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FOUNDATION INVESTIGATION AND DESIGN REPORTS
PROPOSED REPLACEMENT OF CULVERT C4 UNDER HIGHWAY 48
STATION 19+833 WHITCHURCH-STOUFFVILLE TOWNSHIP
SOUTH OF ST. JOHN'S SIDEROAD, YORK REGION, ONTARIO
GWP 2070-13-00, CONTRACT PACKAGE 1

GEOCRES No. 31D-600

Prepared For:
Ainley Group
280 Pretty River Parkway
Collingwood, ON
L9Y 4J5

SPL Project No.: 10000964-1
March 20, 2015

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1. INTRODUCTION

As part of the rehabilitation of Hwy 48, from 0.25 km north of York Road 15 (Aurora Road) to 0.5 km south of York Road 9 (High Street), SPL Consultants Limited (SPL) was retained by Ainley Group (Ainley) under MTO Central Region GWP 2070-13-00, Contract Package 1, to undertake a foundation investigation at the site of the proposed replacement of the existing Culvert C4 under Highway 48 in the Township of Whitchurch-Stouffville, within the Regional Municipality of York, Ontario.

The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of exploratory boreholes, and to determine the engineering characteristics of the subsurface soils by means of field and laboratory tests.

The findings of the investigation are presented in this report.

2. SITE DESCRIPTION AND PHYSIOGRAPHY

The site of the culvert replacement is located on Highway 48, about 0.65 km south of St. John's Sideroad and 1.4 km north of Aurora Road, near Ballantrae, Ontario (see Drawing No. 1A). Highway 48 is a two lane, north-south rural arterial undivided highway. The existing 750 mm diameter CSP culvert at the site is skewed under an earth embankment of about 5.5 to 7 m in height. There are existing private driveways just to the north and south of the culvert. Site Photographs are shown in **Appendix A**.

Based on the Physiography of Southern Ontario (Chapman & Putnam, 1984), the project site is situated within the Oak Ridges Moraine physiographic region. The soils of Oak Ridges Moraine changes from glaciolacustrine to glaciofluvial to glacial till deposits. In particular, the soils at the site generally consist of sands and silts. The bedrock in this area consists of dark grey to black shale of the Whitby Formation and is estimated to be greater than 150 m in depth.

3. FIELD AND LABORATORY WORK

3.1 Field Work

The field investigation for this project was conducted on January 9 to 21, 2015, and this consisted of putting down twelve (12) boreholes (Boreholes BH-1 through BH-4 for the culvert and the remaining boreholes, including BH-1 and BH-2, for possible embankment widening for detour) to depths of 3.7 to 9.8 m below existing ground surface at the locations shown on the attached **Drawing No. 1**. The geodetic elevations of the ground and coordinates at the locations of these boreholes were surveyed by SPL.

The boreholes were advanced using a truck and track-mounted drilling rigs owned and operated by Drilltech Drilling Ltd. of Newmarket, Ontario, under the full-time supervision of engineering staff from SPL. The boreholes were advanced with a power auger machine to the specified depths. The soil stratigraphy was recorded by observing the quality and changes of augered materials which were withdrawn from the boreholes, and by sampling the soils at regular intervals of depth using a 50mm O.D. split spoon sampler, in accordance with the Standard Penetration Test (ASTM D 1586) method. This sampling method recovers samples from the soil strata, and the number of blows required to drive the sampler 0.3m depth into the undisturbed soil (SPT 'N'-values) gives an indication of the compactness condition or consistency of the sampled soil material. Due to access difficulty with a drill rig, Borehole BH-4 was drilled using hand-drilling method. The SPT 'N' values are indicated on the Borehole Logs (Refer to **Appendix B**). Soil samples were visually classified in the field and later re-evaluated by a senior engineer in our laboratory.

Groundwater levels in the open boreholes were observed during the drilling and at completion of each borehole. In addition, a monitoring well was installed in Borehole BH-3 for longer-term monitoring of groundwater levels. The groundwater levels in the monitoring well were measured on January 15 and 22, 2015 and the data are summarized at the bottom of the borehole log sheets.

3.2 Geotechnical Laboratory Testing

The soil samples were taken to our laboratory where they were re-examined. Representative samples were selected for geotechnical index testing. The testing program consisted of the measurement of the natural moisture content of all samples, grain size analyses on eighteen (18) selected samples (ten on fill materials and eight on natural soils). Test results are shown on the individual borehole logs presented in **Appendix B**. The grain size analysis curves are plotted on Figures 1 and 2 attached to this report in **Appendix C**.

4. SUMMARY OF SUBSURFACE CONDITIONS

4.1 Overview

The boreholes revealed, below the topsoil and pavement, the presence of embankment or surficial fill materials consisting mainly of silty sand to sand with occasional sandy silt, gravelly sand and clayey silt layers. The fill is underlain by natural cohesionless soils consisting of silty sand to sand with occasional silt layers. Groundwater was encountered at about 9 m (El. 330.5 m) below the existing road grade at the culvert location.

For details of the subsurface conditions encountered at the borehole locations, reference should be made to the individual borehole log sheets presented in **Appendix B**. The stratigraphic sections and profiles along the culvert and along the road within about 150 m of the culvert are presented in **Drawing Nos. 1 and 2**. The following description of the individual soil strata is to assist the designers of the project with an understanding of the anticipated subsurface conditions underlying the site. It should be noted that the soil and groundwater conditions may vary in between and beyond borehole locations.

The summarized subsurface conditions at the site are described in the following paragraphs.

4.2 Pavement Structure

Borehole BH-2 was drilled on the existing pavement and this encountered 260 mm of asphalt over 260 mm thick of pavement granular fill. Boreholes BH-3, BH-6, BH-8, BH-9 and BH-11 were drilled on the existing gravel shoulders of the road and these contacted about 0.5 to 0.6 m of pavement granular fill. The granular fill varied from crusher run limestone to gravelly sand to sand and gravel with occasional silty sand zones.

4.3 Topsoil and Fill

Topsoil was encountered at the ground surface in Boreholes BH-1, BH-4, BH-5, BH-7, BH-10 and BH-12. The thickness of this material varied from about 280 to 500 mm.

Below the topsoil and pavement granular fill, embankment fill or surficial fill materials were encountered in the boreholes extending to depths ranging from 0.8 to 6.4 m below existing grade. The fill is composed of silty sand to sand with occasional sandy silt, gravelly sand and clayey silt layers.

Grain size distribution tests were conducted on 10 samples of the fill and the results are presented on Figure 1 in **Appendix C**, as indicated below:

Cohesionless Fill (silty sand, sand, sandy silt, gravelly sand):

Gravel:	0 to 7%
Sand:	35 to 79%
Silt:	9 to 53%
Clay:	5 to 12%

Cohesive Fill (clayey silt):

Gravel:	2%
Sand:	33%
Silt:	48%
Clay:	17%

The compactness condition of the fill, in general, was found to be compact to dense, as inferred from SPT 'N' values of 11 to 40 blows per 0.3m penetration. Loose and very dense zones were also encountered in the fill as evidenced by low 'N' values of 4 to 9 blows/0.3m (e.g. 6 blows/0.3m in Borehole BH-3 at a depth of 4.9m) and high 'N' values of 60 to 67 and 50/0.15m. Measured 'N' values in the clayey silt fill layer encountered in Borehole BH-9 were 11 and 18 blows/0.3m indicating stiff to very stiff consistency. The natural moisture content measured in the test samples from the fill materials ranged from 3% to 23%.

4.4 Silty Sand to Sand

Underlying the fill, all the boreholes encountered a predominant deposit of silty sand to sand extending to the full depths of the boreholes, except in Boreholes BH-2 and BH-10 where the silty sand to sand extended to depths of 8.7 and 2.3 m, respectively, overlying the silt. The silty sand to sand deposit contains traces of gravel, trace of clay with occasional sandy silt or clayey silt seams or pockets.

The grain size distribution curves for six (6) tested samples of the silty sand to sand are presented below, in Figure 2 in **Appendix C**.

Gravel:	0 to 2%
Sand:	52 to 90%
Silt:	6 to 41%
Clay:	5 to 8%

SPT 'N' values in this cohesionless soil were in the range of 3 to 67 blows/0.3m penetration, corresponding to very loose to very dense compactness condition, generally compact to dense. Natural moisture contents were measured in the test samples to range from 3% to 22%.

4.5 Silt

Below the silty sand to sand in Boreholes BH-2 and BH-10, a layer of silt deposit was encountered at depths of 8.7 and 2.3 m, respectively, extending to the maximum explored depths of the boreholes. The silt contains traces of sand and clay and occasional silt sand seams.

The grain size distribution curve for one (1) tested sample of the silt is presented below, on Figure 2 in **Appendix C**.

Gravel:	0 %
Sand:	4%
Silt:	88%
Clay:	8%

SPT 'N' values in this cohesionless soil were in the range of 14 to 24 blows/0.3m penetration, corresponding to a compact state condition. Natural moisture contents were measured in the test samples to range from 19% to 24%, indicating wet condition.

4.6 Groundwater Conditions

Groundwater levels in the open boreholes were observed during the drilling and at completion of each borehole. In addition, a monitoring well was installed in Borehole BH-3 to allow groundwater monitoring over a prolonged period of time, without interference from surface water. The observations and recorded values are shown on the individual Record of Borehole sheets.

Most of the boreholes were dry at completion except at Boreholes BH-1, BH-2 and BH-4 in the culvert area, where water levels of 9.1 m or El. 330.5m (in BH BH-3) below the road grade and 3.2 to 4.2 m or El. 329.9 to 330.4m (in BHs 1 and 4) below the bottom of the embankment were observed. The groundwater level in the monitoring well in Borehole 3 showed dry condition to a depth of 9.1m or El. 330.1m.

Based on the above measurements, measured moisture contents and observations of the recovered soils samples, the groundwater table is likely between about El. 330 and 331 m, or about 9 m below the existing road grade. It should, however, be pointed out that the groundwater at the site would be subject to seasonal fluctuations as well as fluctuations due to weather events.

5. CLOSURE

Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated.

Interpretation of data and preparation of this report were carried out by Mr. Ramon Miranda, P. Eng. and Ms. Alka Sangar, P. Eng. The report was reviewed by Dr. Fanyu Zhu, P. Eng., a Designated Principal Contact for MTO Foundations Projects.

Yours very truly,

SPL CONSULTANTS LIMITED

Ramon Miranda, P. Eng.
Senior Geotechnical Engineer

Alka Sangar, P. Eng.
Senior Geotechnical Engineer

Fanyu Zhu, Ph. D., P. Eng.
Designated MTO Foundation Contact

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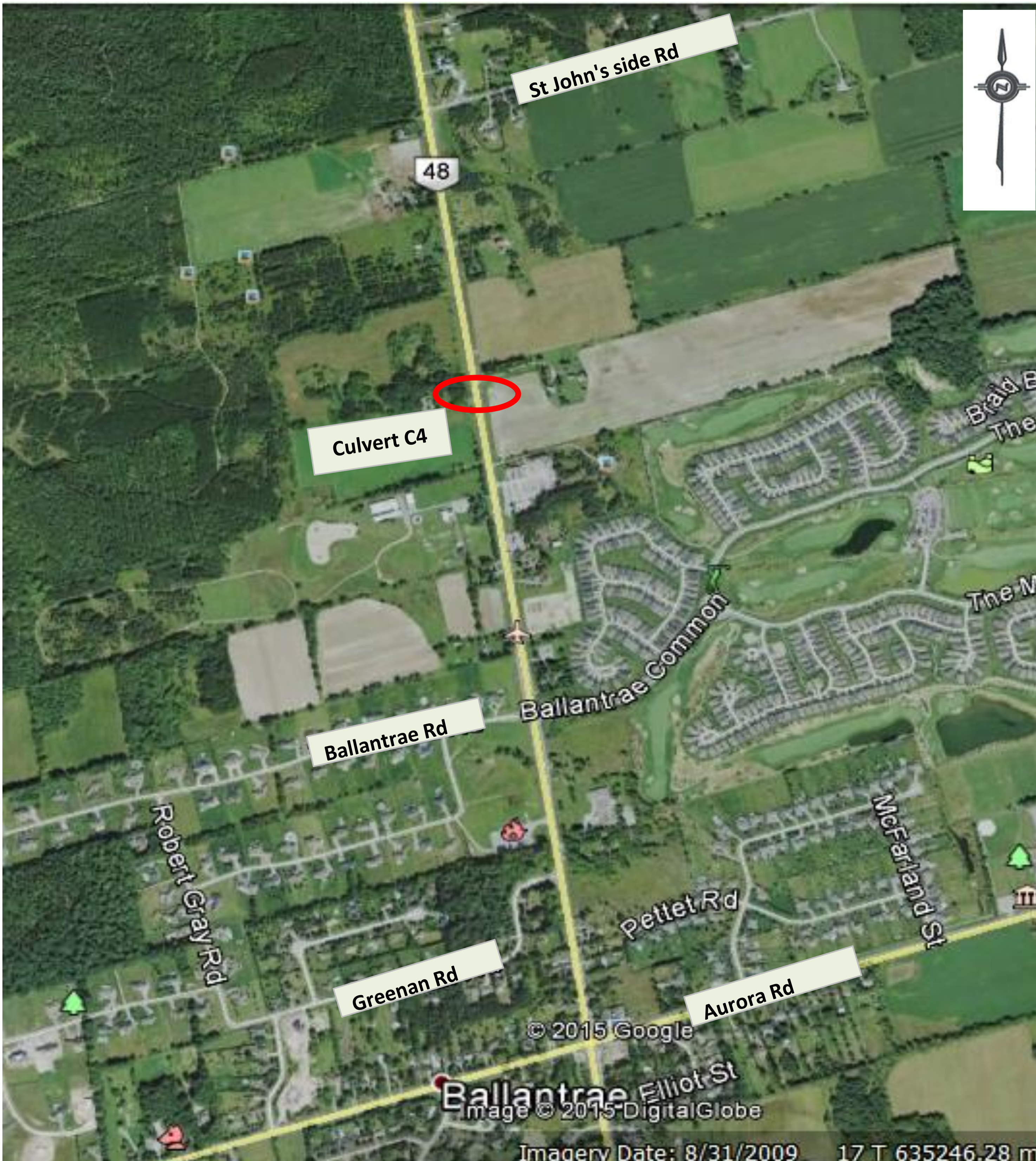
DRAWINGS

