



November 27, 2014

FOUNDATION INVESTIGATION REPORT

DEER CREEK CULVERT AT STA 11+815, SITE 43-165/C
HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER
FROM HIGHWAY 539 EASTERLY TO 0.2 KM EAST
OF WEST JUNCTION OF HIGHWAY 64
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 300-98-00, WP 5081-05-01

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REPORT





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PART A

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH), on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services for the rehabilitation of the Highway 17 Deer Creek culvert (Site 43-165/c) at STA 11+815 in the Municipality of West Nipissing, Ontario. The Key Plan showing the general location of this section of Highway 17 and the location of the investigated area are shown on Drawing 1. The purpose of this investigation is to establish the subsurface conditions at the location of the culvert by borehole drilling, in situ testing and laboratory testing on selected soil samples.

2.0 SITE DESCRIPTION

The Deer Creek culvert is located on Highway 17 east of the Town of Warren approximately 3 km east of the junction with Highway 539. In general, the topography in the area of the overall project limits consists of flat terrain primarily utilized as farmland, with moderate tree cover. The existing highway grade is at about Elevation 208 m with Deer Creek crossing under the embankment about 8 m below the existing highway grade. The side slopes of the existing embankment are inclined at about 1.5 Horizontal to 1 Vertical (1.5H:1V). Rock fill is present on the embankment side slopes with some pieces at least 1 m size. The existing culvert consists of 26 m long, twin 6.1 m square cell concrete boxes.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between January 24 and February 10, 2014, during which time a total of six boreholes were advanced at the approximate locations shown on Drawing 1:

- three boreholes for the culvert alignment (Boreholes DE-1, DE-4 and DE-5);
- one borehole for the proposed roadway protection (Borehole DE-2); and
- two boreholes for the proposed cofferdam (Boreholes DE-3 and DE-6).

Boreholes DE-1 and DE-2, located on the existing highway embankment, were advanced to depths of 20.4 m and 14.8 m, respectively, below ground surface using a truck-mounted CME 75 drill rig outfitted with 108 mm inside diameter continuous flight hollow-stem augers, 150 mm outer diameter (O.D.) continuous flight solid stem augers, and/or 'NW' casing with wash boring techniques. Boreholes DE-3 to DE-6, located at or beyond the existing toe of slope, were advanced by wash boring methods with portable equipment using NQ casing. A Dynamic Cone Penetration Test (DCPT) was advanced adjacent to Boreholes DE-1 and DE-3 to DE-5 to depths between 14.9 m and 20.4 m below ground/ice surface.

The drilling equipment was supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. Soil samples were obtained at intervals of depths of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler driven by an automatic hammer at Boreholes DE-1 and DE-2 and a manual hammer at Boreholes DE-3 to DE-6, and performed in accordance with Standard Penetration Test (SPT) procedure (ASTM D1586). Selected samples of the cohesive soils were obtained using 76 mm O.D. thin-walled 'Shelby' tubes (ASTM D1587, Standard Practice for Thin-Walled Tube Sampling) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573,



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Standard Test Method for Field Vane Strength Shear Test) using MTO Standard 'N' size vanes. The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A. All boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Reg. 903 (as amended).

The fieldwork was supervised throughout by members of our technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are presented on the Record of Borehole sheets in Appendix A and are also included in Appendix B.

A sample of the creek water was obtained on March 10, 2014, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B, together with the detailed analytical laboratory test results.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the marked stations and offsets on the highway or the ends of the culvert, as applicable. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depth at each borehole are presented on the Record of Borehole sheets in Appendix A and are summarized below.

