FOUNDATION INVESTIGATION REPORT
PROPOSED RAINBOW CREEK CULVERT REPLACEMENT
HIGHWAY 556 NEAR NORTHLAND, ONTARIO
WP 37-92-01 SITE NO. 38S-038/C

G.W.P. 5075-06-00

MTO GEOCRES NO. 41K-87

Prepared for:

McIntosh Perry Consulting Engineers

By:

SPL CONSULTANTS LIMITED

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

Project: 750-1001 (Rainbow Creek)
February, 2012

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1.0 INTRODUCTION

SPL Consultants Limited (SPL) was retained by McIntosh Perry Consulting Engineers to conduct a foundation investigation as part of the proposed culvert replacement at Rainbow Creek on Highway 556 approximately 22.9 km east of Highway 17 at Heyden, Ontario.

The terms of reference (TOR) for this investigation are outlined in the Request for Proposal (RFP) issued by the Ministry of Transportation (MTO) under Agreement No. 5010-E-0001 dated April 2010 and SPL's subsequent proposal No. P10.06.018 dated June 2010.

The purpose of the foundation investigation was to obtain subsurface information at the site by means of exploratory boreholes. This report presents the findings of the foundation investigation carried out at the site, as well as general comments and recommendations for the design and construction of the proposed culvert replacement.

As part of this project a geotechnical (pavement) investigation was also carried out at the site concurrent with the foundation investigation. The results of the pavement investigation are presented under separate cover.

2.0 SITE DESCRIPTION

The site is located on Highway 556 approximately 22.9 km east of Highway 17, northeast of Sault Ste. Marie, Ontario. The topography in the general area is comprised of the relatively flat Goulais River valley and floodplain, with steep bedrock-controlled upland areas. Rainbow Creek is a tributary of the Goulais River. The confluence of Rainbow Creek and the Goulais River is just downstream (north) of the crossing location, which is located within the main river valley.

The natural ground in the area of the crossing forms part of the Goulais River valley, and is flat to gently sloping. The elevation of the natural ground in the general vicinity of the Rainbow Creek crossing is approximately 225 m to 227 m. The elevation of the highway (top of pavement) at the crossing is approximately 229 m (the embankment is approximately 2 m to 4 m high at the crossing). Rainbow Creek itself flows within a small stream course approximately 20 m wide and 1 m to 1.5 m deep. At the time of the investigation the creek was partially frozen, with the water level at approximately 225.5 m.

3.0 INVESTIGATION PROCEDURES

The foundation investigation was carried out in February 2011. The scope of work for this assignment included a desk study, field investigations, laboratory testing, analysis and preparation of this report.

3.1 Desk Study

Surficial geology in the area comprises fluvial and glacio-fluvial deposits in the Goulais River valley (within which the Rainbow Creek crossing is located). These deposits generally would be expected to include silt, sand and gravel deposits, as well as potentially cobbles and boulders.

Bedrock geology maps of the general area indicate the bedrock to be foliated to gneissic tonalite and granodiorite.

3.2 Field Investigation

Field investigations were carried out on February 3, 2011 and included drilling a total of 4 boreholes at the crossing location (BH-1 through BH-4). As mentioned previously, additional shallow boreholes were advanced at the same time for the geotechnical (pavement) portion of the work; the results of these boreholes are submitted with the geotechnical (pavement) investigation report under separate cover.

The boreholes were advanced using a truck-mounted drill rig supplied and operated by George Downing Estate Drilling of Hawkesbury, QC. The boreholes were drilled using hollow-stem auger drilling as well as Dynamic Cone Penetration Testing (DCPT) to depths ranging from 2.5 m to 18.3 m below the existing ground surface. During drilling, sampling and in-situ testing including Standard Penetration (SPT) Testing and DCPT testing, were carried out.

During the course of the field investigation, loose flowing conditions were encountered in the sandy soils below the existing water table. Ordinarily, the hollow-stem augers would be filled with water to balance the hydrostatic pressures on the inside and outside of the auger, and to reduce any heaving and soil disturbance caused by unbalanced hydrostatic pressures (which is common in cohesionless soils below the water table). Due to the weather conditions at the time of drilling and the location of the boreholes on the existing highway, the use of additional water during drilling was not permitted. Once the boreholes were advanced below the water table, heaving and flow of the soil into the hollow-stem augers began to occur.

This heaving condition eventually became severe enough to necessitate the abandonment of BH-1 and BH-4 at approximately 6 m depth (or about 2 m to 3 m below the groundwater level).

A standpipe piezometer was installed in borehole BH-4 to allow for subsequent measurement of stabilized groundwater levels at the site. All boreholes were backfilled with bentonite and soil cuttings and were sealed at the ground surface.