Site Plan (Drawing No. 1A)

Borehole Locations and Soil Strata (Drawing Nos. 1 and 2)



Client:	Ainley Group			GWP 2070-13-00, Contract 1	Drawing No:	1A
Drawn:	OB	Approved:	RM	Title:	Key Plan, Culvert C4, Highway 48	
Date:	20/02/2015	Scale:	N.T.S	Project:	Foundation investigation for proposed replacement of Culvert C4 under Hwy 48 Station 19+833	
Original Size:	Letter	Rev:	N/A	SPL Consultants Limited Geotechnical Environmental Materials Hydrogeology		

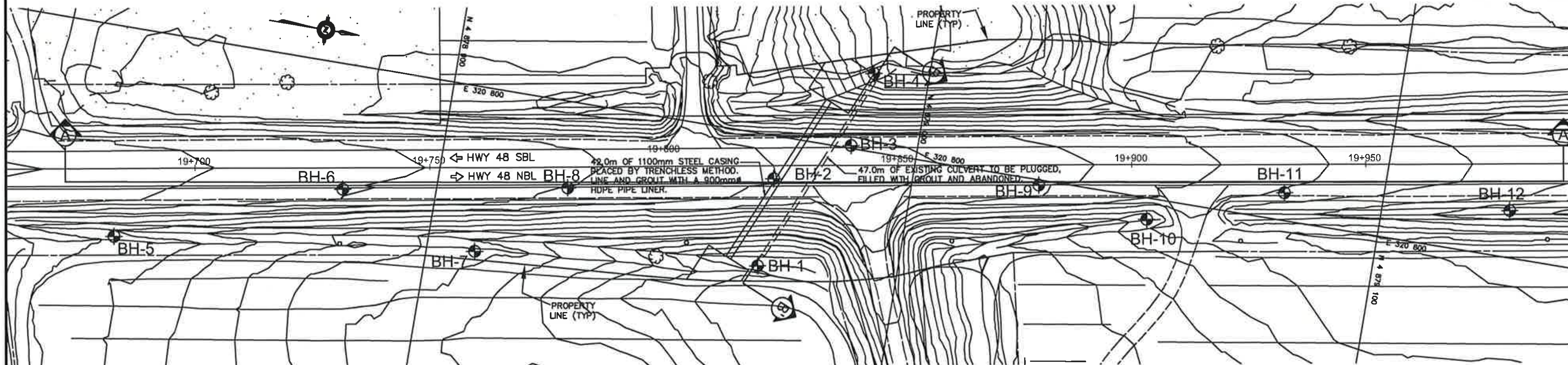
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

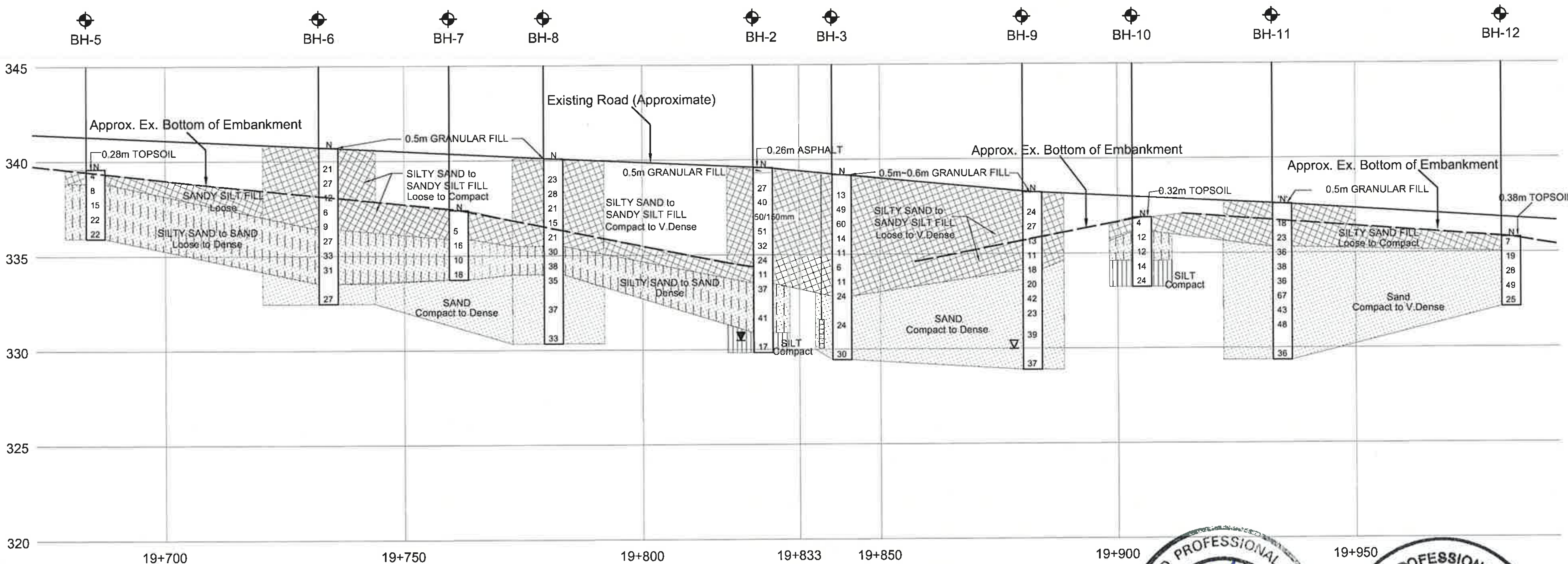
GWP 2070–13–00

SHEET

Culvert C4
Station 19+833– Hwy 48
BORE HOLE LOCATIONS & SOIL STRATA

SPL Consultants Limited
Geotechnical • Environmental • Materials • Hydrogeology





SECTION A-A'

SOIL STRATA SYMBOLS

- Fill
- Silty Sand to Sand
- Sand
- Silt

LEGEND

- BH-1 Borehole
- Water level
- Water level (inferred)

BH No	ELEVATION	NORTHING	EASTING
BH-1	334.6	4878970.3	320828.1
BH-2	339.6	4878970.7	320809.1
BH-3	334.2	4878985.9	320799.4
BH-4	333.0	4878988.2	320783.4
BH-5	339.6	4878834.0	320844.6
BH-6	340.7	4878910.2	320835.0
BH-7	337.4	4878910.2	320835.0
BH-8	340.1	4878927.5	320818.3
BH-9	338.6	4879026.8	320801.1
BH-10	336.9	4879050.8	320804.6
BH-11	337.6	4879079.0	320794.1
BH-12	335.8	4879127.1	320789.9

— NOTES —

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

Locations and Elevations of Boreholes Drilled in 1959 are approximate only and have not been verified.

LICENSED PROFESSIONAL ENGINEER
RAMON MIRANDA
Mar 20/15
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
F. ZHU
Mar. 20/15
PROVINCE OF ONTARIO

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 31D-600

HWY No			DIST
SUBM'D	CHECKED	DATE Jan 28, 2015	SITE
DRAWN OB	CHECKED RM	APPROVED RM	DWG 1

\\SERVER\Geotech\10 GeoProjects\1-1000 Projects\10000964 – Hwy 48-Central Region (Ainley)\Drawings\Final Drawing\10000964 HWY48-March20-2015-Final.dwg Printed: Mar 20, 2015

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

GWP 2070-13-00

Culvert C4
Station 19+833– Hwy 48
BORE HOLE LOCATIONS & SOIL STRATA

SHEET

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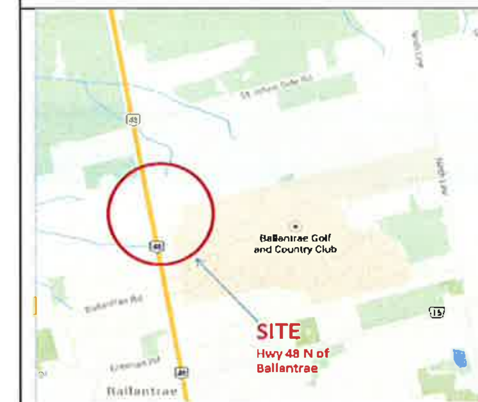
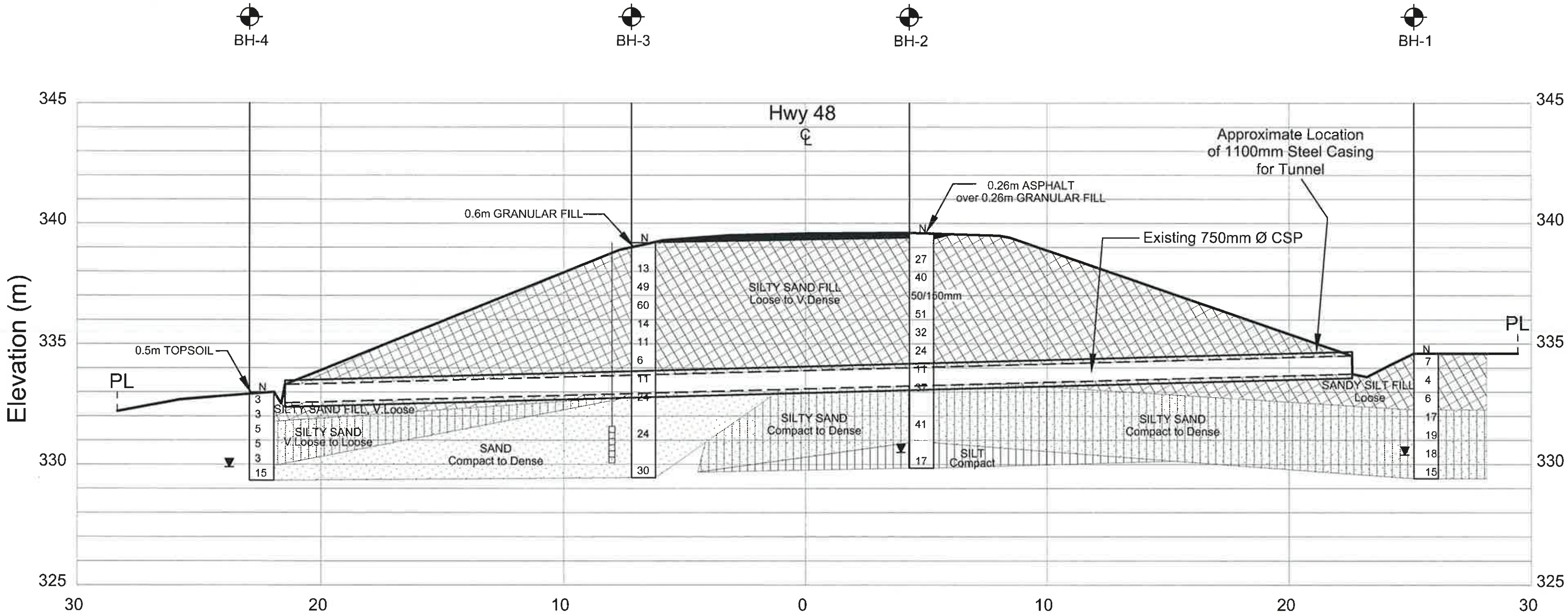


KEY PLAN
NOT TO SCALE



CROSS-SECTION B-B' @ STATION 19+833

LEGEND

BH-1 Borehole

Water level

BH No	ELEVATION	NORTHING	EASTING
BH-1	334.6	4878970.3	320828.1
BH-2	339.6	4878970.7	320809.1
BH-3	334.2	4878985.9	320799.4
BH-4	333.0	4878988.2	320783.4

— NOTES —

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

Locations and Elevations of Boreholes Drilled in 1959 are approximate only and have not been verified.