Borehole	Borehole Location		Ground Surface Elevation (m)	Borehole/DCPT Depth Below Ground/Ice Surface (m)
	Northing	Easting		
DE-1	5144162.2	245673.4	208.2	20.4/20.4
DE-2	5144163.7	245640.8	208.4	14.8
DE-3	5144187.0	245672.5	202.4	15.8/16.7
DE-4	5144189.8	245653.0	202.0	15.8/16.8
DE-5	5144143.7	245655.8	202.9	17.4/14.9*
DE-6	5144137.3	245674.8	202.7	15.8*

*includes 0.3 m thick layer of ice



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on terrain mapping (Ontario Geological Survey¹), the site is located on a glaciolacustrine plain in an area of sand and silt deposits with a bedrock knob located within approximately 100 m to the south of the site.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions, as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil core samples, are given on the Record of Borehole sheets in Appendix A. The results of the in situ tests (i.e., SPT “N”-values and undrained shear strengths from the field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. Detailed results of the laboratory testing of the soil samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile and cross-section shown on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface stratigraphy at the site consists of embankment fill (where encountered) underlain by a surficial deposit of cohesionless soils consisting of sandy silt to gravelly sand, underlain by clayey silt to silty clay, which in turn is underlain by a silt to silt and sand deposit. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Boreholes DE-1 and DE-2 penetrated a layer of asphalt 150 mm thick at Elevation 208.2 m and 208.4 m, respectively, underlain by a fill deposit comprised of sand and gravel to gravelly sand about 8.6 m and 7.0 m thick, respectively. In Boreholes DE-1 and DE-2, auger refusal on cobbles and/or boulders was noted at depths of 0.8 m (Elevation 207.4 m) and 1.4 m (Elevation 207.4 m) and NW casing and NQ coring techniques were required to advance the boreholes through the fill with recovery of cobbles/boulders ranging in thickness from 90 mm to 300 mm.

The SPT ‘N’-values measured within the sand and gravel to gravelly sand fill range between 8 blows and 63 blows per 0.3 m of penetration indicating a loose to very dense relative density. Two SPT ‘N’-values measured within the fill did not penetrate the full sample depth as spoon refusal was encountered, inferred to be as a result of the cobbles/boulders within the fill.

The natural moisture content measured on a selected sample of the fill is about 12 per cent.

¹ Southern Ontario Engineering Geology Terrain Study, 1980. Ontario Geological Survey.



4.2.2 Clayey Silt to Silt

From ground surface in Boreholes DE-3 and DE-4, a deposit of clayey silt to silt was encountered at Elevation 202.4 and 202.0 m, with a thickness of 1.1 m and 0.8 m, respectively.

Two SPT 'N'-values measured within this deposit are 1 blow and 2 blows per 0.3 m of penetration, indicating a very soft consistency.

4.2.3 Sandy Silt to Gravelly Sand

A deposit of sandy silt, sand and silt, silty sand, sand and/or gravelly sand was encountered below the fill in Boreholes DE-1 and DE-2, below the clayey silt to silt in Boreholes DE-3 and DE-4 and from ground surface below a 0.3 m thick layer of snow/ice in Boreholes DE-5 and DE-6. Some organics were noted in the upper 1.2 m of the sandy silt deposit in Boreholes DE-5 and DE-6. Casing refusal was encountered in Borehole DE-6 at a depth of 0.9 m below ground surface (1.2 m below the ice surface) inferred to be on a boulder and the borehole was relocated 0.3 m to the east to continue sampling. The surface of the sandy silt to gravelly sand deposit was encountered between Elevations 202.6 m and 199.5 m and the deposit is between about 2.9 m and 6.1 m thick.

The SPT 'N'-values measured within this deposit range between 2 blows and 25 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

Grain size analyses were carried out on six samples of this deposit and the results are represented on Figure B1 in Appendix B.

An Atterberg limits test was carried out on a sample of the sandy silt in Borehole DE-4 and indicates that the material is non-plastic.

The natural moisture content measured on selected samples of the sandy silt to gravelly sand ranges between about 20 per cent and 28 per cent, with one sample measuring a water content of 45 per cent, the higher value being attributed to the organics in the sample.

