeast along east side of Highway 11 embankment**