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F. ZHU
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SOIL STRATA SYMBOLS

Fill
Silty Sand to Sand
Sand
Silt

REVISIONS		
DATE	BY	DESCRIPTION

Geocres No. 31D-600

HWY No			DIST
SUBM'D	CHECKED	DATE Jan 28, 2015	SITE
DRAWN OB	CHECKED RM	APPROVED RM	DWG 2

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APPENDICES

Appendix A

Site Photographs (taken by SPL in December 2014 and January 2015)

Photo 1: Ditch on East Side of Hwy 48- Looking South

Photo 2: Location of BH 1 and Culvert C4 in ditch East of Hwy 48

Photo 3: Location of BH 2 on East Shoulder of Hwy 48- Looking South

Photo 4: Location of Culvert C4 in ditch West of Hwy 48

Photo 5: Location of BH 4 and Culvert C4 in ditch West of Hwy 48

Photo 6: Ditch on West Side of Hwy 48 – Looking South

Photo 7: Location of BH 3 on West Shoulder of Hwy 48– Looking North

Photo 8: Location of BH 7 in ditch East of Hwy 48- South of Culvert C4

Photo 9: Location of BH 12 in ditch East of Hwy 48- North of Culvert C4

Photo 10: Embankment East side of Hwy 48, South of Culvert C4 – Looking North

Appendix B

Record of Borehole Sheets

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-1

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636183, N 4878892 | ORIGINATED BY OB

DIST ___ HWY 48 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY FL

DATUM Geodetic | DATE Jan/09/2015 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
334.6							
0.0	**TOPSOIL:** 280mm						
334.3 / 0.3	**FILL:** sandy silt, some clay, some topsoil, dark brown, moist, loose.	1	SS	7		334	
		2	SS	4			0 35 53 12
	trace topsoil, contains clayey silt pockets, brown below 1.5m	3	SS	6		333	
332.3 / 2.3	**SILTY SAND:** trace clay, contains sandy silt seams, brown, moist, compact.	4	SS	17		332	
		5	SS	19		331	
	greyish brown, wet below 3.8m	6	SS	18	▽ W. L. 330.4 m		
	contains clayey silt seams at 4.6m	7	SS	15		330	
329.4 / 5.2	**END OF THE BOREHOLE** Note: 1) Borehole open to 4.3m and water level at 4.2m (EL. 330.4m) upon completion.						

Water content (%) plotted: Sample 1 ≈ 30; Sample 2 ≈ 19; Sample 3 ≈ 16; Sample 4 ≈ 14; Sample 5 ≈ 12; Sample 6 ≈ 19; Sample 7 ≈ 19.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+3, ×3: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

ON-MTO-2014 10000964 GINT TUNNEL-FEB-20-2015.GPJ ON_MOT.GDT 25/2/15

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No BH-2

METRIC

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636164, N 4878892 | ORIGINATED BY OB

DIST | HWY 48 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY FL

DATUM Geodetic | DATE Jan/15/2015 | CHECKED BY RM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
339.6 / 0.0	**ASPHALT:** 260mm					
339.3	**GRANULAR BASE:** 130mm crusher run limestone, grey, moist	1	AS			
339.2 / 339.1 / 0.5	**GRANULAR SUBBASE:** 130mm gravelly sand, trace silt, greyish brown, moist	2	AS			
	FILL: sand, trace silt, trace gravel, trace clay, contains sandy silt and clayey silt pockets, brown, moist, compact to dense	3	SS	27		
		4	SS	40		7 79 9 5
337.3 / 2.3	**FILL:** gravelly sand with asphalt pieces, trace silt and clay, greyish brown to black, moist, very dense	5	SS	50/150mm		
336.6 / 3.1	**FILL:** silty sand, trace clay, trace gravel, trace topsoil, brownish grey, moist, compact to very dense	6	SS	51		
		7	SS	32		
	trace to some topsoil, dark brown below 4.6m	8	SS	24		4 48 40 8
		9	SS	11		2 58 34 6
333.5 / 6.1	**SILTY SAND:** trace clay, trace gravel, contains sandy silt seams, brown, moist, dense	10	SS	37		2 56 34 8
	brownish grey below 7.6m	11	SS	41		
330.9 / 8.7	**SILT:** trace clay, trace sand, brownish grey, dilatant /wet, compact	12	SS	17	∇ W. L. 330.5 m	
329.9 / 9.8	**END OF THE BOREHOLE** Note: 1) Borehole open to 9.1m (EL. 330.5m) and with wet bottom upon completion.					

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; ELEVATION SCALE (339 to 330); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

ON-MTO-2014 10000964 GINT TUNNEL-FEB-20-2015.GPJ ON_MOT.GDT 25/2/15

10000964

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-3

METRIC

W.P. GWP 2070-13-00	LOCATION See Borehole Location Plan, E 636154, N 4878907		ORIGINATED BY OB
DIST	HWY 48	BOREHOLE TYPE Solid Stem Auger	COMPILED BY FL
DATUM Geodetic		DATE Jan/14/2015	CHECKED BY RM

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	Water content (%)	GR	SA	SI	CL
339.2 / 0.0	**GRANULAR FILL: 300mm** gravelly sand, trace crushed stone, trace silt and clay, greyish brown, moist	1	AS						
338.9 / 0.3	**GRANULAR FILL: 300mm** sandy gravel, trace silt and clay, greyish brown, moist	2	AS						
338.6 / 0.6	**FILL:** silty sand, trace clay, trace gravel, contains clayey silt pockets, greyish brown, moist, compact to dense. contains clayey silt thin layer below 1.5m	3	SS	13					
		4	SS	49					
336.9 / 2.3	**FILL:** gravelly sand, trace to some silt, trace clay, contains sandy silt pockets, greyish brown, moist, very dense	5	SS	60					
336.2 / 3.1	**FILL:** silty sand, trace to some clay, trace gravel, trace organics, brown to dark brown, moist, loose to compact.	6	SS	14					
		7	SS	11					
	some clay to clayey at 4.6m	8	SS	6					
		9	SS	11		4	53	33	10
332.8 / 6.4	**SILTY SAND TO SAND:** trace clay, trace gravel, contains sandy silt seams, brown, damp to moist, compact to dense.	10	SS	24					
		11	SS	24		2	77	16	5
	brownish grey below 9.1m	12	SS	30					
329.5 / 9.8	**END OF THE BOREHOLE**								

Monitoring well (ground water conditions): Concrete, Holeplug, Sand, Screen, Sand

Elevation scale: 338, 337, 336, 335, 334, 333, 332, 331, 330

Dynamic cone penetration resistance plot: 20, 40, 60, 80, 100

Shear strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20, 40, 60, 80, 100

Plastic limit W_P, Natural moisture content W, Liquid limit W_L — Water content (%) 10, 20, 30

Unit weight γ kN/m³

Remarks & Grain size distribution (%)

Notes:
1) Borehole open and dry upon completion.
2) 50mm dia. monitoring well was installed upon completion, screened at depth of 7.6m to 9.1m.

Water level measured in monitoring well:

Date	W. L. Depth (m)
Jan. 15, 2015	Dry
Jan. 22, 2015	Dry

ON-MTO-2014 10000964 GINT TUNNEL-FEB-20-2015.GPJ ON_MOT.GDT 25/2/15

10000964

GROUNDWATER ELEVATIONS

Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-4

METRIC

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636138, N 4878909 | ORIGINATED BY OB

DIST | HWY 48 | BOREHOLE TYPE Hand Drillin | COMPILED BY FL

DATUM Geodetic | DATE Jan/21/2015 | CHECKED BY RM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
333.0													
0.0	**TOPSOIL:** 500mm		1	SS	3			61					
332.5 0.5	**FILL:** sandy silt mixed with topsoil, trace clay, dark brown, moist, very loose.		2	SS	3		332						
331.8 1.2	**SILTY SAND:** trace clay, trace rootlets /organics, brown to dark brown, moist, very loose to loose. (possible fill)		3	SS	5					0	52	41	7
			4	SS	5		331						
			5	SS	3								
329.9 3.1	**SAND:** some silt, trace clay, grey, wet, compact.		6	SS	15	∇ W. L. 329.9 m	330						
329.3 3.7	**END OF THE BOREHOLE** Note: 1) Borehole open to 3.1m (EL. 329.9m) and with wet bottom upon completion.												

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30

REMARKS & GRAIN SIZE DISTRIBUTION (%)

ON-MTO-2014 10000964 GINT TUNNEL-FEB-20-2015.GPJ ON_MOT.GDT 25/2/15

10000964

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-5

METRIC

W.P. GWP 2070-13-00 LOCATION See Borehole Location Plan, E 636202, N 4878756 ORIGINATED BY OB

DIST HWY 48 BOREHOLE TYPE Solid Stem Auger COMPILED BY FL

DATUM Geodetic DATE Jan/09/2015 CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
339.6 / 0.0	**TOPSOIL:** 300mm							
339.3 / 0.3	**FILL:** sandy silt, some clay, some topsoil, dark brown, moist, loose.		1	SS	4		339	
338.8 / 0.8	**SILTY SAND:** trace clay, contains clayey silt seams, brown, moist, loose. (possible fill)		2	SS	8			
338.1 / 1.5	**SILTY SAND:** trace clay, contains clayey silt seams, greyish brown, moist, compact.		3	SS	15		338	
			4	SS	22		337	
			5	SS	22			
335.9 / 3.7	**END OF THE BOREHOLE** Note: 1) Borehole open and dry upon completion.						336	

Plot columns: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³.

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GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+3, ×3: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

RECORD OF BOREHOLE No BH-6

METRIC

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636183, N 4878802 | ORIGINATED BY OB

DIST ______ HWY 48 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY FL

DATUM Geodetic | DATE Jan/14/2015 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
340.7					
0.0 / 340.4	**GRANULAR FILL:** 260mm gravelly sand, trace silt and clay, grey, moist	1	AS		
0.3 / 340.2	**GRANULAR FILL:** 270mm sand and gravel, trace silt and clay, brown, moist	2	AS		
0.5	**FILL:** sand, trace silt and clay, occasional gravel, brown, moist, compact	3	SS	21	
339.2 / 1.5	**FILL:** silty sand, trace clay, trace gravel, contains sandy silt /clayey silt pockets, brown, moist, compact	4	SS	27	7 64 23 6
	contains sandy silt pockets, dark brown below 2.3m	5	SS	12	
337.7 / 3.1	**FILL:** sandy silt, some clay, trace gravel, trace topsoil, dark brown, moist, loose	6	SS	6	1 35 53 11
	contains clayey silt pockets /layers above 3.8m	7	SS	9	
336.4 / 4.3	**SILTY SAND:** trace clay, trace gravel, brown, moist, compact to dense	8	SS	27	1 59 35 5
		9	SS	33	
		10	SS	31	
333.5 / 7.2	**SAND:** trace silt, trace clay, brown, moist, compact	11	SS	27	
332.5 / 8.2	**END OF THE BOREHOLE** Note: 1) Borehole open and dry upon completion.				

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

ELEVATION SCALE: 340, 339, 338, 337, 336, 335, 334, 333

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GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-7

METRIC

W.P. GWP 2070-13-00 LOCATION See Borehole Location Plan. E 636191, N 4878832 ORIGINATED BY OB

DIST HWY 48 BOREHOLE TYPE Solid Stem Auger COMPILED BY FL

DATUM Geodetic DATE Jan/09/2015 CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
337.4 / 0.0	**TOPSOIL:** 320mm		1	AS				
337.1 / 0.3	**FILL:** clayey silt, sandy, some topsoil, dark brown, moist, firm. trace topsoil, greyish brown, below 0.8m		2	AS			337	
			3	SS	5			
335.9 / 1.5	**SILTY SAND TO SAND:** some silt, trace clay, greyish brown, moist, compact.		4	SS	16		336	0 79 14 7
			5	SS	10		335	
			6	SS	18		334	
333.7 / 3.7	**END OF THE BOREHOLE** Note: 1) Borehole open and dry upon completion.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No BH-8

METRIC

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636174, N 4878849 | ORIGINATED BY OB

DIST ____ HWY 48 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY FL

DATUM Geodetic | DATE Jan/14/2015 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
340.1 / 0.0	**GRANULAR FILL:** 250mm gravelly sand with crushed stone, trace silt and clay, grey, moist.	1	AS		340	
339.9 / 0.3	**GRANULAR FILL:** 250mm silty sand, some gravel, trace clay, brown, moist.	2	AS			
339.6 / 0.5	**FILL:** sand, some silt, trace gravel, trace clay, contains organics sandy silt pockets, brown, moist, compact.	3	SS	23	339	
		4	SS	28		7 73 14 6
337.8 / 2.3	**FILL:** silty sand, trace clay, trace gravel, trace organic sandy silt pockets, dark brown, moist, compact.	5	SS	21	338	
		6	SS	15	337	
	brown below 3.8m	7	SS	21	336	1 72 21 6
335.5 / 4.6	**SILTY SAND:** trace clay, contains clayey silt pockets, brown, moist, dense.	8	SS	30	335	
		9	SS	38		
334.0 / 6.1	**SAND:** trace silt, trace clay, occasional gravel, brown, damp to moist, dense.	10	SS	35	334	
		11	SS	37	333, 332	
		12	SS	33	331	
330.4 / 9.8	**END OF THE BOREHOLE** Note: 1) Borehole open and dry upon completion.					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+3, ×3: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-9

METRIC

W.P. GWP 2070-13-00 LOCATION See Borehole Location Plan, E 636155, N 4878948 ORIGINATED BY OB

DIST ______ HWY 48 BOREHOLE TYPE Solid Stem Auger COMPILED BY FL

DATUM Geodetic DATE Jan/15/2015 CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
338.6							
0.0 338.4 / 0.2	**GRANULAR FILL:** 240mm gravelly sand with crushed stone, trace silt and clay, brownish grey, moist	1	AS				
338.1 / 0.5	**GRANULAR FILL:** 250mm sand and gravel, trace silt and clay, brown, moist	2	AS			338	
	FILL: silty sand, trace clay, brown, moist, compact	3	SS	24			
337.1 / 1.5	**FILL:** sand, some silt, trace clay, brown, moist, compact	4	SS	27		337	
336.3 / 2.3	**FILL:** sandy silt, trace gravel, trace clay, trace asphalt pieces, contains organics silt pockets, dark brown, moist, compact	5	SS	13		336	
335.6 / 3.1	**FILL:** clayey silt mixed with sand pockets /layers, dark brown, moist, stiff to very stiff	6	SS	11		335	2 33 48 17
334.5 / 4.1	**SAND:** trace to some silt, trace clay, brown, moist, compact to dense	7	SS	18			
		8	SS	20		334	0 84 10 6
		9	SS	42		333	
		10	SS	23		332	
	trace silt, trace gravel below 7.6m	11	SS	39		331	
	wet				▽ W. L. 330.0 m	330	
		12	SS	37		329	
328.9 / 9.8	**END OF THE BOREHOLE** Note: 1) Borehole open to 8.2m upon completion.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

10000964

GROUNDWATER ELEVATIONS

Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

+³, ×³: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-10

METRIC

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636158, N 4878972 | ORIGINATED BY OB

DIST | HWY 48 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY FL

DATUM Geodetic | DATE Jan/09/2015 | CHECKED BY RM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
336.9 / 0.0	**TOPSOIL:** 320mm											
336.6 / 0.3	**FILL:** silty sand, some topsoil, trace clay, dark brown, moist, loose	1	SS	4								
336.1 / 0.8	**SILTY SAND:** trace clay, contains sandy silt seams, brown, moist, compact	2	SS	12		336						
	contains silt seams below 1.5m	3	SS	12		335						
334.6 / 2.3	**SILT:** trace clay, trace sand, brownish grey, wet, compact	4	SS	14		334			0	4	88	8
	contains silty sand seams below 3.1m	5	SS	24								
333.2 / 3.7	**END OF THE BOREHOLE** Note: 1) Borehole open and with wet bottom upon completion.											

