



THURBER ENGINEERING LTD.

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

G.W.P. No. 6910-12-00, W.P. No. 6911-12-00, SITE No. 48C-186/C

GEOCRES Number: 52H-40

Report

to

HATCH

Date: August 25, 2016
File: 13639



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**FOUNDATION INVESTIGATION REPORT
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THUNDER BAY DISTRICT, ONTARIO**

G.W.P. NO. 6910-12-00, W.P. NO. 6911-12-00, SITE NO. 48C-186/C

GEOCRES NUMBER: 52H-40

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 West 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 West, Highway 11, Unsurveyed Territory, Thunder Bay District", prepared by DST Consulting Engineers Inc. (DST), dated March 17, 2015; Geocres No. 52H-26. 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 30.9 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 McKirdy 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 33.3 m long, 4.0 m span by 2.44 m high, concrete rigid frame, open footing culvert, with a height of fill of 5 m. An Ontario Structure Inspection Manual (OSIM) report prepared in 2014 notes the presence of multiple medium to wide cracks and other deterioration, but that the structure was considered to be in overall good condition. In 2004, repairs were made to spalled concrete at the inlet and outlet of the culvert.

The grade level of Highway 11 at the existing culvert is an approximate Elevation of 263.6 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 259 m at McKirdy 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 gravel and sand, 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 7 to 8, 2016, and consisted of drilling and sampling two (2) boreholes, designated as Boreholes 16-01 and 16-02. Borehole 16-01 was located near the culvert inlet and Borehole 16-02 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 track-mounted CME 55 drill rig was used to advance Borehole 16-01 using hollow stem augers, and a portable tripod drill rig was used to advance Borehole 16-02 using NW casing and wash boring techniques. Both drill rigs were supplied and operated by RPM Drilling Inc. of Thunder Bay, Ontario. The boreholes were advanced to depths of 14.3 m and 5.0 m respectively. Borehole 16-02 was extended beyond 5.0 m depth by conducting a Dynamic Cone Penetration Test (DCPT) to a depth of 5.9 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 16-01. 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

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
16-01	14.3 / 243.3	13.7 / 243.9	Filter sand to 11.9 m, bentonite holeplug to 11.0 m, bentonite holeplug and cuttings to ground surface.
16-02	5.9 / 251.5	None installed	Bentonite holeplug from 5.9 m 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 14.3 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	263.5
BH2	99.6	263.3
BH3	99.6	263.3
BH4	100.1	263.7

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 with varying amounts of gravel and silt. Peat and silty sand were also noted at the locations where there was no fill. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes BH1 to BH4 were drilled through the existing asphalt pavement on Highway 11. The asphalt thickness measured in the boreholes ranged from 40 to 200 mm.

5.2 Fill

Underlying the asphalt, a 100 mm thick layer of granular fill consisting of sand and crushed gravel was encountered in Boreholes BH1 to BH4.

A sand embankment fill containing trace gravel and trace to some silt was encountered below the granular fill in Boreholes BH1 to BH4. The sand fill ranged in thickness from 5.9 to 7.4 m, and extended to depths from 6.1 to 7.6 m (Elev. 255.9 to 257.2 m). SPT 'N' values within the sand fill ranged from 2 to 30 blows per 0.3 m penetration, indicating a very loose to compact relative density.

The measured moisture content of the fill generally ranged from 4% to 17%, with the exception of one sample in BH1, where the presence of organic material in the fill resulted in a moisture content of 48%. 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 29
Sand	61 to 88
Silt and Clay	8 to 28

5.3 Peat

A layer of peat with some rootlets and occasional wood fibres was encountered at the ground surface in Borehole 16-02, which was drilled near the culvert outlet. The peat extended to a depth of 1.5 m (Elev. 255.9 m). SPT 'N' values of 3 and 10 blows per 0.3 m penetration were recorded



in the peat, indicating a stiff to soft consistency. Moisture contents of 86% and 234% were measured in the peat.

5.4 Silty Sand

A deposit of silty sand with occasional rootlets was encountered at the ground surface in Borehole 16-01, which extended to a depth of 0.7 m (Elevation 256.9 m). The deposit was very loose, based on an SPT 'N' value of 2 blows per 0.3 m of penetration. A moisture content of 48% was measured on a sample of the silty sand.