Borehole locations are shown in Drawing 2. Borehole logs are included in Appendix A of this report.

3.3 Laboratory Testing

Upon completion of drilling and in-situ testing, soil samples were returned to SPL's laboratory for further examination and classification. A laboratory testing program, including determination of natural water content, soil density, grain size distribution (sieve and hydrometer) and chemical analyses, was carried out on selected representative soil samples.

The results of natural water content tests are included on the relevant borehole logs in Appendix A. The results of determination of grain size distribution are summarized on the individual borehole logs and are presented in Drawings 3 and 4.

Chemical testing to determine sulphate content, chloride content, pH and soil resistivity was also carried out on selected soil samples obtained during drilling. The results of these tests are included in Appendix B.

4.0 SUBSURFACE CONDITIONS

The subsurface conditions at the site are discussed in the following sections. Detailed descriptions of the soil and groundwater conditions encountered at each of the borehole locations are included in the individual borehole logs in Appendix A.

4.1 Soil Conditions

4.1.1 Granular Fill

All of the boreholes drilled as part of this investigation were drilled on the existing highway. At all locations a layer of asphalt of approximately 200 mm thick was encountered, underlain by granular fill; these form the pavement structure of the highway, as well as the existing highway embankment.

The granular fill ranged from silty sand to sand and gravel, and in places included numerous cobbles and boulders. Auger refusal on cobbles and boulders was encountered within this layer at shallow depths at several locations during the field investigation.

The grain size curves for several samples of the granular fill are presented in Drawing 3. A summary of the grain size distribution of these samples is also presented in Table 1 below. It should be noted that these grain size distribution tests were carried out on samples obtained through SPT testing which does not recover coarse gravel, cobble and boulder sized particles. Because of this it is expected that the grain size distributions shown on Drawing 3 are likely finer overall than portions of the materials in the field. Based on observations during drilling, zones of predominantly cobbles and boulders and/or rock fill should be anticipated in the field.

Table 1 – Results of Grain Size Analyses for Fill Material

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH-2	SS3	3	55	38	4
BH-3	SS2	17	71	10	2
BH-3	SS3	14	53	31	2
BH-4	SS3	24	49	24	3

The density of the fill material (as interpreted based on SPT "N" values) typically ranged from dense to very dense, with localized areas being compact to dense. In coarser granular materials SPT "N" values can be influenced by the size of particles. Very high "N" values often reflect the presence of cobbles and boulders, rather than a very high density of the soil matrix itself.

The fill material extended to a depth of 2.3 m to 4.4 m below the existing road surface in the boreholes drilled as part of this investigation. This corresponds to elevations of 224.6 m to 226.8 m.

4.1.2 Native Silt, Sand and Gravel

The granular fill layer was underlain by native granular soils which extended to the depth of drilling in all of the boreholes drilled as part of this investigation.

The native soil deposits are an interlayered mix of soils ranging from sandy silt to sand and gravel, and would be expected to be fluvial or glaciofluvial deposits associated with the Goulais River valley (which is consistent with the information contained in published surficial geology maps of the area). The grain size distributions of several samples of the native soils are presented in Drawing 4, and are summarized in Table 2 below.

Table 2 – Results of Grain Size Analyses for Native Soils

Borehole No.	Sample No.	Grain Size Distribution			
		% Gravel	% Sand	% Silt	% Clay
BH-1	SS5	51	42	6	1
BH-1	SS6	25	69	5	1
BH-2	SS4	0	28	66	6
BH-2	SS5	12	35	50	3
BH-2	SS6	16	25	55	4
BH-4	SS4	0	43	54	3
BH-4	SS5	50	42	7	1
BH-4	SS6	17	68	14	1

The density of the native soils (as interpreted based on SPT "N" and DCPT resistance values) was found to be typically loose to compact near the interface between the granular fill and native soils, and

increase gradually with depth. SPT "N" values and DCPT resistance values are presented on the borehole logs included in Appendix A as well as on the Geosection provided as Drawing 2.

As discussed in Section 3.2 above, the use of water to balance hydrostatic pressures on the inside and outside of the augers during drilling below the water table was not permitted. As a result, some disturbance of the native soils at the base of the hollow-stem auger likely occurred due to heaving and loosening of the soil when the hollow-stem plug was removed to facilitate SPT testing and soil sampling. This disturbance tends to reduce the strength and density of the soil, yielding SPT "N" values which are lower than would otherwise exist in undisturbed soils. For this reason, it is considered that the density of the soil (very loose to loose) inferred based on "N" values indicated on the borehole logs likely represents a lower bound, or conservative estimate of the in-situ soil conditions. This assumption is generally supported by DCPT test results which typically show an increase in resistance to 5 to 10 blows per 300 mm of penetration after the cone is advanced a short distance below the base of the augered boreholes, indicating a loose to compact state.