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

SPL

RECORD OF BOREHOLE No BH-11

METRIC

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636147, N 4879000 | ORIGINATED BY OB

DIST ____ HWY 48 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY FL

DATUM Geodetic | DATE Jan/15/2015 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
337.6							
0.0	**GRANULAR FILL:** 300mm gravelly sand with crushed stone, trace silt and clay, dark brown, moist	1	AS				
337.3 / 0.3	**GRANULAR FILL:** 300mm gravelly sand, trace silt and clay, greyish brown, moist	2	AS		337		
337.0 / 0.6	**FILL:** silty sand, trace gravel, trace clay, contains clayey silt pockets, brown, moist, compact	3	SS	18			
		4	SS	23	336		
335.3 / 2.3	**SAND:** trace silt, trace clay, contains clayey silt seams, greyish brown, moist to damp, dense to very dense	5	SS	36	335		0 90 6 4
		6	SS	38	334		
		7	SS	36	333		
		8	SS	67			
	trace gravel, trace silt below 5.3m	9	SS	43	332		
		10	SS	48	331		
					330		
		11	SS	36			
329.4 / 8.2	**END OF THE BOREHOLE** Note: 1) Borehole open to 6.9m upon completion.						

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

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GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

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

○ ε=3% Strain at Failure

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No BH-12

W.P. GWP 2070-13-00 | LOCATION See Borehole Location Plan, E 636142, N 4879048 | ORIGINATED BY OB

DIST | HWY 48 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY FL

DATUM Geodetic | DATE Jan/09/2015 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
335.8 / 0.0	**TOPSOIL:** 380mm								
335.4 / 0.4	**FILL:** silty sand, trace gravel, trace silt and clay, trace topsoil, dark brown, moist, loose	1	SS	7					
335.0 / 0.8	**SAND:** trace to some silt, trace clay, occasional gravel, contains sandy silt seams, greyish brown, moist, compact to dense	2	SS	19		335			
		3	SS	28		334			
		4	SS	49		333			
		5	SS	25					
332.1 / 3.7	**END OF THE BOREHOLE** Note: 1) Borehole open and dry upon completion.								

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

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GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+³, ×³: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

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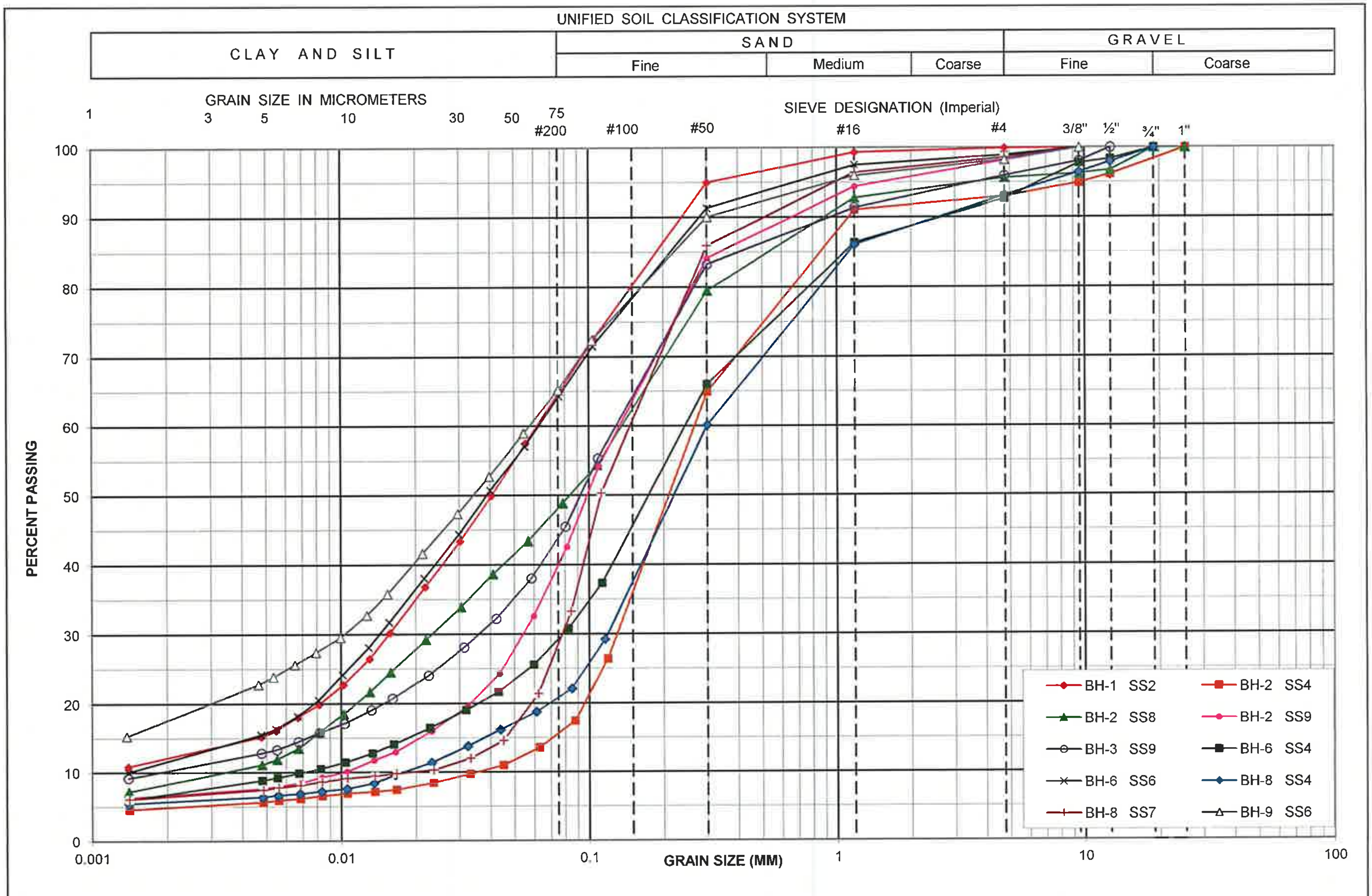
Appendix C

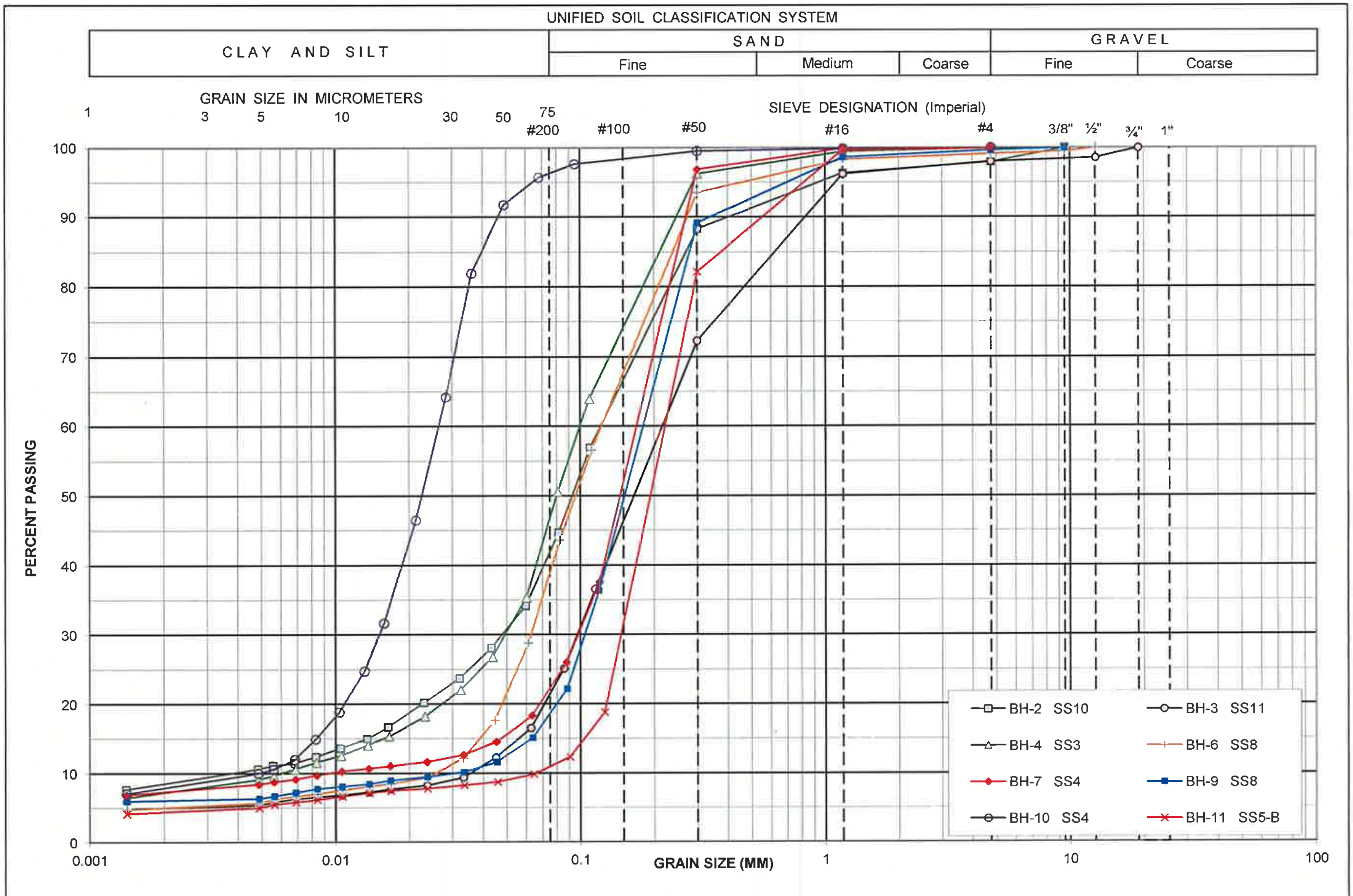
Laboratory Test Results



SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

GRAIN SIZE DISTRIBUTION
Fill Materials

Figure No.:	1
Project No.	10000964
Date :	FEB-05-2015



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Geotechnical Environmental Materials Hydrogeology

GRAIN SIZE DISTRIBUTION
Sands & Silts

Figure No.:	2
Project No.	10000964
Date :	FEB-05-2015

Appendix D

Explanation of Terms Used in Report

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Explanation of Terms Used in the Record of Borehole

Sample Type

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Dimension type sample
FS	Foil sample
NR	No recovery
RC	Rock core
SC	Soil core
SS	Spoon sample
SH	Shelby tube sample
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

Penetration Resistance

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in) required to drive a 50 mm (2 in) drive open sampler for a distance of 300 mm (12 in).

WH – Samples sinks under "weight of hammer"

Dynamic Cone Penetration Resistance, N_d:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in) to drive uncased a 50 mm (2 in) diameter, 60^o cone attached to "A" size drill rods for a distance of 300 mm (12 in).