4.2.4 Clayey Silt to Silty Clay

A deposit of clayey silt to silty clay was encountered below the sandy silt to gravelly sand deposit in all of the boreholes with the surface of the deposit encountered between about Elevations 197.2 m and 195.9 m. The thickness of the deposit in Boreholes DE-1 and DE-3 to DE-6 is between about 7.0 m and 9.4 m and Borehole DE-2 did not fully penetrate the deposit after exploring for about 3.1 m. Sand and/or silt laminations/layers were observed within the deposit as noted on the borehole logs.

The SPT 'N'-values measured within the clayey silt to silty clay deposit generally range between 0 blows (weight of hammer) and 5 blows per 0.3 m of penetration and 'N'-values in the sand and/or silt laminations/layers range from 6 blows to 25 blows per 0.3 m of penetration. In situ field vane testing measured undrained shear strengths ranging from 26 kPa to greater than 100 kPa, with a sensitivity between 2 and 4. The in situ vane test results indicate that the deposit generally has a firm to very stiff consistency, with the shear strength results greater than 100 kPa likely a result of the presence of silt laminations/layers in the cohesive layer tested.



Atterberg limits testing were carried out on twelve samples of the cohesive deposit and measured liquid limits ranging from about 29 per cent to 42 per cent, plastic limits ranging from about 16 per cent to 21 per cent, and plasticity indices ranging from about 13 per cent to 21 per cent. The results, which are plotted on a plasticity chart on Figures B2 in Appendix B, indicate that the tested samples of the overall deposit consist of clayey silt of low plasticity to silty clay of intermediate plasticity.

The results of the grain size distribution testing completed on one sample of the silt interlayer in Borehole DE-6 is shown on Figure B3 in Appendix B. An Atterberg limits test was also carried out on one sample of the silt interlayer in Borehole DE-6 and indicates that the material is non-plastic.

The natural moisture content measured on selected samples of the clayey silt to silty clay deposit ranges between about 27 per cent and 44 per cent; whereas, the natural moisture content measured on three samples of the silt interlayer ranges between 22 per cent and 35 per cent.

4.2.5 Silt to Silt and Sand

A deposit of silt to sandy silt to silt and sand, some clay, was encountered below the clayey silt to silty clay deposit in Boreholes DE-1 and DE-3 to DE-6. The surface of this deposit was encountered between Elevations 189.5 m and 187.1 m and sampled boreholes did not fully penetrate the deposit after exploring for thicknesses of between approximately 0.9 m and 4.0 m.

The SPT 'N'-values measured within this deposit range between 11 blows and 28 blows per 0.3 m of penetration, indicating a compact relative density.

Grain size analyses were carried out on four samples of this deposit and the results are represented on Figure B3 in Appendix B.

Atterberg limits testing carried out on four samples of the silt to silt and sand deposit indicates that the material is non-plastic.

The natural moisture content measured on selected samples of the silt to silt and sand deposit ranges between about 25 per cent and 29 per cent.

4.2.6 Groundwater Conditions

In Borehole DE-1, the borehole caved at 12.2 m upon the completion of drilling and the borehole was noted to be dry to this depth. The unstabilized water level in Borehole DE-2 upon completion of drilling was at a depth of 7.2 m below roadway level, corresponding to Elevation 201.2 m. The unstabilized water levels in Boreholes DE-3 to DE-6 upon completion of drilling range between 1.3 m and 2.6 m below ground surface, between Elevations 201.4 m and 200.1 m. On January 31, 2014, the ice surface in the creek on the south side of the embankment was surveyed at Elevation 200.9 m.

Groundwater levels encountered in the boreholes shortly after drilling may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Groundwater levels are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.