5.5 Sand

A native deposit of sand was encountered below the embankment fill, peat and silty sand layers in all of the boreholes at the site. The boreholes were each terminated in the sand at depths ranging from 5.0 to 14.3 m (Elev. 243.3 to 252.4 m). A Dynamic Cone Penetration Test was conducted at the base of Borehole 16-02, where cone refusal of greater than 100 blows per 0.3 m penetration was encountered at a depth of 5.9 m (Elev. 251.5 m). The sand was grey in colour and contained trace to some gravel and trace to some silt.

SPT 'N' values within the sand generally ranged from 5 to 54 blows per 0.3 m penetration, indicating a loose to dense relative density, with occasional very loose (3 blows per 0.3 m penetration) and very dense (greater than 50 blows per 0.3 m penetration) zones. The measured moisture content of the sand ranged from 3% to 42%. 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.

Soil Particle	Percentage (%)
Gravel	0 to 16
Sand	72 to 96
Silt and Clay	4 to 25

5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes and in the 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	
16-01	June 8, 2016	0.0	257.6	Standpipe piezometer
	June 9, 2016	0.0	257.6	
	June 10, 2016	0.0	257.6	
	June 11, 2016	0.1	257.5	
	June 12, 2016	0.1	257.5	
16-02	June 8, 2016	0.0	257.4	Open borehole
BH1	October 14, 2014	6.1	257.4	Reported by DST
BH2	October 14, 2014	6.1	257.2	Reported by DST
BH3	October 14, 2014	6.1	257.2	Reported by DST
BH4	October 14, 2014	6.1	257.6	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 257.38 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 16-01, 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	
			16-01, SS#2, 2.5'-4.5'	Shamrock Lake West
			(Sand)	(Creek Water)
Sulphide	%	mg/L	0.02	<0.006
Chloride	µg/g	mg/L	49	1.3
Sulphate	µg/g	mg/L	61	1.6
pH	No unit	No unit	7.28 to 7.82	7.44



Parameter	Units (Soil)	Units (Water)	Test Results	
			16-01, SS#2, 2.5'-4.5'	Shamrock Lake West
			(Sand)	(Creek Water)
Electrical Conductivity	µS/cm	µS/cm	118	87
Resistivity	Ohms.cm	MOhms.cm	8500	11500
Redox Potential	mV	mV	284	206

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

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			

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S 13639-MTO.GPJ 2015TEMPLATE(MTO).GDT 7/13/16

RECORD OF BOREHOLE No 16-01

2 OF 2

METRIC

W.P. 6911-12-00 LOCATION Shamrock Lake West Culvert N 5 458 583.0 E 222 042.0 ORIGINATED BY GA
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.06.07 - 2016.06.07 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) 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																
			10	SS	25												
			11	SS	28												
	becoming Dense																
243.3			12	SS	31											1 94 5 (SI+CL)	
14.3	END OF BOREHOLE AT 14.3m. BOREHOLE OPEN TO 14.3m AND WATER LEVEL AT 0.1m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2016.06.08 0.0 257.6 2016.06.09 0.0 257.6 2016.06.10 0.0 257.6 2016.06.11 0.1 257.5 2016.06.12 0.1 257.5 2016.06.12 Decommissioned																




ONTMT4S 13639-MTO.GPJ 2015TEMPLATE(MTO).GDT 7/13/16

RECORD OF BOREHOLE No 16-02

1 OF 1

METRIC

W.P. 6911-12-00 LOCATION Shamrock Lake West Culvert N 5 458 612.0 E 222 016.8 ORIGINATED BY GA
 HWY 11 BOREHOLE TYPE Tripod/NW Casing/Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2016.06.07 - 2016.06.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) 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								
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE											
257.4	GROUND SURFACE																
0.0	PEAT , some rootlets, occasional wood fibres Stiff to Soft Brown Wet		1	SS	10		257							86			
																234	
			2	SS	3		256										
255.9																	
1.5	SAND , coarse grained, trace to some gravel, trace silt Compact Grey Wet becoming Very Dense		3	SS	20												
					4		SS	20	255								
					5		SS	24	254								
			6	SS	50/	253											
					0.150												
252.4																	
5.0	End of sampling at 5.0m and start DCPT						252										
251.5																	
5.9	END OF BOREHOLE AT 5.9m UPON DCPT REFUSAL. BOREHOLE OPEN AND WATER LEVEL AT GROUND SURFACE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																