4.1.3 Bedrock

Bedrock was not encountered in any of the boreholes drilled as part of this investigation and is, therefore expected to be greater than 18 m below the existing road surface.

4.2 Groundwater Conditions

Groundwater was encountered in all of the boreholes drilled below the elevation of the existing creek (approximately elevation 225.5 m). As discussed in Section 3.2 and 4.1 above, the use of water to balance the hydro-static head inside the boreholes due to weather conditions and the location of the boreholes was not premitted. Boreholes BH-1 and BH-4 had to be abandoned due to flowing sand within the hollow-stem augers when drilling advanced to about 2 m to 3 m below the existing creek.

A standpipe piezometer was installed in BH-4. The groundwater level at the site was measured the day after completion of drilling and found to be at elevation 225.4 m, which is approximately coincident with the level of the creek at the time of the investigation (which would be expected given the granular nature of the soils in the area).

It should be noted that the groundwater levels can vary and are subject to seasonal fluctuations as well as fluctuations in response to major weather events, and in particular for this site, in response to changes in the level of the creek. If construction is carried out at a time when the creek level is higher than the level in February 2011, a corresponding increase in groundwater levels should be anticipated.

4.3 Summary

A summary of the soil and groundwater conditions encountered at the Rainbow Creek crossing location is presented in Table 3 below.

Table 3 – Simplified Stratigraphy and Groundwater Elevations

Borehole No.	Ground Surface Elevation	Simplified Stratigraphy (Depth)		Measured Groundwater Elevation	Notes
		Granular Fill	Native Soils		
BH11-RC-1	229.0	0.0– 4.4 m	4.4 – 10. 7 m	--	Auger drilling ended at 6.1 m due to flowing sands
BH11-RC-2	229.1	0.0 – 2.3 m	2.3 – 18.3 m	--	--
BH11-RC-3	228.9	0.0 – 2.5 m	--	--	Auger refusal at 2.5 m
BH11-RC-4	229.0	0.0 – 3.0 m	3.0 – 18.3 m	El. 225.4 m	Auger drilling ended at 5.9 m due to flowing sands

5.0 CLOSURE

The field investigations were supervised by Mr. N'eem Tavakkoli, P.Eng. This report was prepared by Mr. Chris Hendry, P.Eng. Mr. Fanyu Zhu, who is the project manager and SPL's designated MTO contact and Mr. Shaheen Ahmad who is the project quality control auditor, provided quality control and independent review of the technical aspects of this report.

We trust that the information contained in this report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

SPL CONSULTANTS LIMITED

Chris Hendry, M.Eng., P.Eng.

Fanyu Zhu, Ph.D., P.Eng.

Shaheen Ahmad, M.A.Sc., P.Eng.

Drawings

Client:	**Ministry of Transportation Ontario**		Project No.:	**750-1001 (Rainbow Creek)**	Drawing No.: **1**
Drawn:	**NT**	Approved: **CH**	Title:	**SITE PLAN - RAINBOW CREEK**	
Date:	**February 22, 2011**	Scale: **N.T.S.**	Project:	**Foundation Investigation – Rainbow Creek Culvert Replacement Highway 556, Ontario**	
Original Size:	**Letter**	Rev: **N/A**		SPL Consultants Limited Geotechnical • Environmental • Materials • Hydrogeology	