5.0 CLOSURE

The drilling program was supervised by Mr. Gabriel Mathieu, Mr. Trevor Moxam and Mr. Mat Riopelle. This report was prepared by Mr. Matthew Thibeault, EIT and reviewed by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report



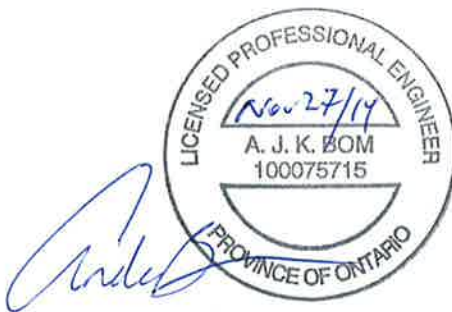
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Report Signature Page

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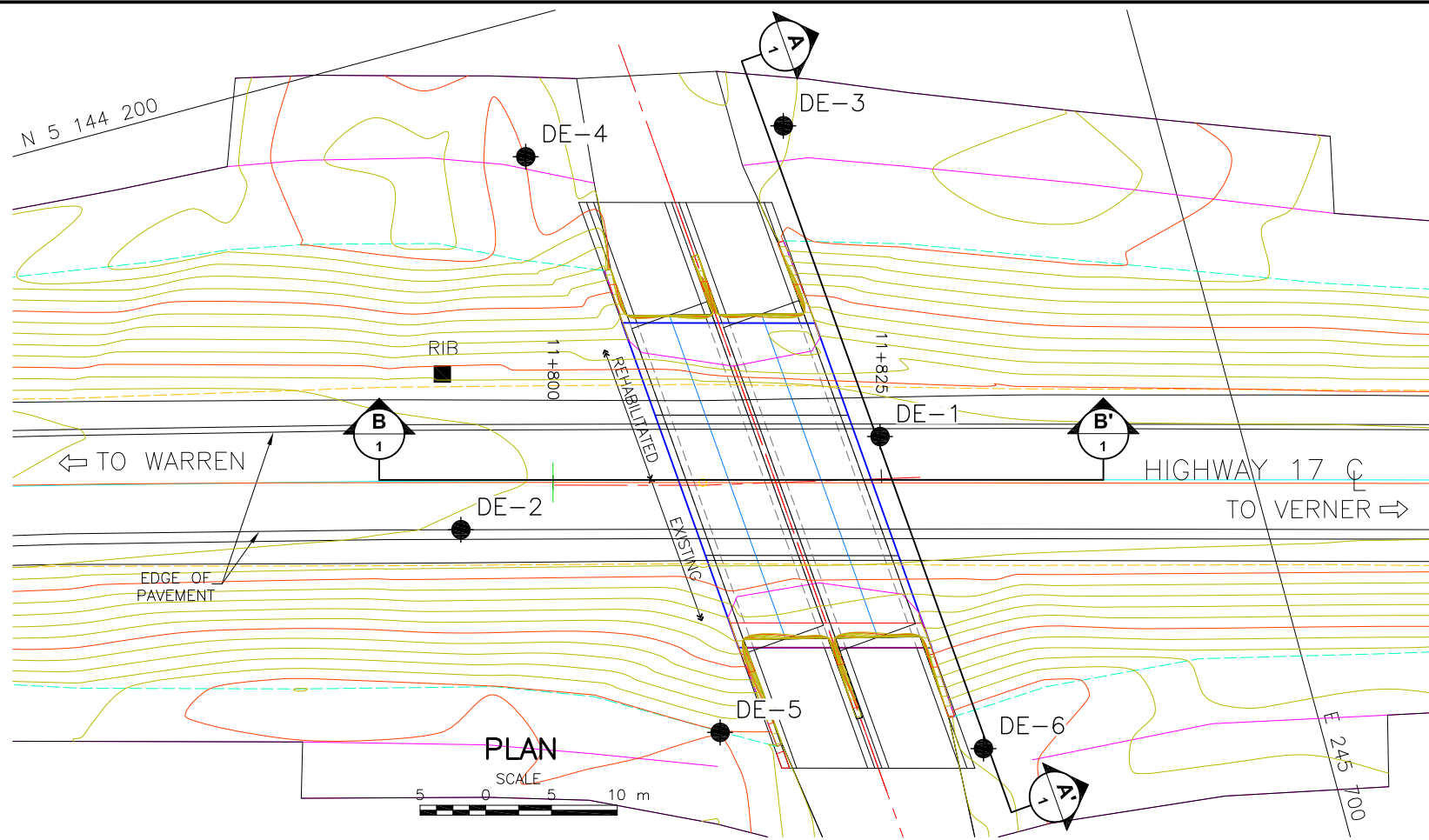