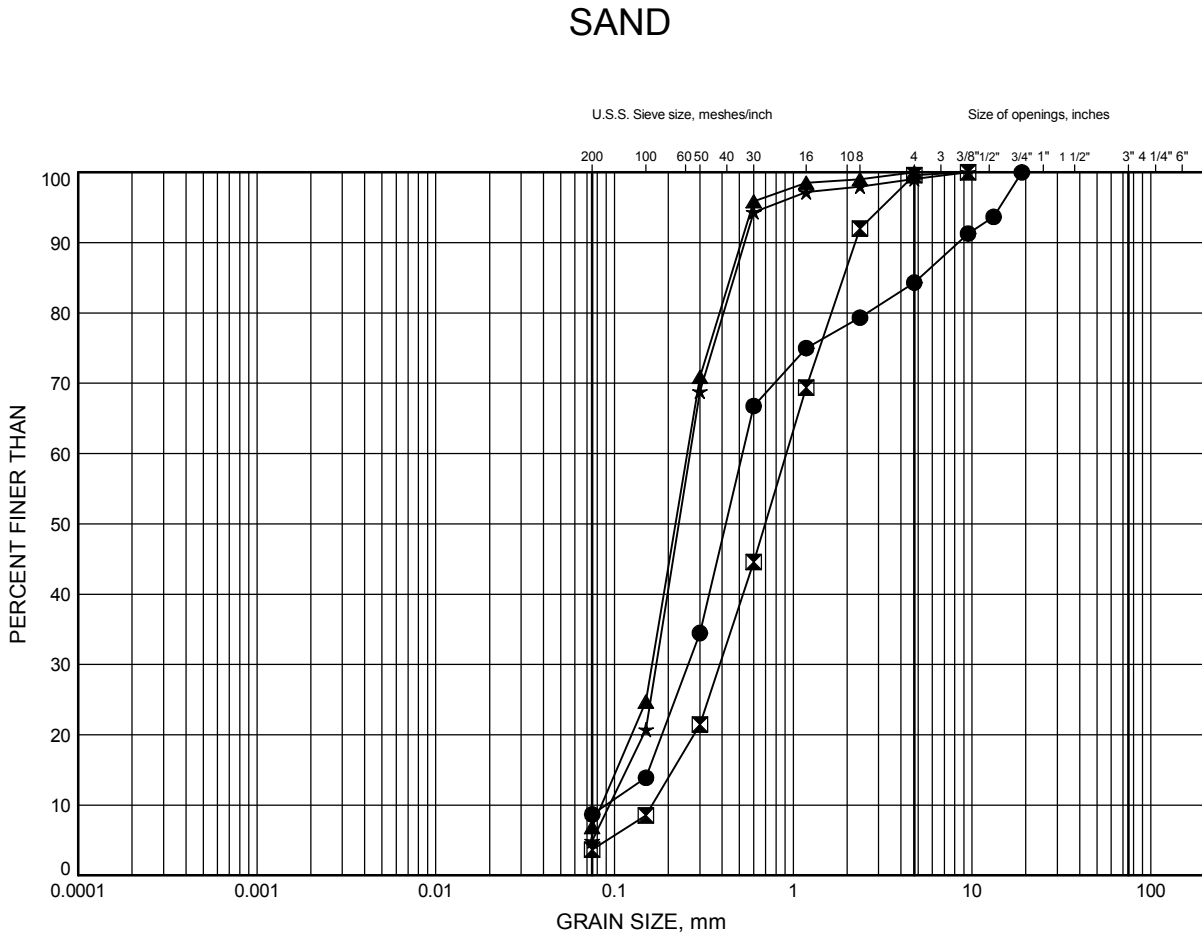
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

Appendix B

Geotechnical and Analytical Laboratory Test Results

Shamrock Lake West 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)
●	16-01	2.59	255.01
⊠	16-01	6.40	251.20
▲	16-01	9.45	248.15
★	16-01	14.02	243.58

Date July 2016
W.P. 6911-12-00



Prep'd MFA
Chkd. MEF

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
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 Phone: 705-652-2000 FAX: 705-652-6365

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

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 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**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: 16-01 SS #2, 2.5'-4.5'	6: 16-04 SS #2, 2.5'-4.5'	7: 16-05 SS #2, 2.5'-4.5'
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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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



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

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				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: 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			

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
 Lakefield - Ontario - KOL 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

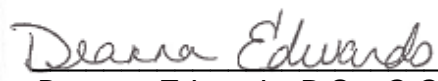
CERTIFICATE OF ANALYSIS

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

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.