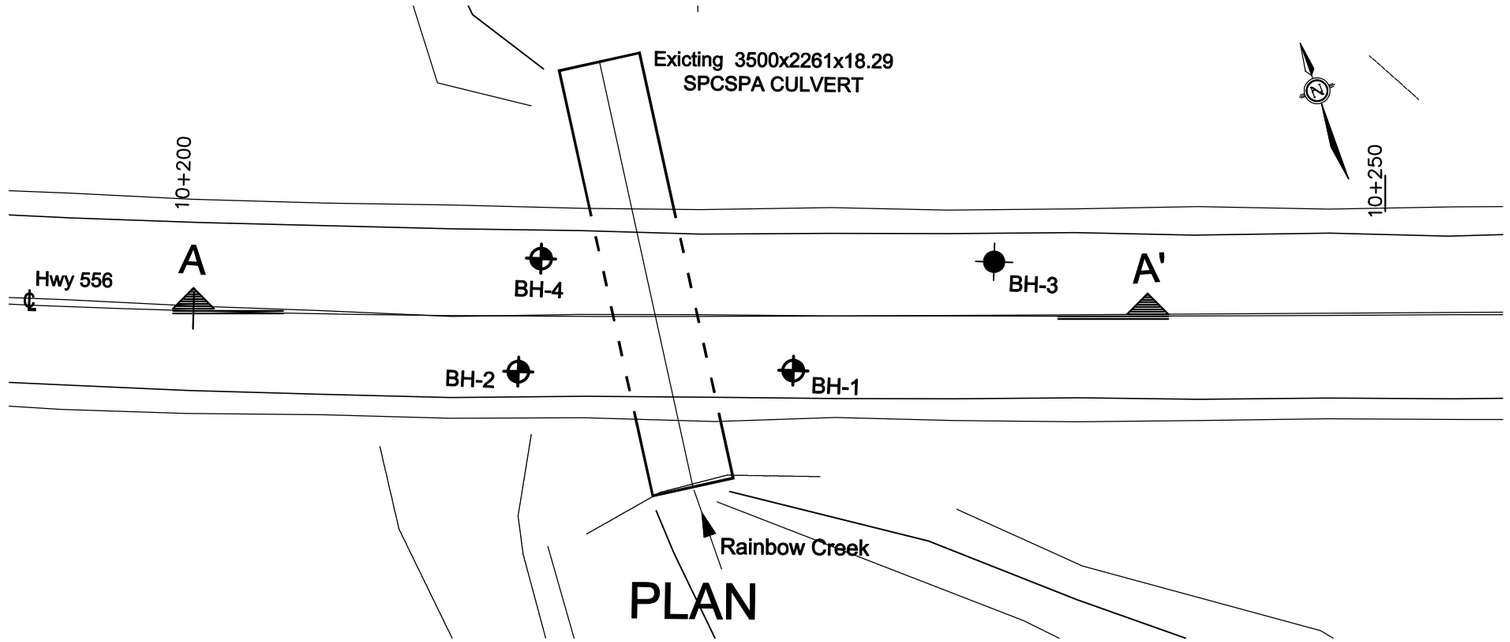
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

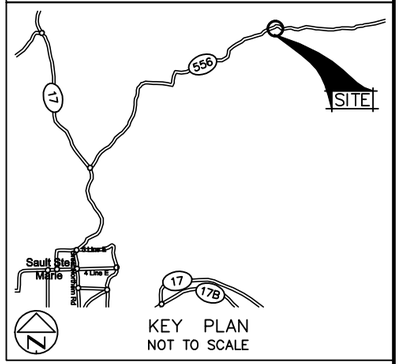
CONT No 2012-5108
WP No 37-92-01

RAINBOW CREEK CULVERT
HIGHWAY 556
BORE HOLE LOCATIONS & SOIL STRATA

SHEET
–

SPL Consultants Limited
Geotechnical • Environmental • Materials • Hydrogeology



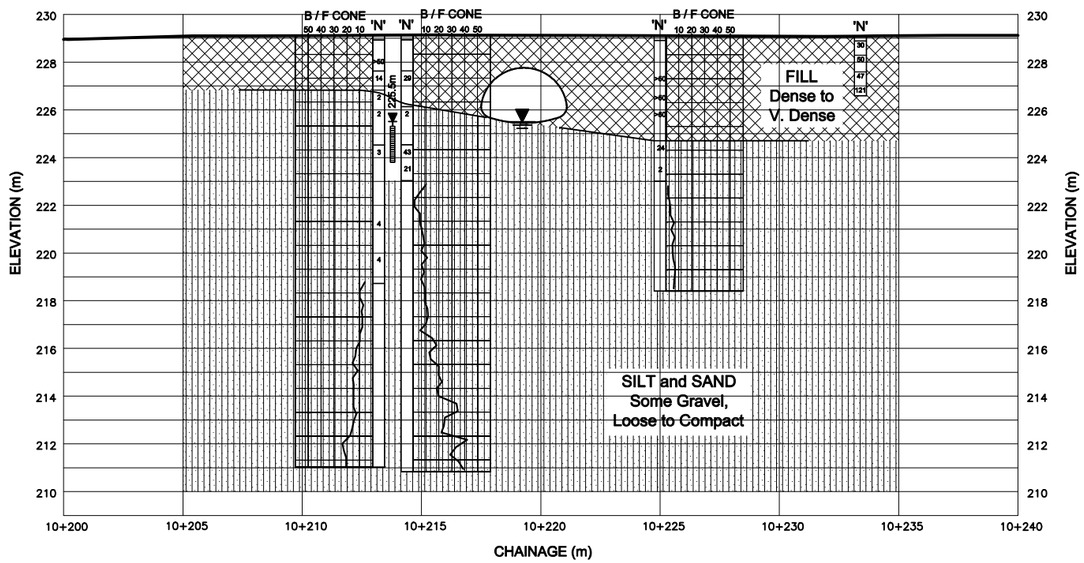


LEGEND

- Bore Hole
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- WL at time of investigation July 2011
- WL in Piezometer
- Piezometer