Textural Classification of Soils (ASTM D2487-10)

Classification	Particle Size
Boulders	> 300 mm
Cobbles	75 mm - 300 mm
Gravel	4.75 mm - 75 mm
Sand	0.075 mm – 4.75 mm
Silt	0.002 mm-0.075 mm(*)
Clay	<0.002 mm

(*) Canadian Foundation Engineering Manual (4th Edition)

Coarse Grain Soil Description (50% greater than 0.075 mm)

Terminology	Proportion
Trace	0-10%
Some	10-20%
Adjective (e.g. silty or sandy)	20-35%
And (e.g. sand and gravel)	> 35%

Soil Description

a) Cohesive Soils(*)

Consistency	Undrained Shear Strength (kPa)	SPT "N" Value
Very soft	<12	0-2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very stiff	100-200	15-30
Hard	>200	>30

(*) Hierarchy of Shear Strength prediction
1. Lab triaxial test
2. Field vane shear test
3. Lab. vane shear test
4. SPT "N" value
5. Pocket penetrometer

b) Cohesionless Soils

Density Index (Relative Density)	SPT "N" Value
Very loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very dense	>50

Soil Tests

w	Water content
w_p	Plastic limit
w_l	Liquid limit
C	Consolidation (oedometer) test
CID	Consolidated isotropically drained triaxial test
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement
D_R	Relative density (specific gravity, Gs)
DS	Direct shear test
ENV	Environmental/ chemical analysis
M	Sieve analysis for particle size
MH	Combined sieve and hydrometer (H) analysis
MPC	Modified proctor compaction test
SPC	Standard proctor compaction test
OC	Organic content test
U	Unconsolidated Undrained Triaxial Test
V	Field vane (LV-laboratory vane test)
γ	Unit weight

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FOUNDATION DESIGN REPORT
PROPOSED REPLACEMENT OF CULVERT C4 UNDER HIGHWAY 48
STATION 19+833 WHITCHURCH-STOUFFVILLE TOWNSHIP
SOUTH OF ST. JOHN'S SIDEROAD, YORK REGION, ONTARIO
GWP 2070-13-00, CONTRACT PACKAGE 1

GEOCRES No. 31D-600

Prepared For:
Ainley Group
280 Pretty River Parkway
Collingwood, ON
L9Y 4J5

SPL Project No.: 10000964-1
March 20, 2015

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FOUNDATION DESIGN REPORT
PROPOSED REPLACEMENT OF CULVERT C4 UNDER HIGHWAY 48
STATION 19+833 WHITCHURCH-STOUFFVILLE TOWNSHIP
SOUTH OF ST. JOHN'S SIDEROAD, YORK REGION, ONTARIO
GWP 2070-13-00, CONTRACT PACKAGE 1

6. DISCUSSION AND RECOMMENDATIONS

We understand that the existing 750 mm diameter CSP Culvert C4 is a 'dry' culvert (no base flow) at Station 19+833 under Highway 48 in the Township of Whitchurch-Stouffville and it will be replaced with a 900 mm diameter HDPE pipe with about the same length and invert as the existing culvert. This existing culvert is about 47 m in length and is at a skew angle of about 33 degrees (from perpendicular line to the road alignment). The existing culvert inverts were surveyed and are at about elevations 333.8 m at the upstream end and 332.5 m at the downstream end. The road embankment over the culvert is about 5.5 to 7 m in height, with a road elevation of about 339.5 m, along the existing culvert alignment. From Drawing No. 1, the road grade at the site falls from south to north and varies from about El. 343 m (south end) to El. 337 m (north end) along the 300 m project length, for about 2% grade.

The construction methods described in this report must not be considered as being specifications or direct recommendations to the contractors, or as being the only suitable methods. Prospective contractors should evaluate all of the factual information, obtain additional subsurface information as they might deem necessary and should select their construction methods, sequencing and equipment based on their own experience in similar ground conditions. The readers of this report are also reminded that the conditions are known only at the borehole locations and in view of the generally wide spacing of the boreholes, conditions may vary significantly between boreholes.

The proposed 900 mm diameter HDPE pipe can be installed using trenchless construction method or alternatively by open cut construction method, probably with a detour, as summarized in the following table.

Table 6.1: Comparison of Installation Methods

Construction Method	Comments	Recommendations
Trenchless Construction	Fairly uniform soil conditions along the tunnel alignment, low ground water table, will not cause traffic disruptions considering high traffic volumes on Hwy 48	Recommendations based on no traffic disruptions and less risky due to low groundwater table
Open Cut Construction	Open cut construction is considered more reliable than tunnelling, but due to high traffic volume, a detour may be required which could be considered costly	Not recommended due to traffic disruption on high traffic volume road

We understand that for this project, trenchless construction is proposed and open cut construction is not being considered. However, for completeness, open cut method with a detour will also be discussed in this report.

6.1 Overview of Subsurface Conditions

In simplified terms, the subsurface profile consists of surficial topsoil and fill underlain by silty sand to sand.

The groundwater table lies between 9.1 m and 9.7 m below existing road grade (between El. 329.9 and 330.5 m) or about 3$\pm$ m below the existing ditch.

6.2 Trenchless Construction

We understand that an about 42 m long and 1100 mm diameter steel casing can be installed by trenchless method to accommodate the 900 mm diameter HDPE culvert. The casing will be installed at a clear distance of about 5 m to the south of the existing pipe, as shown in **Drawing No. 1**.

For the installation of the 900 mm HDPE culvert under the Highway 48, trenchless construction will be advanced mainly through the silty sand to sand material and silty sand fill. The invert of the steel casing will probably be about 0.1 to 0.2m below the quoted invert elevations of the existing culvert. The groundwater level was about 2.5 m below the invert of the pipe.

A classification of soils for tunneling purposes, commonly used in Ontario, is given in Appendix E. The anticipated soil conditions along the proposed tunnel alignment consist generally of compact silty sand fill, possibly encountering a loose sand fill at the obvert in the area of BH3 and dense sand at the invert in the area of BH2, as well as very loose to loose fill at the toes of the embankment. From this information, it can be surmised that the tunnel can be expected to possibly proceed on mixed face conditions. According to this, the soils fall into the "slow to fast raveling" conditions, as per the Tunnelman's Ground Classification presented in **Appendix E**.

Different possible options for tunneling which are commonly used in Ontario were considered. These are as follows:

- Jack and Bore / Auger Boring
- Pipe Ramming
- Microtunneling

The above list of options for trenchless construction with their advantages and disadvantages/limitations are presented in Table F-1 in **Appendix F**.

Based on the Table F-1, Jack and Bore/Auger Boring and Pipe Ramming are considered the most cost-effective options. However, considering the presence of loose sand zones in the fill (e.g. 'N' value of 6 in BH 3) above the proposed pipe, the risk of formation of voids or densification of the loose sand due to the vibrations created by the pipe ramming, and thus possible embankment settlement or slope instability, is considered high. It is therefore considered that Jack and Bore/Auger Boring is the preferred option for the installation of the casing for the culvert. This will be discussed in the next section.

6.2.1 Jack and Bore / Auger Boring

The length of the culvert crossing under Highway 48 is currently about 42 m (shaft to shaft) and the proposed invert elevations are at about 333.8 m at the upstream end and 332.5 m at the downstream end. At this vertical alignment, the earth cover above the tunnel at the road centreline is about 5.5 m or approximately 5.5 times the bored diameter of 1.1 m. This is considered to be sufficient earth cover.

Between about El. 334.5 and 332.5 m, the tunnel will be driven through mostly loose to compact silty sand fill, occasionally on the compact to dense silty sand to sand. At the proposed ends of the pipe at the bottom of the embankment, loose silty sand to sandy silt fills are anticipated. No groundwater is anticipated to be encountered during tunnelling. In carrying out the trenchless crossing, consideration should be given to the presence of loose sand above the pipe.

The preferred option of Jack and Bore /Auger Boring forms a borehole from a drive shaft to a reception shaft by means of rotating cutting head. Spoil is transported back to the drive shaft by helical auger flights rotating inside a steel casing. The casing is jacked in place simultaneously with the augering operation. After the installation of the steel casing, the utility pipe is installed inside the casing and the gap between the casing and pipe is grouted. The maximum casing diameter used in this operation is typically limited to about 1.5 m for most contractors in Ontario.

As mentioned in Table E-1 in **Appendix E**, the presence of loose sand at the obvert may present some risk but this risk can be mitigated by providing a soil plug (about 0.3 m of dirt inside the casing) at the advancing end of the pipe at all time and by utilizing a short advance technique, where the casing is pushed a very short distance (say less than 0.3m) at a time before augering to the plug. The plug should be maintained at all time. It should also be noted that the surficial soils encountered at the culvert shaft locations will provide little or no passive resistance for a thrust block to facilitate jacking operations (i.e. deep foundation and/or soils anchors may be required) and this aspect should be considered in the design of the drive shaft.

6.2.2 Shafts

We understand that two (2) shafts, one at each end of the crossing, will be constructed for the trenchless crossing. The subsurface conditions encountered in the boreholes at or near these shafts are shown in **Drawing No. 1,** and are briefly summarized in Table 6.2.

Table 6.2. - Subsurface Conditions at Shafts

BH No.	Soil Type	Water Table
BH-1	0.28m topsoil underlain by loose sandy silt fill to 2.3 m depth (El. 332.3m) which is further underlain by compact silty sand.	Groundwater at 4.2 m below ground surface or at El. 330.4 m.

BH No.	Soil Type	Water Table
BH-4	0.5m topsoil underlain by very loose sandy silt fill mixed with topsoil to 1.2 m depth (El. 331.8m) which is further underlain by very loose to loose silty sand to a depth of 3.1m (E. 330.0m), which is further underlain by compact sand. Adjacent BH 3 noted compact to dense sand at greater depth.	Groundwater at 3.1 m below ground surface or at El. 329.9 m.

The fill would be classified as Type 3 Soils defined by the Occupational Health and Safety Act of Ontario above the groundwater table. The native silty sand to sand above the groundwater table also falls into the category of Type 3 Soils. The cohesionless soils (sand, silty sand and silt) can be classified as Type 4 below the groundwater table.

Vertical cuts in the overburden soils should be supported with shoring. Soldier piles and lagging or similar methods are recommended. The soldier piles and lagging could be supported by tie-back anchors or struts. The earth pressure distribution shown on **Drawing No. 3** should be utilized for multiple strut or tie-back shored system. All shoring designs should be in accordance with the current Edition of the Canadian Foundation Engineering Manual and must be reviewed by a qualified geotechnical engineer. No water pressure has been assumed to act against the shoring. Lagging walls are assumed to permit drainage of perched water, if any, between the lagging boards. The surcharge must account for construction machinery.

6.2.3 Settlement Monitoring

A settlement monitoring program for any trenchless crossing alternative underpassing Highway 48 is required as per MTO's Guidelines for Foundation Engineering – Tunnelling Speciality for Corridor Encroachment Permit Application. Settlement monitoring shall be in accordance with the NSSP for Pipe Installation by Trenchless Method (Item 58, Code 9999-4051 SP in the Contract Document). The settlement monitoring system should consist of deep/shallow and surface monitoring points installed at different depths in the road, shoulders and near utilities. The monitoring points should be located at not greater than 5 m intervals along the tunnel alignment. The interval of the points could be changed with MTO's approval where traffic disruption might occur. Care must be taken so as to stay a safe distance above the obvert to minimize the hydrofacturing potential into an instrument hole.

Ground movements of these points should be monitored at regular intervals during and after the tunnelling operations. In the event that unacceptable ground movements are observed, the tunnelling and ground support operations should be immediately modified.

The installation locations, details and monitoring frequency and accuracy are presented in **Drawing Nos. 4 and 5**. For shallow monitors (SSP) along the slopes, the monitors could be in a form of standard iron bar (SIB) provided the monitoring is conducted during non-freezing condition (e.g. summer months). A minimum of two (2) sets of repeatable baseline readings should be taken on all of the settlement points well in advance of the start of the tunnelling. Settlement monitoring should be conducted at least three

(3) times daily. Upon completion of tunnelling, the frequency of readings can then be reduced to daily for a minimum of two (2) weeks, twice weekly for a period of one month and then once monthly for the following five months. Monitoring can be stopped, with consultation with the monitoring Geotechnical Engineer, two weeks after completion of the tunnel provided further settlement has stopped.

Should settlement monitoring indicate excessive ground movement, immediate changes to the tunnelling method and ground support procedures must be adopted. The following table details the recommended 'Review/Alert Levels' for in-ground settlement rods.

Table 6.3. - Settlement 'Review/Alert Levels'

Ground Movement as Measured in Settlement Rods	Notes
<10 mm	Proceed. No action required.
Review Level: 10 mm	Immediately notify MTO & the geotechnical engineer for further assessment; Proceed with caution.
Alert Level: >15 mm	Halt tunnelling until further assessment is carried out by the MTO & geotechnical engineer; Carry out immediate remedial work to the settlement zone as approved by the MTO.

With good workmanship, loss of ground and soil relaxation can be minimized, and it should be possible to keep settlements at road level to less than 10mm.

Embankment slope monitoring may be required within the MTO right of way, in the vicinity of the tunnelling. The slopes should be monitored at the same time of the settlement monitoring using the shallow monitors to be installed on the shoulders, slopes and ditches along the tunnel alignment, as well as visual observations of the slopes before, during and after tunnelling.

The survey benchmark or control point to be used for the monitoring should either be established on structures, such as buildings or bridges/concrete culverts, or on deep temporary benchmark(s) (installed by drilling on site) which will not be influenced by site activities. These benchmarks can be used to survey both lateral and vertical movements. These benchmarks should also be indicated on the monitoring plan once the location of benchmark is finalized. Survey targets can be reflective to facilitate remote surveying.

A preconstruction condition survey of Highway 48 pavement in the proximity of the tunneling, as well as the existing utilities in the immediate vicinity of the tunnel alignment, should be carried out prior to start of construction. The surface survey should be completed during the installation of the monitors and again once the tunnel has been completed. The condition survey will describe, detail and document with photographic evidence of any cracks, distortions, deviations, heaves and depressions in the pavement surface.

The existing road pavement in the vicinity of the tunnelling should be reinstated (such as surface paving) by the Contractor should movements or other surface distresses occur, and a warranty period acceptable to MTO must be provided by the Contractor.