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: 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

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 West STA 13+081, 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 14 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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED	+ FIELD VANE							
						□ QUICK TRIAXIAL	× LAB VANE		WATER CONTENT (%)							
						20	40	60	80	100	20	40	60			
99.9	GROUND SURFACE															
99.9	ASPHALT		AS1	AS			99								17 68 (15)	
99.1	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	8											
99.2	FILL-SAND-trace gravel, trace to with silt, BROWN, Very Loose to Compact		SS3	SS	7		98									
			SS4	SS	7											
			SS5	SS	16		97								0 79 (21)	
			SS6	SS	8		96									
			SS7	SS	3		95								1 75 (24)	
							94									
			SS8	SS	2		93									
							92									
92.3	-black organics		SS9	SS	8		91									
7.6	SAND-trace to with silt, trace gravel, GREY, Loose to Dense		SS10	SS	20		90								4 86 (10)	
			SS11	SS	9		89									
			SS12	SS	33		88									
			SS13	SS	26		87									
85.6							86								7 73 (20)	
14.3	END OF BOREHOLE															

NR = NO RECOVERY +³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 1

RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake West STA 13+071, 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 14 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 γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								○ UNCONFINED	+ FIELD VANE							□ QUICK TRIAXIAL	× LAB VANE	
99.6	GROUND SURFACE						20	40	60	80	100				GR SA SI CL			
98.5	ASPHALT		AS1	AS										25 63 (12)				
98.4	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	9													
98.2	FILL-SAND-trace gravel, trace to with silt, BROWN, Very Loose to Compact		SS3	SS	4													
			SS4	SS	3									1 77 (22)				
			SS5	SS	12													
			SS6	SS	17													
			SS7	SS	14													
93.5																		
6.1	SAND-trace to some gravel, trace to some silt, GREY, Loose to Dense		SS8	SS	9									4 88 (8)				
			SS9	SS	44													
			SS10	SS	23													
			SS11	SS	25									7 81 (12)				
			SS12	SS	15													
			SS13	SS	20									15 79 (6)				
85.3																		
14.3	END OF BOREHOLE																	

NR = NO RECOVERY +³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 2

ONL MOT GS-TB-019794 SHAMROCK 30.8.GPJ DST_MIN.GDT 2/23/15

RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake West STA 13+074, 4.6 LT ORIGINATED BY PR
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
DATUM Local DATE 2014 10 14 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 γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+ FIELD VANE						□ QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)
99.6	GROUND SURFACE						20	40	60	80	100				GR SA SI CL		
98.5	ASPHALT		AS1	AS													
98.2	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	16										29 61 (10)		
	FILL-SAND-trace gravel, trace to some silt, BROWN, Very Loose to Compact		SS3	SS	9												
			SS4	SS	7										1 85 (14)		
			SS5	SS	6												
			SS6	SS	2												
			SS7	SS	6										9 75 (16)		
93.5																	
6.1	SAND-trace to some gravel, trace to some silt, GREY, Loose to Compact		SS8	SS	5												
			SS9	SS	9										13 78 (9)		
			SS10	SS	12												
			SS11	SS	29										4 80 (16)		
			SS12	SS	14												
			SS13	SS	9										3 87 (11)		
85.3																	
14.3	END OF BOREHOLE																