No	ELEVATION	STATION	OFFSET
BH-1	229.1	10+225.2	2.3m S
BH-2	229.1	10+213.7	2.4m S
BH-3	229.1	10+233.5	2.2m N
BH-4	229.1	10+214.5	2.3m N

BH-2 (Offset 2.4m S) BH-4 (Offset 2.3m N) BH-1 (Offset 2.3m S) BH-3 (Offset 2.2m N)



SOIL STRATA SYMBOLS
- GRANULAR FILL
- SILT AND SAND

— NOTES —
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

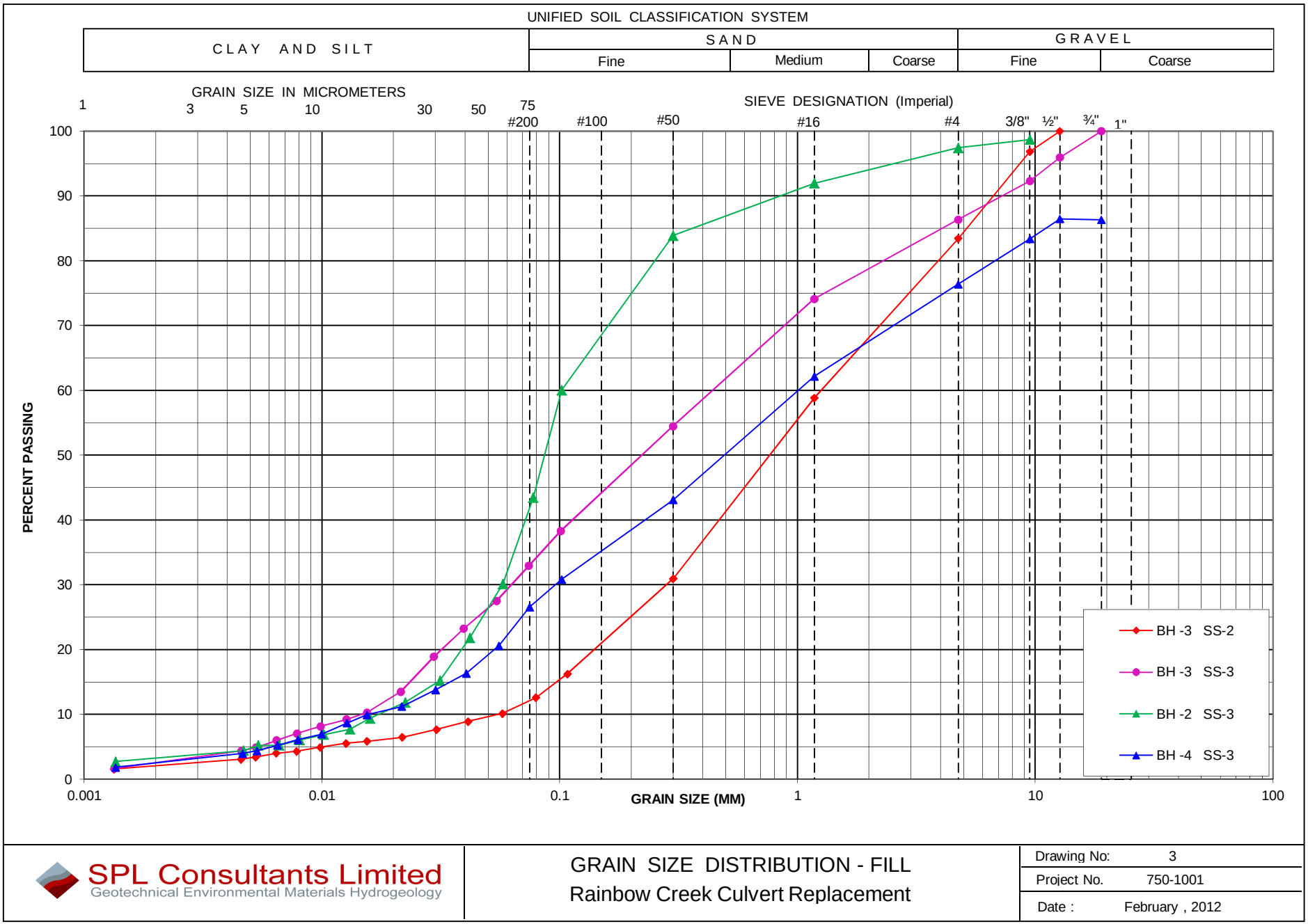
CROSS SECTION A-A'