6.2.4 Lateral Earth Pressure

Lateral Earth Pressure in Overburden Soils

The earth pressure distribution on shafts can be taken as hydrostatic, i.e. which is increasing uniformly with depth according to the formula:

$$P_h = K.\gamma.h + K.q$$

where

P_h = horizontal pressure at depth h (kN/m²)
γ = unit weight of soil (kN/ m^3), taken as 21 kN/ m^3
h = depth below ground surface (m)
q = surcharge load at ground surface (kPa)
K = coefficient of lateral earth pressure, assumed to be 0.50

6.3 Open Cut Construction

For an open cut construction, the existing embankment fill will be excavated to the invert level. If vertical excavations are required, temporary shoring will be necessary for ground support, due to limited space of the roadway. Locally, temporary shoring typically consists of soldier pile and lagging, while sometimes driven interlocking sheet piling is also used.

6.3.1 Foundation Support for Culvert C4

The boreholes show, at the proposed invert elevations, the presence of compact to dense silty sand to sand and very loose to compact silty sand fill. From foundation engineering point of view, the underlying soils are not competent enough for the use of concrete structure. The use of flexible structure such as a CSP or semi-flexible pipe such as HDPE culvert is the preferred option for the replacement of the existing culvert, which is the case for this project, provided a suitable bedding is placed between the undisturbed soils and the culvert.

A minimum bedding thickness of 300 mm is recommended for the HDPE culvert, but this bedding should be gradually increased to 500 mm beyond underneath the rounding of the road. After excavating the site to the underside of the bedding (i.e. to 0.3 to 0.5 m below the invert level), the exposed subgrade should be carefully inspected and approved. If organic or other unsuitable soils are found, they should be removed to the surface of the inorganic, suitable soil and replaced with suitable soils.

Provided that all the unsuitable soils are removed, where necessary, replaced with suitable granular soils (i.e. where the grade needs to be raised after sub-excavation) and the subgrade is not duly disturbed, there should be no problems with bearing resistance and settlements, since there will be virtually no load increase over and above the existing conditions, except near the edges where temporary widening may be applied during the construction period.

The overburden under the existing embankment would have consolidated and settled under the stresses generated by the existing embankment. Therefore, since there will be no additional loading, theoretically there should be negligible additional settlements. However, a settlement of about 25 mm should be allowed for, due to rebound during the brief construction period as well as due to the exchange of the lighter, unsuitable soils, if any, with granular backfill which is relatively heavier.

In the widening sections for the detour, settlements of up to 50 mm can be expected. The settlements should take place rather rapidly, as the soils consist of granular deposits (i.e. relatively pervious). In view of this, in the widening section where the fill is placed before the pipe is installed, some of these anticipated settlements would have taken place and therefore cambering is considered unnecessary. Where the fill is placed after the pipe was installed, consideration can be given to some cambering towards this end. We will be pleased to discuss this aspect after the details are known.

6.3.2 Bedding

The bedding materials should consist of an approved well-graded granular material, such as Granular 'A' or Granular B Type II. The bedding material should be placed as soon as practicable after the preparation of the subgrade, its inspection and approval, as was discussed is the previous section of this report. The bedding material should be in accordance with appropriate standard (e.g. OPSD-802.010 and 802-014 for flexible pipes). The recommended minimum bedding thicknesses were given in the previous section of this report. The bedding material should be compacted to MTO standards.

6.3.3 Backfilling

The bedding and embedment material should be extended along the sides and to cover the top of the pipe. The selection and placing of the backfill should be in accordance with OPSD-802.010 and 802.014 for flexible pipes. The backfill should consist of free-draining, non-frost susceptible granular materials such as Granular 'A' or 'B' (OPSS-1010). All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and should be compacted to at least 96% of the materials Standard Proctor Maximum Dry Density (SPMDD). The Granular 'A' base Granular 'B' sub-base courses should be compacted to 100% of the material's SPMDD.

We would like to point out that the performance of flexible pipe culverts is largely dependent on the side support provided by the backfill and the adjacent soils. The use of proper backfill material and especially good compaction are, therefore, necessary for proper side support. The use of heavy compaction equipment should, however, be avoided immediately adjacent and above the pipes, as per MTO practice. During backfill placement, the height of the backfill should be maintained at approximately same level on both sides of the pipe, to avoid lateral displacement of the pipe.

6.3.4 Construction

The construction of the culvert should be in accordance with OPSS 421 and any special provisions for pipe culvert installation in open cut method.

The groundwater at the site was at about 2.5 m below the pipe invert and therefore we do not anticipate any problem with regards to groundwater as all excavations are expected to be above groundwater. Any excavation below the groundwater, if any, will require dewatering.

All excavations should be carried out in accordance with the Province's Occupational Health and Safety Act (OHSA), O. Reg. 213/91 and its Amendments, as well as the following:

OPSS.PROV 539 – Construction Specification for Temporary Protection Systems

In accordance with the Province's Safety Regulations, the following soil classification would be applicable.

Granular Pavement Fill	Type 3 soil
Embankment Fill	Type 3 soil above water level
Silty Sand to Sand	Type 3 soil above water level; Type 4 soil below water level

It is understood that the proposed excavations may be supported by a temporary shoring system consisting of timber lagging and soldier piles. The shoring system must be designed in accordance with the Fourth Edition of the Canadian Foundation Engineering Manual. Shoring systems should be designed so that the lateral movement of any portion of the roadway protection system will not exceed the established criterion for the structural performance level. In this case, the required performance level is considered 2. The soil parameters estimated to be applicable for this design are as follows:

1) Earth Pressure Coefficients

   (a) where minor movement (25 mm maximum) can be tolerated, K=0.3
   (b) passive earth pressure for soldier piles (unfactored), Kp=4

2) For stability check

   $\phi = 32^\circ$
   c= 0

γ = 21 kN/m^3
Surcharge is to be determined by shoring contractor.

3) For earth anchors

Allowable bond value of 48 kPa is suggested for earth anchor in the compact to dense silty sand to sand; but this value depends on anchor installation methods and grouting procedures. Gravity poured concrete can result in low bond values while pressure grouted anchors will give higher values and produce a more satisfactory anchor.

Casing will be required during the construction of the tiebacks to prevent caving of soils. The soldier piles should be installed in pre-augered holes taken below the deepest excavation. The holes should be filled with concrete below the excavation level and half bag mix above the base of the excavation. The concrete strength must be specified by the shoring designer. Temporary liners may be required to help prevent the sand from caving during the installation period. Positive measures may be required to prevent the loss of soil through the spaces between the lagging boards. This could probably be achieved by placing well-graded sand and gravel behind the lagging boards or by installing a geotextile filter cloth.

Soil anchors will be required to support the shoring. The anchors must be of a length that meets the Canadian Foundation Manual recommendations. It is important to note that the minimum length lies beyond the (45 - ϕ/2 + .15H) line drawn from the base of the soldier pile and the overall stability of the system must be checked at each anchor level, where ϕ is the soil friction angle and H is the shoring height.

Anchors will require casing when penetrating through wet sand and silt layers. The bond values suggested above are arbitrary since the contractors installation procedures will determine the actual soil to concrete bond value. Hence, the contractor must decide on a capacity and confirm its availability. All anchors must be tested as indicated in the Foundation Manual, 4th edition.

Adhesion on the buried caisson shaft or behind the shoring system must be neglected when designing this shoring system.

Movement of the shoring system is inevitable. Vertical movements will result from the vertical load on the soldier piles resulting from the inclined tiebacks and inward horizontal movement results from earth and water pressures. The magnitude of this movement can be controlled by sound construction practices, and it is anticipated that the horizontal movement will be in the range of 0.1 to 0.25% of the shoring height (H).

To ensure that movements of the shoring are within an acceptable range, monitoring must be carried out. Vertical and horizontal targets on the soldier piles must be located and surveyed before excavation begins. Weekly readings during excavation should show that the movements will be within those predicted; if not, the monitoring results will enable directions to be given to improve the shoring.

6.3.5 Detour Construction

In order to replace the culvert in open cut, if necessary, a temporary detour may need to be constructed. Prior to the investigation, a detour on the east side of the road was decided by the Prime Consultant and this consist of widening the existing embankment by about a lane width (i.e. about 4 m), for about 300 m in total length.

In addition to Boreholes BH-1 and BH-2 for the culvert, Boreholes BH-5 through BH-12 were drilled for the detour. Boreholes BH-6, BH-8, BH-2, BH-9 and BH-11 were drilled on the existing road and these encountered embankment fill consisting mainly of silty sand to sandy silt over generally compact to dense silty sand to sand. On the other hand, Boreholes 5, 7, 1, 10 and 12 were drilled in the ditch and these contacted about 0.3 to 0.4m of topsoil over surficial layer of loose to compact silty sand to sandy silt fill extending to depths of about 0.8 to 2.3 m below existing ditch grade. Groundwater was not encountered in these boreholes except at Borehole 1 where the water level was observed at a depth of about 4 m below existing grade.

Slope Stability analysis was conducted for the widening on the east side of the road using the computer program SLIDE, version 6, assuming side slope of 2H:1V and using clean granular fill (e.g. Granular B Type 1) for the proposed widening. The results of the analysis are presented in **Appendix G**. The analysis assumed that topsoil stripping to a depth about 0.4m will be carried out prior to construction of the fill. The factor of safety determined was greater than 1.3 for the proposed widening, indicating stable slope for the duration of construction. Steeper side slopes are not recommended. We understand that the fill materials used for the widening will be removed after the construction and the original ditch will be maintained.

The temporary widening will cause some settlements in the foundation soils. Based on the borehole data and assuming that the widening will be removed promptly after the construction, the anticipated settlements should not exceed 50 mm, over a construction period. We will be pleased to elaborate on this subject once the details are known (e.g. cambering).

For the widening of the embankment, proper benching of the existing slopes should be implemented as per OPSD-208.010. Imported material should consist of an easily compactible material. The upper 300 to 400 mm should consist of Granular ‘A’ or ‘B’ Type II material to accommodate the traffic loading. Temporary hotmix (minimum 50 mm of SP19.0) should be provided over the pavement granular.

6.4 Erosion Protection

Erosion and scour protection should be provided at the culvert inlet and outlet (including the slopes and sides). Considering that this culvert is a ‘dry’ culvert (i.e. no base flow), a simple erosion protection should suffice. In this case, consideration should be given to the use of OPSD 810.010 Rip-Rap Treatment for Culvert Sites.

6.5 Frost Protection

Design frost protection for the general area is 1.5 m. Therefore, a permanent soil cover of 1.5 m or its thermal equivalent of artificial insulation is required for frost protection of foundations. In case of riprap (rock fill), only one-half of the rock fill thickness should be assumed to be effective in providing frost protection.

7. LIMITATIONS OF REPORT

The statement of limitations, as provided in **Appendix H**, forms an integral part of this report. Engineering analysis and preparation of report were carried out by Mr. Ramon Miranda, P. Eng. and Ms. Alka Sangar, P. Eng. The report was reviewed by Dr. Fanyu Zhu, P. Eng., a Designated Principal Contact for MTO Foundations Projects.

Thank you for the opportunity to be of service to you. Should you have any questions or require further clarification on any aspect of this report, please do not hesitate to contact this office.

Yours very truly,

SPL CONSULTANTS LIMITED

LICENSED PROFESSIONAL ENGINEER
RAMON MIRANDA
Mar 20/15
PROVINCE OF ONTARIO

Ramon Miranda, P. Eng.
Senior Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
A. SANGAR
100141185
Mar 20/2015
PROVINCE OF ONTARIO

Alka Sangar, P. Eng.
Senior Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
F. ZHU
Mar. 20/15
PROVINCE OF ONTARIO

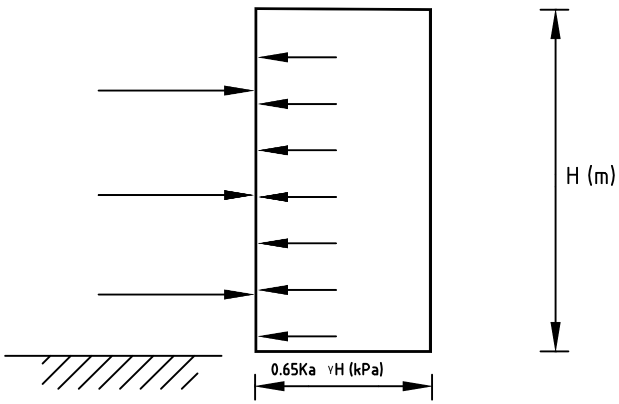
Fanyu Zhu, Ph. D., P. Eng.
Designated MTO Foundation Contact

DRAWINGS

Earth Pressure Distribution (Drawing No. 3)

Preliminary Layout of Ground Monitoring Arrays (Drawing No. 4)

Installation Details of Ground Monitoring Arrays (Drawing No. 5)

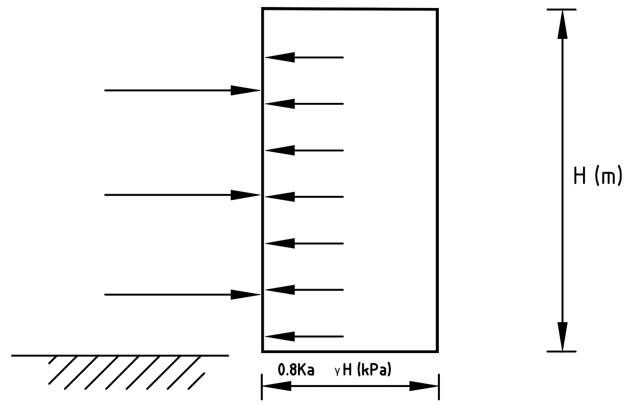


γ = unit weight of soil = 21.0 kN/m^3

γ' = submerged unit weight of soil (i.e. below ground water level)= 11.2 kN/m^3

Ka = 0.3

IN COMPACT TO VERY DENSE NON-COHESIVE SOILS (SANDS AND SILTS)