NR = NO RECOVERY +³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 3

ONL MOT GS-TB-019794 SHAMROCK 30.8.GPJ DST_MIN.GDT 2/23/15

RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

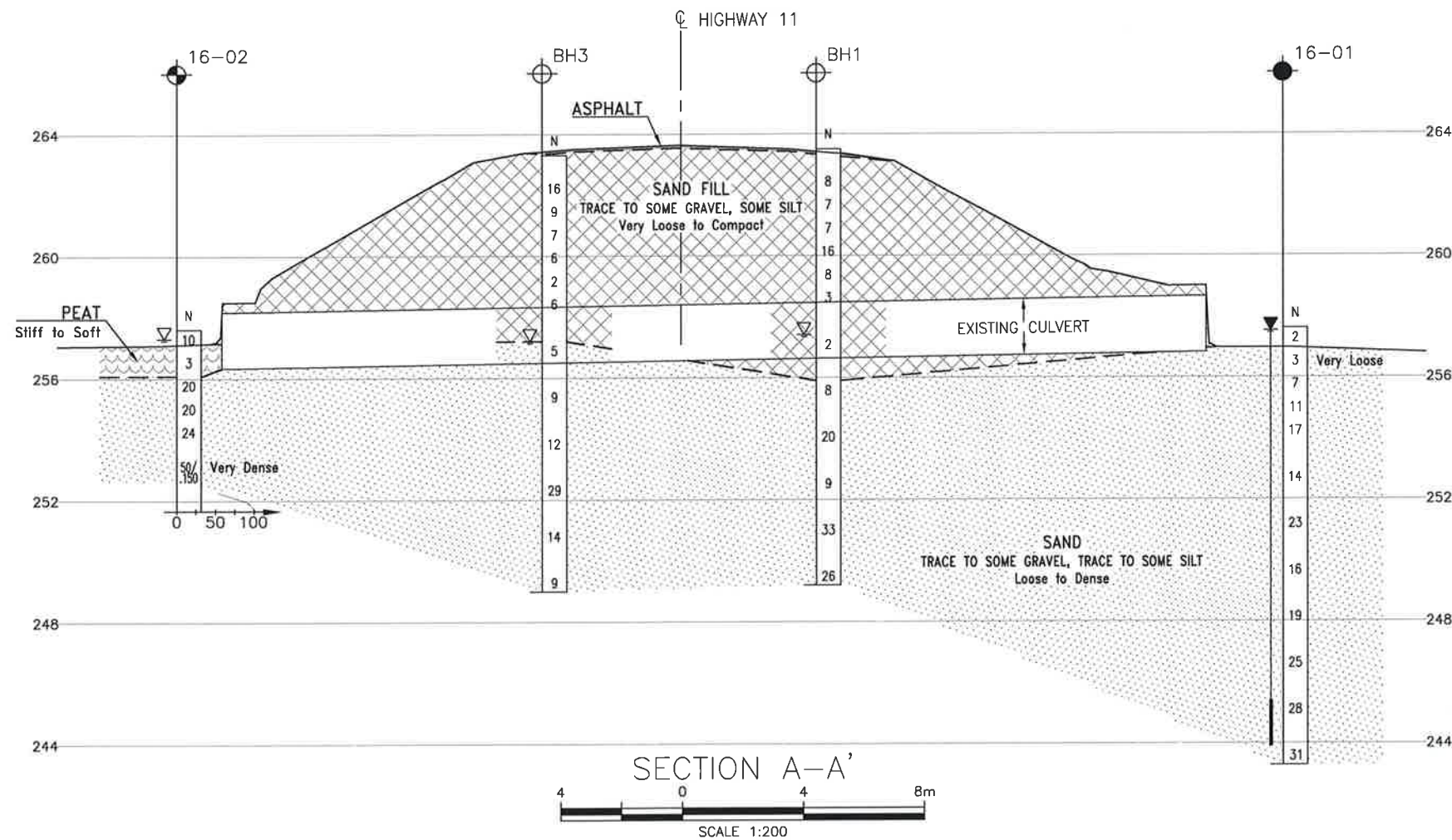
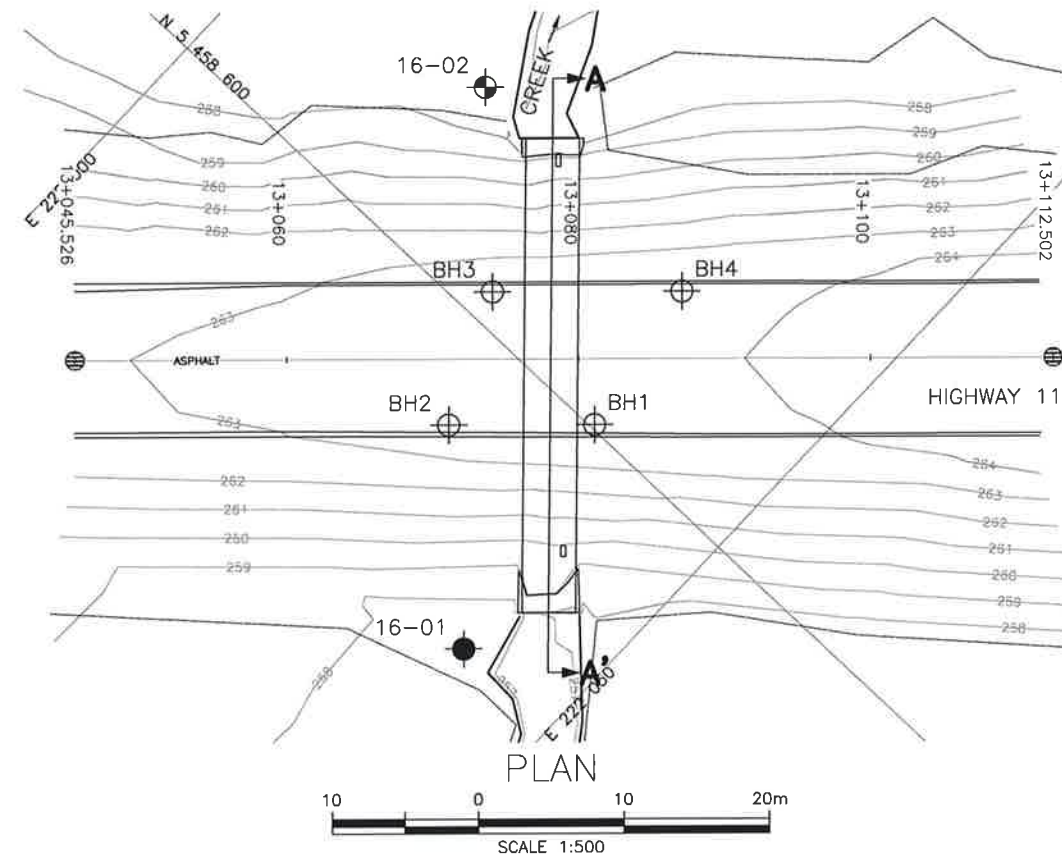
W.P. 6013-E-0021 LOCATION Shamrock Lake West STA 13+087, 4.6 LT ORIGINATED BY PR
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
DATUM Local DATE 2014 10 14 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED		+ FIELD VANE		□ QUICK TRIAXIAL			x LAB VANE
100.1	GROUND SURFACE						20	40	60	80	100	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	
99.9	ASPHALT		AS1	AS								●			16 68 (16)
99.8	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	30							●			
90.3	FILL-SAND-trace to with gravel, some to with silt, BROWN, Very Loose to Compact		SS3	SS	15							●			23 64 (12)
			SS4	SS	5							●			
			SS5	SS	6							●			
			SS6	SS	4							●			
			SS7	SS	2							●			1 72 (28)
			SS8	SS	2							●			
92.5	SAND-some to with silt, trace to some gravel, GREY, Loose to Dense		SS9	SS	5								●		1 74 (25)
7.6			SS10	SS	32								●		
			SS11	SS	54								●		12 72 (16)
			SS12	SS	27								●		1 78 (21)
			SS13	SS	33								●		
85.8	END OF BOREHOLE														
14.3															