SCALE
2.5m 0 2.5 5m

REVISIONS			
Feb16/12	TJC	Final Reversion	
DATE	BY	DESCRIPTION	

GEOCRES No 41K-87

HWY No 556				DIST Algoma
SUBM'D CH	CHECKED CH	DATE Feb 16, 2012		SITE 385-038/C
DRAWN TJC	CHECKED CH	APPROVED FZ		DWG 2



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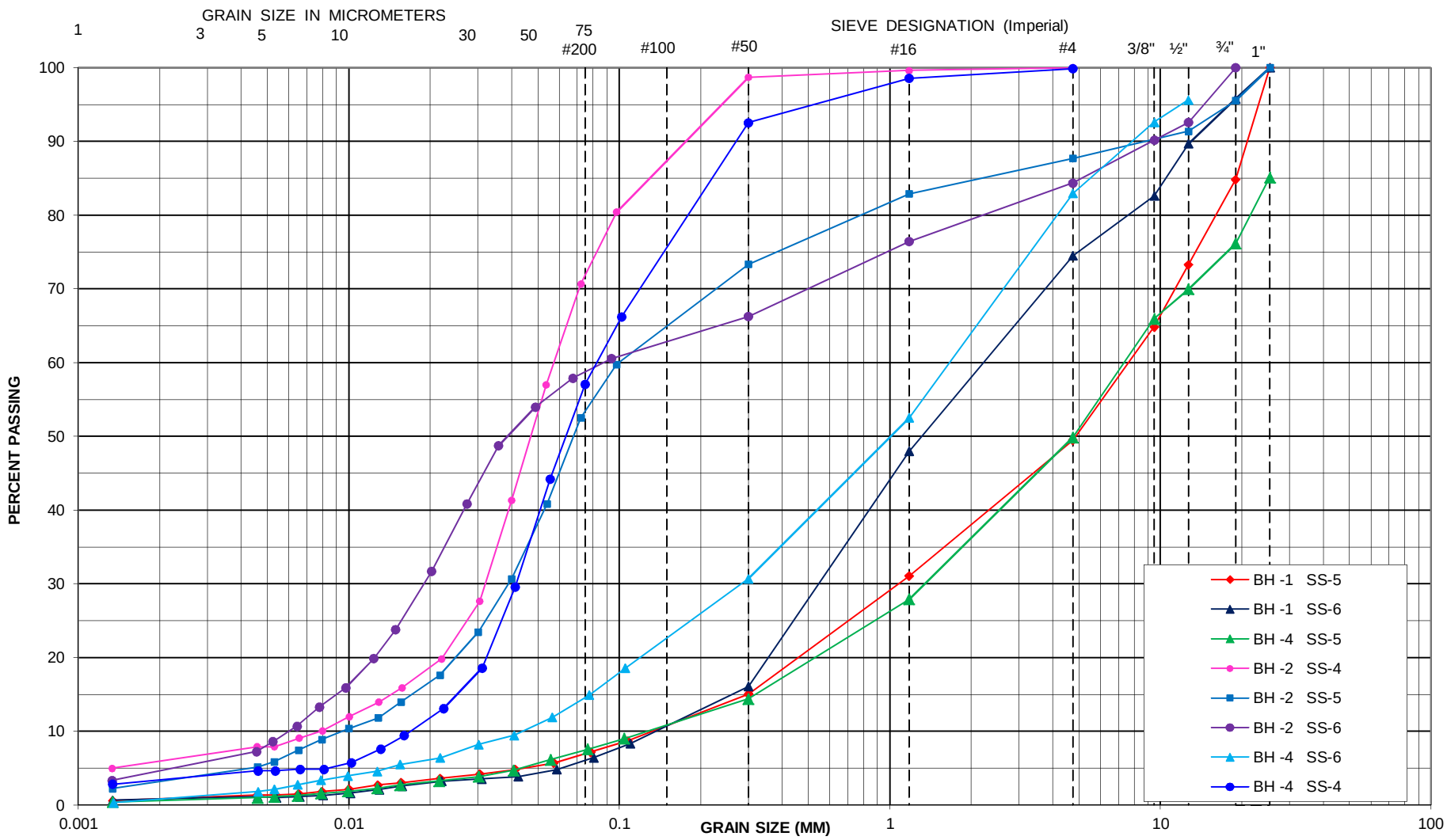
GRAIN SIZE DISTRIBUTION - FILL
Rainbow Creek Culvert Replacement

Drawing No: 3
Project No. 750-1001
Date : February , 2012

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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GRAIN SIZE DISTRIBUTION - NATIVE MATERIAL
Rainbow Creek Culvert Replacement

Drawing No: 4
Project No. 750-1001
Date : February , 2012

Appendix A

Borehole Logs (Record of Borehole Sheets)