Jorge M.A. Costa, P.Eng
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METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5081-05-01

HIGHWAY 17
DEER CREEK CULVERT - STA 11+815
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

SCALE
0 8 km

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
DE-1	208.2	5144162.2	245673.4
DE-2	208.4	5144163.7	245640.8
DE-3	202.4	5144187.0	245672.5
DE-4	202.0	5144189.8	245653.0
DE-5	202.9	5144143.7	245655.8
DE-6	202.7	5144137.3	245674.8

NOTES

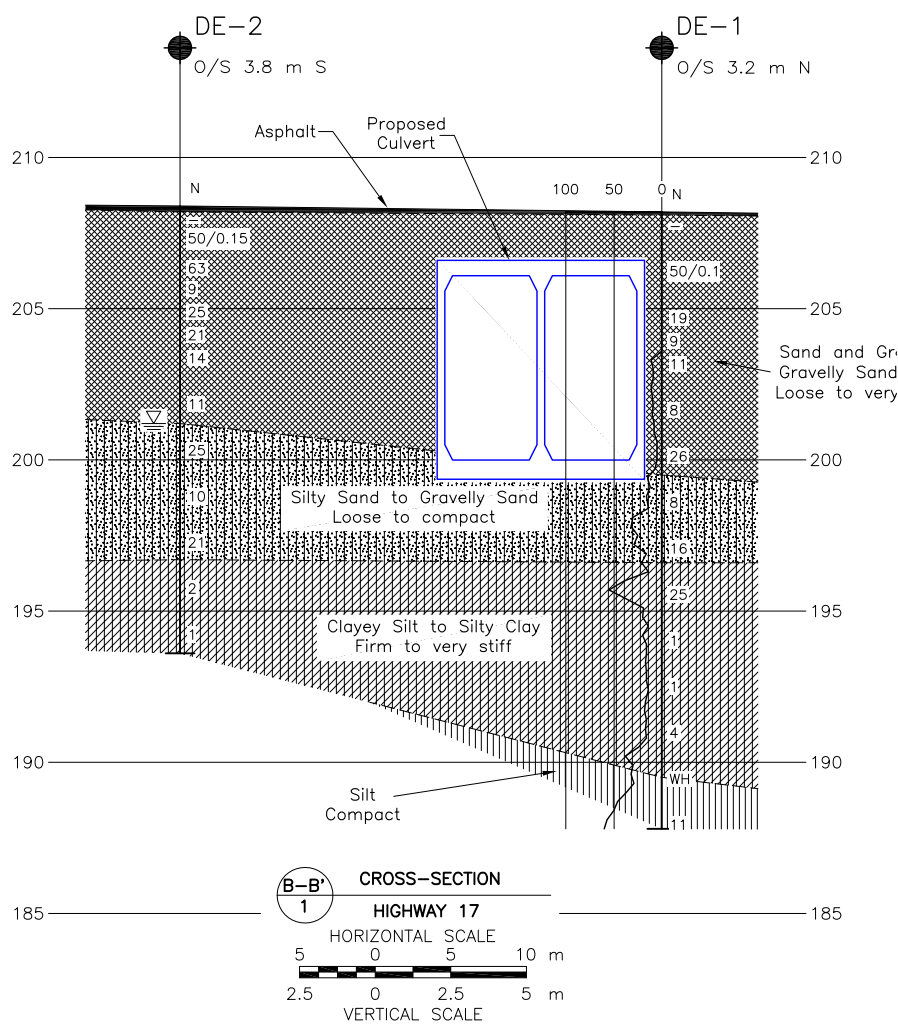
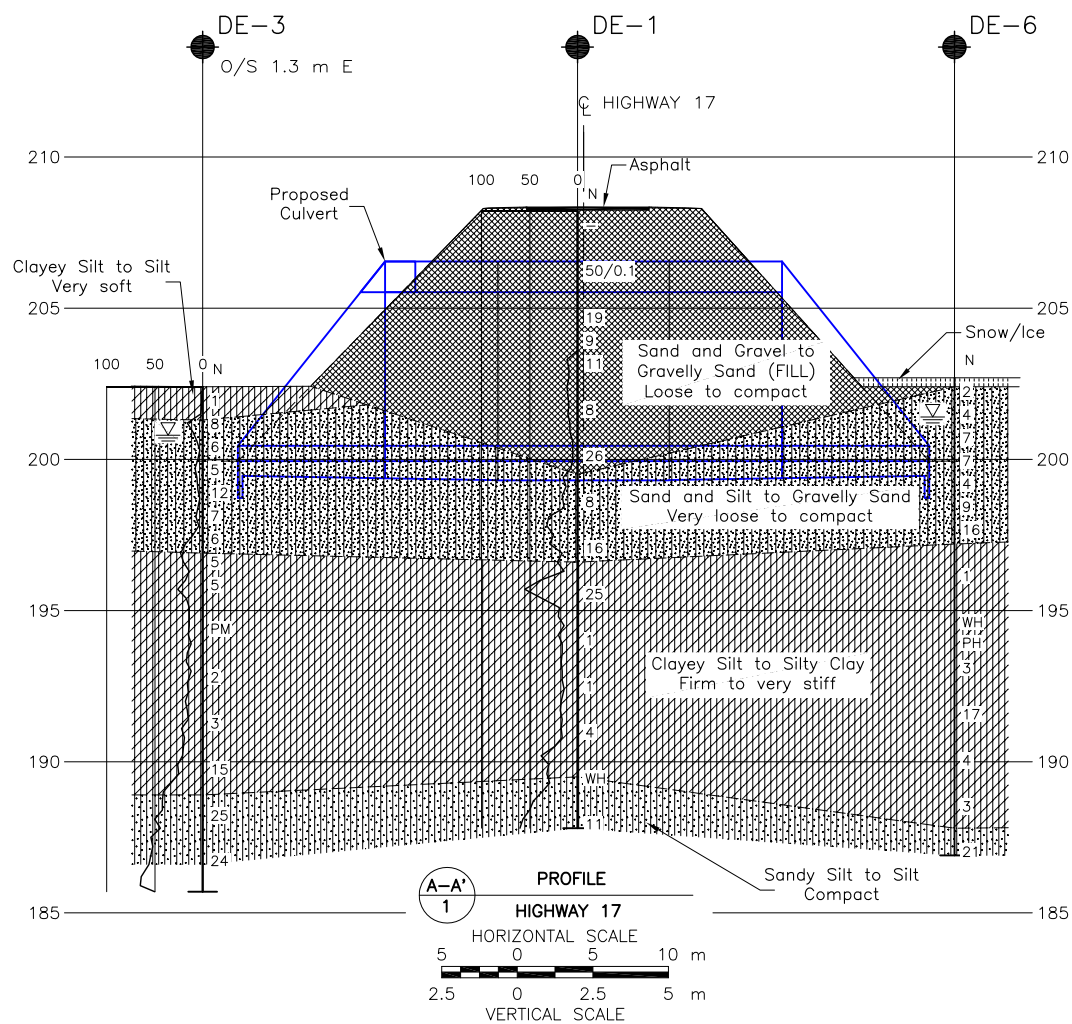
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by Morrison Hershfield, drawing file no. X-1130113_Base Plan.dwg, received NOV 13, 2014 and 43-165C_01.dwg, received NOV 13, 2014.