γ = unit weight of soil = 19.0 kN/m^3

γ' = submerged unit weight of soil (i.e. below ground water level)= 9.2 kN/m^3

Ka = 0.36

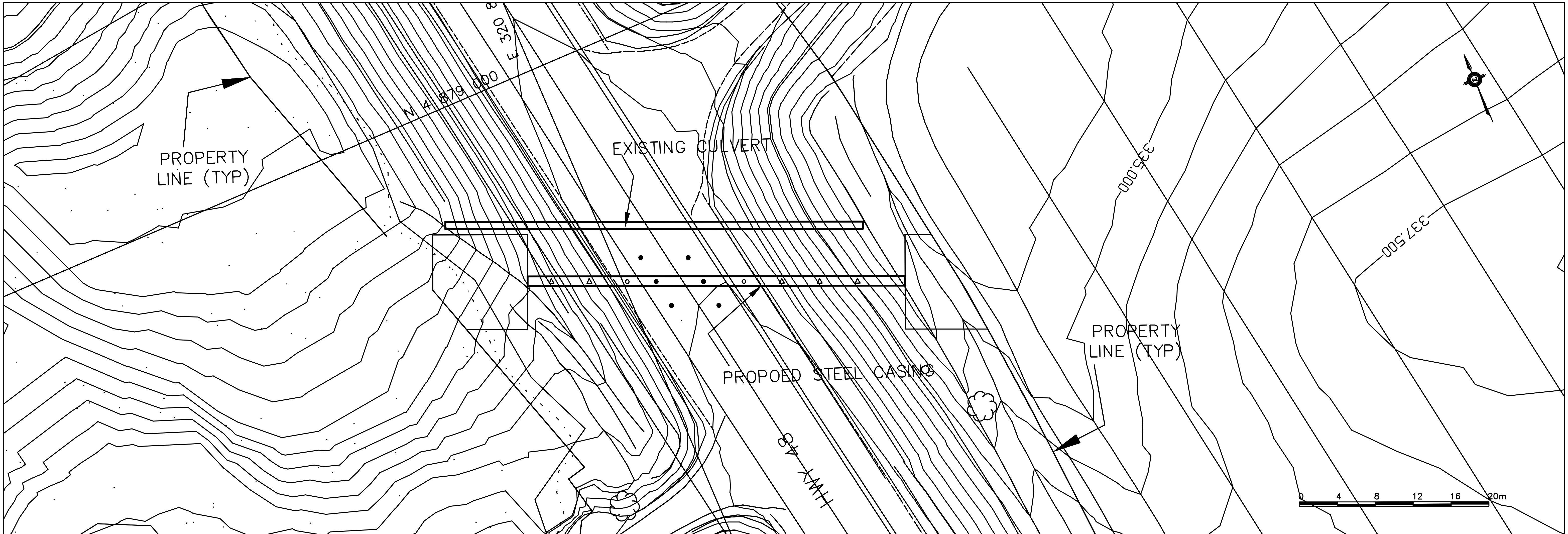
IN LOOSE OR DISTURBED NON-COHESIVE SOILS (SANDS AND SILTS)

Notes:

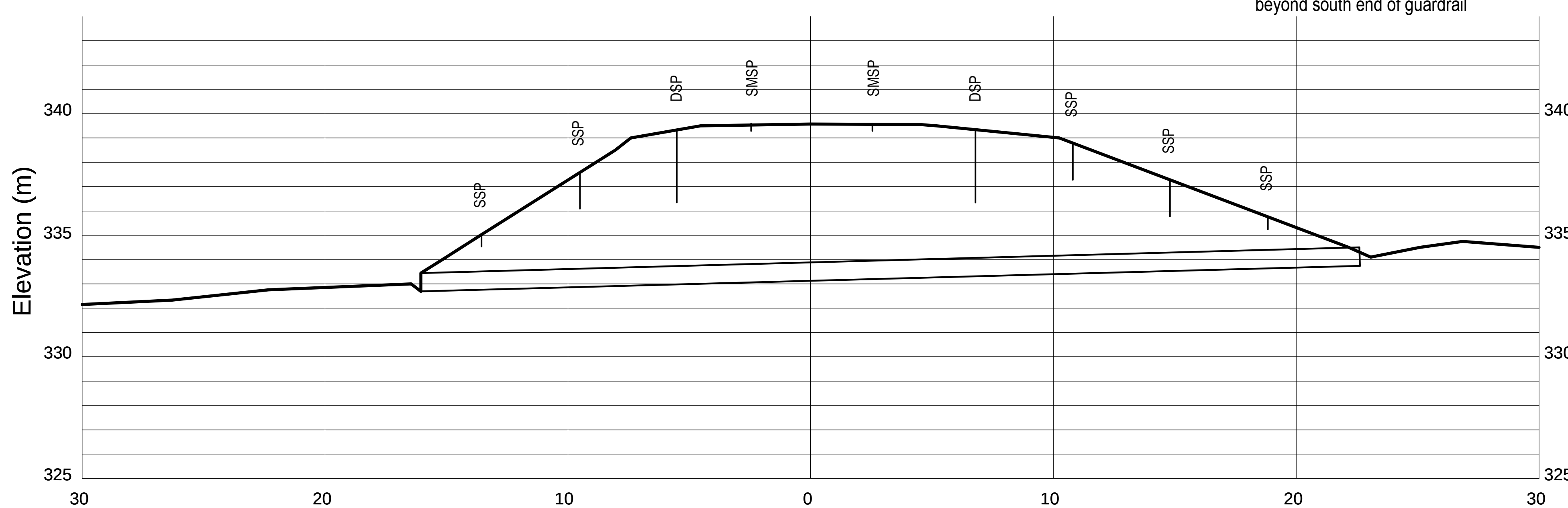
1. Check system for partial excavation condition.
2. If the free water level is above the base of the excavation, the hydrostatic pressure must be added to the above pressure distribution.
3. If surcharge loadings are present near the excavation, these must be included in the lateral pressure calculation.

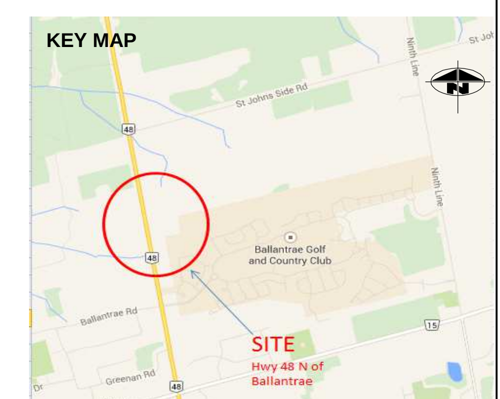
Client:	**Ainley Group**			Project No.: **10000964-1**	Drawing No.: **3**
Drawn:	**TJ**	Approved:	**LC**	Title:	**EARTH PRESSURE DISTRIBUTION ON BRACED EXCAVATIONS**
Date:	**February, 2015**	Scale:	**N.T.S**	Project:	**Proposed Replacement of Culvert C4 Under Highway 48 York Region, Ontario**
Original Size:	**Letter**	Rev:	**N/A**		SPL Consultants Limited Geotechnical ⋆ Environmental ⋆ Materials ⋆ Hydrogeology

SERVER\Geotech\10 GeoProjects\1-1000 Projects\10000964 - Hwy 48-Central Region (Ainley)\Drawings\D4-10000964 HWY48-Feb25-2015-Monitoring.dwg



DBM - Deep Benchmark at shoulder beyond south end of guardrail



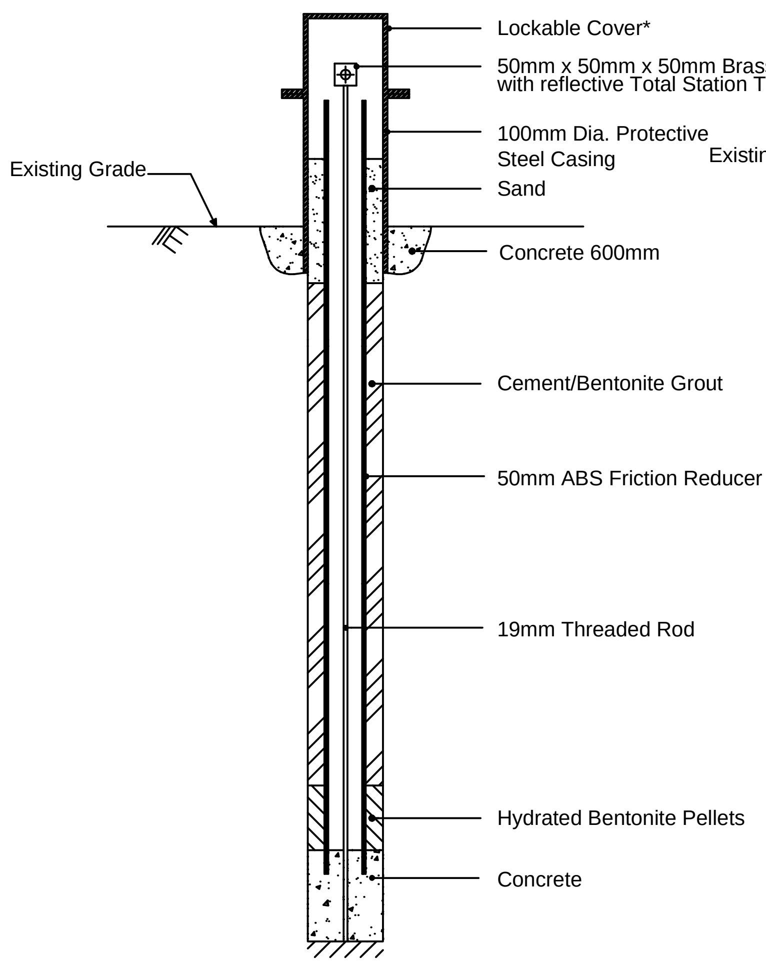


LEGEND

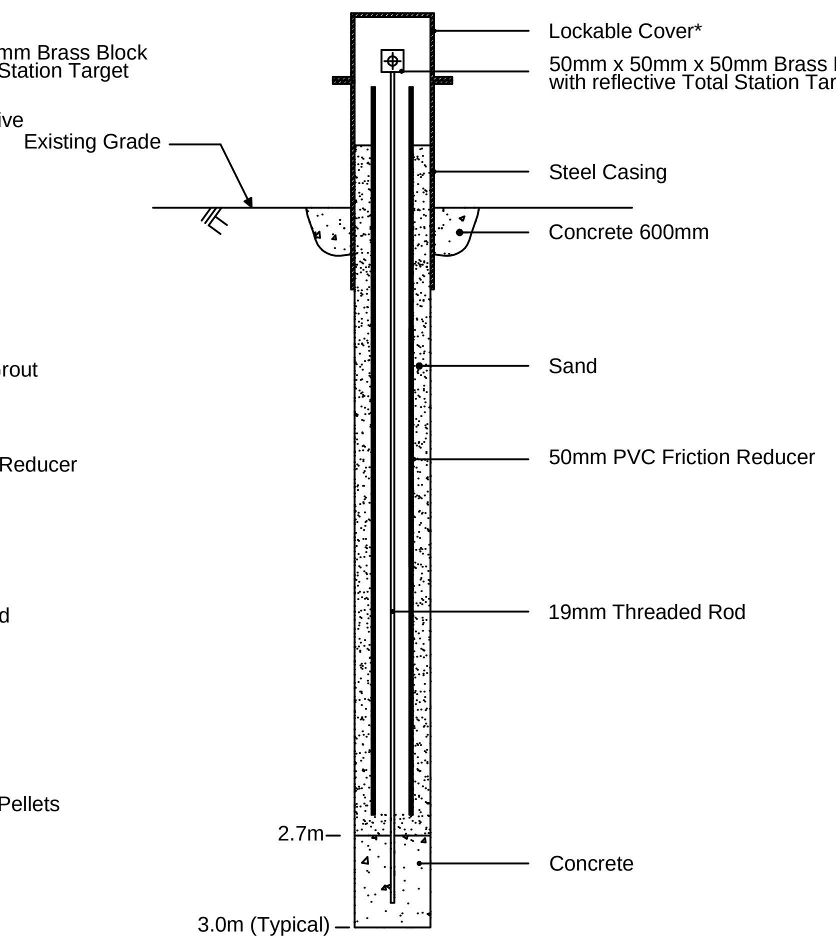
- DBM - Deep Benchmark
- SSP - Shallow Settlement Point
- SMSP - Surface Mounted Settlement Point
- DSP - Deep Settlement Point

Client: Ainley Group		Project No.: 10000964	Drawing No.: 4
Drawn: TJ	Approved: RM	Title: Preliminary Layout of Ground Monitoring Arrays	
Date: Feb.25, 2015	Scale: As Shown	Project: Geotechnical Investigation of Culvert C4 Replacement on Highway 48	
Original Size: Tabloid	Rev: N/A	SPL Consultants Limited Geotechnical • Environmental • Materials • Hydrogeology	