NR = NO RECOVERY +³, X³: 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

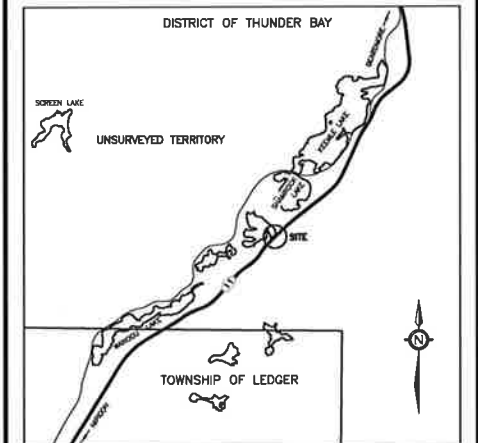
CONT No
WP No 6911-12-00

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

HATCH



THURBER ENGINEERING LTD.



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
16-01	257.6	5 458 583.0	222 042.0
16-02	257.4	5 458 612.0	222 016.8
BH1	263.5	5 458 600.3	222 038.1
BH2	263.3	5 458 593.4	222 030.8
BH3	263.3	5 458 602.1	222 026.7
BH4	263.7	5 458 611.0	222 036.2

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-40



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

Appendix E

Site Photographs



Photo 1: Shamrock Lake West Culvert Inlet



Photo 2: Shamrock Lake West Culvert Outlet



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



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



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