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$
$$\text{shear strength} = (\text{compressive strength})/2$$



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. 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.)

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° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	C_u, S_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
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
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT		13-1184-0074											
W.P.		5081-05-01											
DIST		HWY 17											
DATUM		GEODETIC											
LOCATION		N 5144162.2; E 245673.4											
BOREHOLE TYPE		Solid Stem Augers, NW Casing, Wash Boring											
DATE		February 5 and 6, 2014											
ORIGINATED BY		TM											
COMPILED BY		MT											
CHECKED BY		DAM											
SOIL PROFILE		SAMPLES		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	RESISTANCE PLOT	W _p	W	W _L	γ	GR SA SI CL
208.2	GROUND SURFACE												
0.9	ASPHALT (150 mm)		1	AS	-		208						
0.1	Sand and gravel to gravely sand (FILL) Loose to compact Brown Moist to wet						207						
	Auger refusal at 0.8 m depth. Switched to NW casing.		-	SS	50/0.1		206						
	No sample recovered at 1.5, 3.0 and 3.8 m depths. Cobbles/Boulders as follows: Depth (m) Thickness (mm) 0.8 150 1.1 100 2.1 300 2.7 150 5.8 120 7.1 90 7.3 90						205						
			2	SS	19		204						
			-	SS	9		203						
			3	SS	11		202						
			4	SS	8		201						
			5	SS	26		200						
199.5			6	SS	8		199						
8.7	SAND to Gravelly SAND, some silt, trace clay Loose to compact Grey Wet		7	SS	16		198						
			8	SS	25		197						
196.6			9	SS	1		196						
11.6	CLAYEY SILT to SILTY CLAY Firm to very stiff Grey Wet Approximately 0.8 m thick sandy silt layer at 12.5 m depth.						195						
							194						

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-1			2 OF 2 METRIC															
W.P. 5081-05-01			LOCATION N 5144162.2; E 245673.4			ORIGINATED BY TM															
DIST HWY 17			BOREHOLE TYPE Solid Stem Augers, NW Casing, Wash Boring			COMPILED BY MT															
DATUM GEODETIC			DATE February 5 and 6, 2014			CHECKED BY DAM															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L										
189.5	CLAYEY SILT to SILTY CLAY Firm to very stiff Grey Wet		10	SS	1		193														
							192														
							191														
							190														
18.7	SILT, some sand, some clay Compact Grey Wet		12A	SS	WH		189														
			12B																		
187.8			13	SS	11		188														
20.4	END OF BOREHOLE Note: 1. Borehole caved at 12.2 m upon completion of drilling. Borehole dry to 12.2 m depth. 2. DCPT advanced 1 m east of Borehole DE-1, preaugered to 4.6 m.																				

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No DE-2		1 OF 2 METRIC	
W.P. <u>5081-05-01</u>		LOCATION <u>N 5144163.7; E 245640.8</u>		ORIGINATED BY <u>TM</u>	
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring</u>		COMPILED BY <u>MT</u>	
DATUM <u>GEODETIC</u>		DATE <u>February 6 and 10, 2014</u>		CHECKED BY <u>DAM</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W _p	W	W _L						
208.4	GROUND SURFACE																				
0.0	ASPHALT (150 mm)																				
0.2	Sand and gravel to gravelly sand (FILL) Loose to very dense Brown Moist Augers grinding between 1.1 m and 1.4 m depth. Auger refusal at 1.4 m depth, switched to NW Casing and recovered 300 mm boulder at 1.4 m depth. No sample recovered at 2.3 m depth.		1	AS	-																
			2	SS	50/0.15																
			3	SS	63																
			-	SS	9																
			4	SS	25																
		5	SS	21																	
		6	SS	14																	
		7	SS	11																	
201.2																					
7.2	Silty SAND to SAND, trace clay, trace organics Compact Grey Wet		8	SS	25																
			9	SS	10																
		10	SS	21																	
196.7																					
11.7	SILTY CLAY Very stiff Grey Wet		11	SS	2																
			12	SS	1																
193.6																					
14.8																					