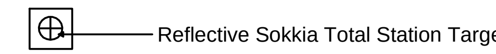
TYPICAL INSTALLATION DETAILS



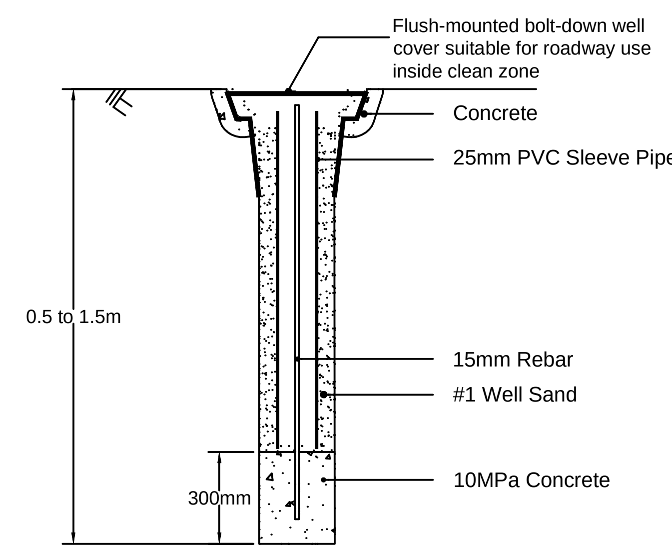
PROPOSED TYPICAL
DEEP SEATED BENCHMARK (DBM)



PROPOSED TYPICAL
DEEP SETTLEMENT POINT (DSP)
(IN UNPAVED AREA)



PROPOSED TYPICAL
SURFACE MOUNTED SETTLEMENT POINT (SMSP)
(ON ASPHALT PAVEMENT)



PROPOSED TYPICAL
SHALLOW SETTLEMENT POINT (SSP)
(IN UNPAVED AREA)

NOTES: *USE OF ABOVE-GRADE PROTECTIVE CASING IS PERMISSIBLE ONLY OUTSIDE OF THE HIGHWAY/RAMP 'CLEAR ZONE'; ELSEWHERE USE FLUSH-MOUNTED COVERS.

TABLE 1
FREQUENCY AND ACCURACY OF MONITORING

Installation Schedule	Baseline Reading	Monitoring Schedule	Monitoring Duration
At least one week prior to start of tunnelling	Minimum of two (2) sets of readings prior to tunnelling. Accuracy of readings should be 0.5mm or better.	Three (3) times per day including during work stoppages (eg. weekends).	On completion of tunnelling, monitoring is to be maintained at least once daily for a minimum of two weeks; then twice weekly for a period of one month; then once month for the following five months. Monitoring can be stopped, with consultation with the monitoring Geotechnical Engineer, two weeks after completion of the tunnel provided further settlement has stopped.

Note:
- During each monitoring visit, all monitoring points are to be recorded.
- The above outline is recommended for all installed monitoring devices including the Deep, Shallow and Surface-mounted Settlements Points.

NOTES:
1) Deep settlement points are to be founded into the embankment fill; but no closer than 2m above the crown of the tunnel.

2) Accurate ground surface elevations and depths to the proposed tunnel obvert are required prior to the installation of any Deep Settlement Points.

3) Deep Seated Benchmarks are to be installed to a minimum depth of 6m and located at least 20m away from the tunnel alignment.

4) Shallow Settlement Points are to be flush with or recessed below the surrounding paved shoulder to protect settlement points and passing traffic from potential damage.

SETTLEMENT CRITERIA:

Definition	Movement
Review Level	≥ 10mm for SSP & DSP ≥ 5mm for SMSP

-Immediately notify MTO & the geotechnical engineer for further assessment; Proceed with caution.

Definition	Movement
Alert Level	≥ 15mm for SSP & DSP ≥ 10mm for SMSP

- Halt tunnelling until further assessment is carried out by the MTO & geotechnical engineer; Carry out immediate remedial work to the settlement zone as approved by the MTO.

SPL Consultants Limited
Geotechnical • Environmental • Materials • Hydrogeology

Installation Details of Ground Monitoring Arrays

Geotechnical Investigation of Culvert C4 Replacement on Highway 48

Scale:	Project No.:
NOT TO SCALE	10000964
Date:	Drawing No.:
Feb. 2015	5

APPENDICES

Appendix E

Tunnelman's Ground Classification and Probable Working Conditions

Tunnelman's Ground Classification and Probable Working Conditions

Soil Classification	Representative Soil Samples	Tunnel Working Conditions
Hard	Very hard calcareous clay; Cemented sand and gravel	Tunnel heading may be advanced without roof support.
Firm	Loess above GWT; Various calcareous clay with low plasticity	Tunnel heading may be advanced without roof support. Permanent support can be constructed before the ground will start to move.
Slow Ravelling and Fast Ravelling	Fast ravelling occurs in residual soils or in sand with clay binder below the GWT. Above the GWT, the same soils may be Slow Ravelling or even Firm.	Chunks of material may drop out of the crown or the sides some time after the ground has been exposed. In Fast Ravelling ground, the process starts within a few minutes; otherwise, it is classed as Slow Ravelling.
Squeezing	Soft or medium-soft clay	Ground slowly advances into tunnel without fracturing and without perceptible increase of water content in ground surrounding the tunnel.
Swelling	Heavily pre-compressed clays with a plasticity index greater than 30. Sedimentary formations containing layers of anhydrite.	Like squeezing ground, moves slowly into tunnel, but the movement is associated with a very considerable volume increase in the ground surrounding the tunnel.
Cohesive Running and Running	Occurs in clean, fine moist sand Occurs in clean, coarse or medium sand above the GWT	Removal of the lateral support of any surface rising at an angle of more than about 34° to the horizontal is followed by a 'run', whereby the material flows like granulated sugar until the slope angle is approx. 34°. If the 'run' is preceded by a brief period of ravelling, the ground is called Cohesive Running.
Very Soft Squeezing	Clays and silts with high plasticity indices	Ground advances rapidly into the tunnel in a plastic flow
Flowing	Below the water table in silt, sand or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.	Flowing ground moves like a viscous liquid. It can invade the tunnel not only through the roof and the sides, but also through the invert. If the flow is not stopped, it will eventually completely fill the tunnel.
Bouldery	Boulder glacial till; riprap fill; some land slide deposits, some residual soils. The matrix between boulders may be gravel, sand, silt, clay and in any combination.	Problems incurred in advancing shield or in forepoling; blasting or hand mining ahead of machine may become necessary.

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Appendix F

Tunnelling Options

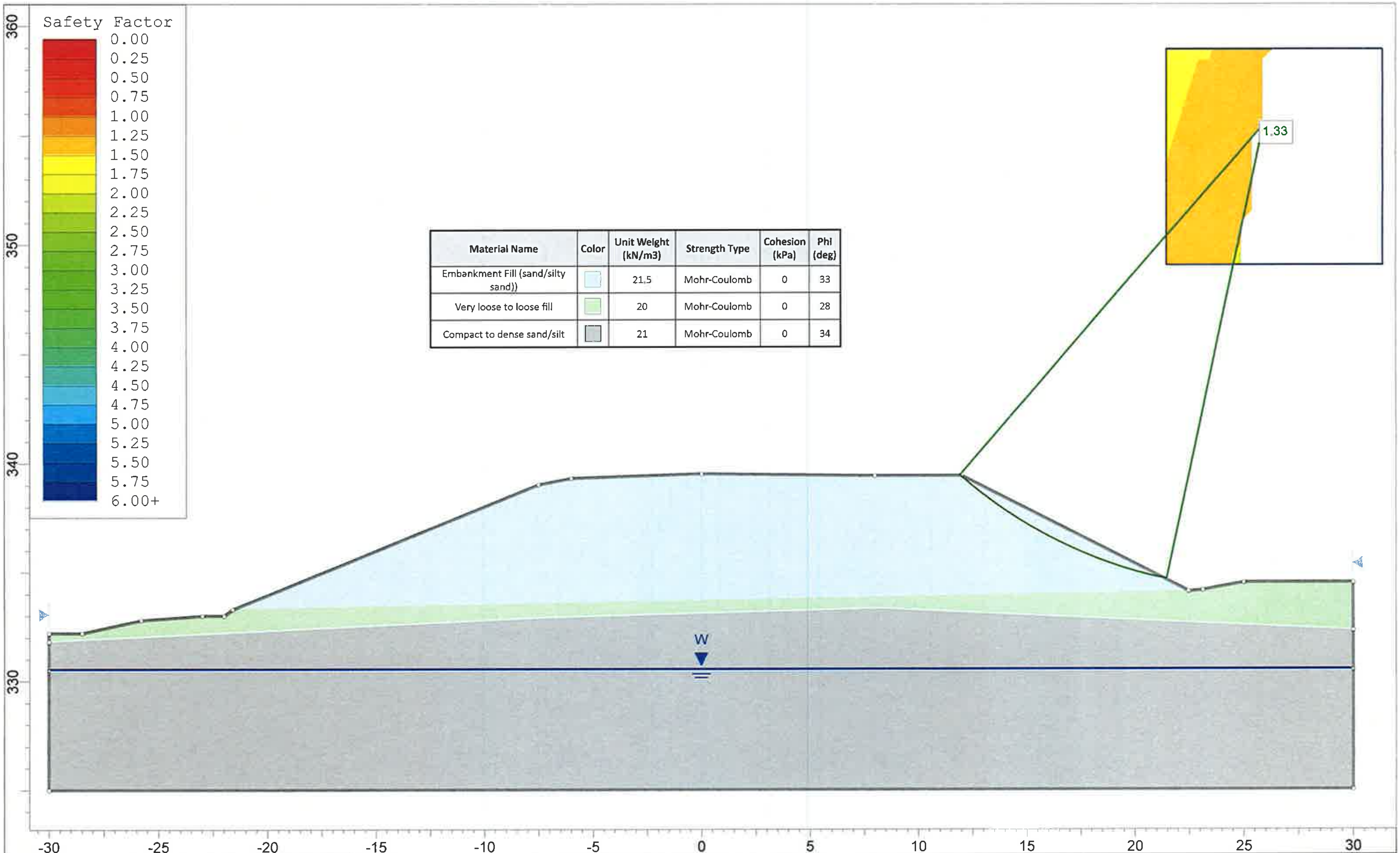
Table F-1: SUMMARY OF TUNNELLING OPTIONS

Option	Construction Method	Application Range		Description	Temporary Support	Permanent Lining	Alignment Control	Advantage	Limitation	Cost* Comparison
		Length	Diameter							
1	Jack and Bore / Auger Boring	Up to ~ 60m	0.1 to 1.5m	A horizontal borehole is advanced from a drive shaft to an exit shaft by the use of a continuous flight auger. Spoil is transported back to the drive shaft by rotating the auger inside a steel casing. The casing is jacked in placed simultaneously during the augering operation.	Provided by the steel casing during the jack and bore operations	After the steel casing installation, the pipe is installed inside the casing and the gap between the casing and the pipe is grouted.	By hydraulic jacks in shafts pushing steel casing Not very good control in mixed face conditions	Technique commonly used locally Skilled labour, equipment and contractor available locally Relatively lower cost	Maybe risky in loose cohesionless soils but can be mitigated by providing a soil plug at the advancing end of the pipe at all times and by utilizing a short advance technique	$2,700 x 42m = $113,400
2	Pipe Ramming	Up to ~50 m	0.15 to 1.5m	This method uses pneumatic percussive blows to the end of the pipe, ramming an open ended casing through the soil. The leading edge or cutting shoe provides a small overcut to reduce friction and to swallow soils rather than compacting it outside of the pipe. Spoil removal from the pipe can be done after the installation is complete.	Casing provided during pipe ramming	After the steel casing installation, the pipe is installed inside the casing and the gap between the casing and the pipe is grouted.	none	Technique commonly used locally Skilled labour, equipment and contractor available locally Relatively lower cost Fast construction schedule	Does not have good alignment control Loose soils above the pipe could densify due to vibration and may cause void and/or settlement of the embankment fill; noise generated which may be objectionable to the adjacent property owners and while traffic is maintained on this highway	$3,000 x 42m = $126,000
3	Microtunnelling	Up to 200m (with internal jacking stations)	0.6 to 3.5m	A tunnel is advanced using a MicroTunnel Boring Machine (MTBM). As the TBM advances temporary or permanent support is installed as spoils are removed.	Jacking Pipe.	Pipe installed during the tunnelling operations, or the pipe can be installed within the larger tunnel lining and the gap grouted.	Can tolerate some misalignment Good control	Method can be executed with any ground condition	High capital cost and setup Specialized operation requiring good operator skill and experience Requires large jacking frame to deal with jacking forces for long tunnelling	$4,400 x 42m = $184,800

*Unit rate provided by Ainley Group

Appendix G

Slope Stability Analysis Results



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Embankment Fill (sand/silty sand))		21.5	Mohr-Coulomb	0	33
Very loose to loose fill		20	Mohr-Coulomb	0	28
Compact to dense sand/silt		21	Mohr-Coulomb	0	34

rocscience

SLIDEINTERPRET 6.026

Project			
Analysis Description			
Drawn By	*Scale* 1:240	*Company*	
Date		*File Name*	Long-Term 1.sli

Appendix H

Limitations of Report

LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to SPL Consultants Limited at the time of preparation. Unless otherwise agreed in writing by SPL Consultants Limited, it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

The conclusions and recommendations given in this report are based on information determined at the test hole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of test holes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. SPL Consultants Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.