Ministry of Transportation Ontario

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SPL 750-1001

RECORD OF BOREHOLE No BH-1 1 OF 2 METRIC

W.P. 37-92-01 LOCATION See Borehole Location Plan ORIGINATED BY NT

DIST HWY 556 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NT

DATUM Geodetic DATE 03/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
229.0								20 40 60 80 100	10 20 30		
0.0 / 228.8	0.20m **ASPHALT**										
0.2	**Fill: Sandy Gravel & Cobbles** with occasional boulders brown, damp very dense		1	AS			228		○		
			2	SS	> 50		227				
			3	SS	> 50		226				
			4	SS	> 50		225				
224.6											
4.4	**SAND & GRAVEL** trace silt dark brown, saturated compact		5	SS	24		224		○		51 42 6 1
	---------- gravelly sand disturbed due to flowing sand		6	SS	2		223		○		25 69 5 1
222.8											
6.3	End of auger drilling due to flowing sand. Continued with Dynamic Cone Penetration test						222				
							221				
							220				

Continued Next Page

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

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Geotechnical Environmental Materials Hydrogeology

SPL 750-1001

RECORD OF BOREHOLE No BH-1 2 OF 2 METRIC

W.P. 37-92-01 LOCATION See Borehole Location Plan ORIGINATED BY NT

DIST HWY 556 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NT

DATUM Geodetic DATE 03/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
218.3	End of auger drilling due to flowing sand. *(continued)*										
10.7	**End of Borehole** Notes: 1. Water level in borehole at approximately 4m depth at the end of auger drilling.										

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

ON_MOT SPL-M -MTO-750-MAR15-RAINBOWBRIDGE.GPJ ON_MOT.GDT 15/2/12

Ministry of Transportation Ontario

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

SPL 750-1001

RECORD OF BOREHOLE No BH-2

1 OF 2

METRIC

W.P. 37-92-01 LOCATION See Borehole Location Plan ORIGINATED BY NT

DIST HWY 556 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NT

DATUM Geodetic DATE 03/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
229.1								20 40 60 80 100	10 20 30		
0.0 / 228.9	0.20m **ASPHALT**						229				
0.2	**Fill: Silty Sand** with gravel and cobbles brown, damp very dense		1	AS					○		
			2	SS	> 50		228		○		
	---------- sandy silt, trace gravel, trace clay moist, compact		3	SS	14				○		3 55 38 4
226.8							227				
2.3	**SANDY SILT** trace clay brown, wet very loose to loose		4	SS	2				○		0 28 66 6
	---------- some gravel (likely disturbed due to flowing sandy soil)		5	SS	2		226		○		12 35 50 3
	---------- grey		6	SS	3		225		○		16 25 55 4
							224				
							223				
							222				
			7	SS	4		221		○		
							220				
			8	SS	4				○		

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

ON_MOT SPL-M -MTO-750-MAR15-RAINBOWBRIDGE.GPJ ON_MOT.GDT 15/2/12

Ministry of Transportation Ontaio

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

SPL 750-1001

RECORD OF BOREHOLE No BH-2

2 OF 2 **METRIC**

W.P. 37-92-01 LOCATION See Borehole Location Plan ORIGINATED BY NT

DIST HWY 556 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NT

DATUM Geodetic DATE 03/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
218.7							219				
10.4	End of augering. Continued with Dynamic Cone Penetration test						218				
							217				
							216				
							215				
							214				
							213				
							212				
210.8							211				
18.3	**End of Borehole** Notes: 1. Water level in borehole at approximately 4m depth at the end of auger drilling.										

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

ON_MOT SPL-M -MTO-750-MAR15-RAINBOWBRIDGE.GPJ ON_MOT.GDT 15/2/12

Ministry of Transportation Ontario

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Geotechnical Environmental Materials Hydrogeology

SPL 750-1001

RECORD OF BOREHOLE No BH-3 1 OF 1 METRIC

W.P. 37-92-01 LOCATION See Borehole Location Plan ORIGINATED BY NT

DIST HWY 556 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NT

DATUM Geodetic DATE 03/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
228.9								20 40 60 80 100	10 20 30		
0.0 / 228.7	0.20m **ASPHALT**										
0.2 / 228.1	**Fill: Sandy Gravel** with cobbles, trace clay, brown, damp, dense		1	SS	30				○		
0.8	**Fill: Sand** some gravel, some silt to silty, trace clay, with cobbles, brown, moist, very dense		2	SS	50		228		○		17 71 10 2
	wet, dense		3	SS	47		227		○		14 53 31 2
226.4	very dense		4	SS	121						
2.5	**End of Borehole** Notes: 1. Auger refusal at 2.5 m during drilling. 2. No water found in borehole at the end of drilling.										

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

ON_MOT SPL-M -MTO-750-MAR15-RAINBOWBRIDGE.GPJ ON_MOT.GDT 15/2/12

Ministry of Transportation Ontario

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

SPL 750-1001

RECORD OF BOREHOLE No BH-4

1 OF 2

METRIC

W.P. 37-92-01 LOCATION See Borehole Location Plan ORIGINATED BY NT

DIST HWY 556 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NT

DATUM Geodetic DATE 03/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
229.0								20 40 60 80 100	10 20 30		
0.0 / 228.8	0.20m **ASPHALT**										
0.2	**Fill: Sand & Gravel** brown, damp dense		1	AS					○		
			2	AS			228		○		
227.5											
1.5	**Fill: Silty Sand** with gravel, trace clay brown, damp compact		3	SS	29		227		○		24 49 24 3
226.0											
3.0	**SAND & SILT** trace clay brown, wet very loose to loose (likely disturbed due to flowing sandy soil)		4	SS	2		226		○		0 43 54 3
224.4							225				
4.6	**SAND & GRAVEL** trace silt brown, saturated dense		5	SS	43		224		○		50 42 7 1
223.7											
5.3	**SAND** some silt, some gravel brown, saturated compact		6	SS	21				○		17 68 14 1
223.1							223				
5.9	End of augering due to flowing sand Continued with Dynamic Cone Penetration test						222				
							221				
							220				

Continued Next Page

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

Ministry of Transportation Ontaio

SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

SPL 750-1001

RECORD OF BOREHOLE No BH-4 2 OF 2 METRIC

W.P. 37-92-01 LOCATION See Borehole Location Plan ORIGINATED BY NT

DIST HWY 556 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NT

DATUM Geodetic DATE 03/02/2011 CHECKED BY CH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	End of augering due to flowing sand Continued with Dynamic Cone Penetration test *(continued)*						218 217 216 215 214 213 212 211				
210.7 18.3	**End of Borehole** Notes: 1. Piezometer installed to depth of 5.3 m. 2. Water level in piezometer Date / Depth (m) / Elevation (m) Feb.03, 2010 3.65 225.35 Feb.04, 2010 3.60 225.40										

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

ON_MOT SPL-M-MTO-750-MAR15-RAINBOWBRIDGE.GPJ ON_MOT.GDT 15/2/12

Appendix B

Chemical Test Results

EXOVA ACCUTEST

REPORT OF ANALYSIS

Exova Accutest

Client: **SPL Consultants LTD**
146 Colonnade Rd
Ottawa, ON
K2E 7Y1
Attention: **Mr.Neem Tavakkoli**

Report Number: 1103444
Date: 2011-03-01
Date Submitted: 2011-02-23

Project: 750-1001

P.O. Number: Visa
Matrix: Soil

Chain of Custody Number: 740883

			LAB ID:	863876	863877				GUIDELINE		
			Sample Date:	2011-02-23	2011-02-23						
			Sample ID:	BH11-RC-2/SS-8	BH11-RC-4/SS-3						
PARAMETER	**UNITS**	**MRL**							**TYPE**	**LIMIT**	**UNITS**
Chloride	%	0.002		<0.002	0.027						
Electrical Conductivity	mS/cm	0.05		0.08	0.83						
pH				8.7	7.2						
Resistivity	ohm-cm	1		12500	1210						
Sulphate	%	0.01		0.03	0.02						

MRL = Method Reporting Limit INC = Incomplete AO = Aesthetic Objective OG = Operational Guideline MAC = Maximum Allowable Concentration IMAC = Interim Maximum Allowable Concentration

Comment:

APPROVAL: _____
Lorna Wilson
Agriculture Lab Supervisor

Methods references and/or additional QA/QC information available on request.

Appendix C

Explanation of Terms Used in Report

EXPLANATION OF TERMS USED IN REPORT

N-VALUE: THE STANDARD PENETRATION TEST (SPT) N-VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5 kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N-VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N-VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60˚ CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

C_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINT AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
σ_1, σ_2, σ_3	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
ε_1, ε_2, ε_3	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICALL PROPERTIES OF SOIL

m_v	kPa $^{-1}$	COEFFICIENT OF VOLUME CHANGE
c_c	1	COMPRESSION INDEX
c_s	1	SWELLING INDEX
c_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
Φ'	-^{o}	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
Φ_u	-^{o}	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	s_r	%	DEGREE OF SATURATION	D_n	mm	N PERCENT – DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_P	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_P	%	PLASTICITY INDEX = (W_L – W_L)	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = (W – W_P)/ I_P	i	1	HYDAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = (W_L – W) / 1_P	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERED SOIL	$e_{,max}$	1,%	VOID RATIO IN LOOSEST STATE	j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						