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

Continued Next Page


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

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-3			1 OF 2 METRIC													
W.P. 5081-05-01			LOCATION N 5144187.0; E 245672.5			ORIGINATED BY MR													
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT													
DATUM GEODETIC			DATE February 5, 2014			CHECKED BY DAM													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED			WATER CONTENT (%) W _p — W — W _L			γ			GR SA SI CL		
202.4	GROUND SURFACE							20	40	60	80	100	20	40	60	kN/m ³			
0.0	CLAYEY SILT to SILT, trace to some sand, trace to some organics Very soft Moist (frozen) Grey		1	SS	1		202												
201.3	SAND, trace to some silt, trace clay Loose to compact Grey Wet		2A	SS	8		201												
1.1			2B																
			3	SS	6		200												
			4	SS	5														
	Approximately 0.6 m thick organic (wood fragments) layer at 3.0 m depth.		5	SS	12		199												
			6	SS	7		198												
			7	SS	6														
196.9	CLAYEY SILT to SILTY CLAY Firm to stiff Grey Wet		8A	SS	5		197												
5.5			8B																
	Silt laminations above 7.2 m depth.		9	SS	5		196												
			10	TO	PM		195												
			11	SS	2		194												
			12	SS	3		193												
			13	SS	15		192												
	Silt laminations below 12.2 m depth.		14	SS	25		191												
188.9	SILT and SAND, trace to some clay Compact Grey Wet						190												
13.5							189												
							188												

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT 13-1184-0074				RECORD OF BOREHOLE No DE-3				2 OF 2 METRIC									
W.P. 5081-05-01				LOCATION N 5144187.0; E 245672.5				ORIGINATED BY MR									
DIST HWY 17				BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY MT									
DATUM GEODETIC				DATE February 5, 2014				CHECKED BY DAM									
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100						
186.6	SILT and SAND, trace to some clay Compact Grey Wet		15	SS	24											NP	0 33 60 7
15.8	END OF BOREHOLE																
185.7																	
16.7	END OF DYNAMIC CONE PENETRATION TEST																
	Note: 1. Water level at a depth of 1.6 m below ground surface (Elev. 200.8 m) upon completion of drilling. 2. DCPT advanced 0.4 m north of Borehole DE-3.																


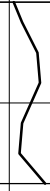
SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-4			1 OF 2 METRIC											
W.P. 5081-05-01			LOCATION N 5144189.8; E 245653.0			ORIGINATED BY MR											
DIST HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT											
DATUM GEODETIC			DATE February 3 and 4, 2014			CHECKED BY DAM											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60	W _p W W _L	γ	GR SA SI CL					
202.0	GROUND SURFACE																
0.0	CLAYEY SILT to SILT, trace to some sand, trace to some organics Very soft Grey Moist (frozen)		1	SS	2												
201.2	Sandy SILT to Silty SAND, trace to some clay, trace gravel, trace organics Very loose to loose Grey to brown Moist		2	SS	2		201				NP	2 27 63 8					
0.8			3	SS	3		200										
	Wet below 1.5 m depth.		4	SS	5		199										
			5	SS	3		198										
			6	SS	6		197										
			7	SS	7		196										
195.9	CLAYEY SILT to SILTY CLAY Firm to very stiff Grey Wet		8	SS	2		195										
6.1			9	SS	22		194										
	Approximately 0.9 m thick silt layer at 7.6 m depth.		10	SS	2		193										
			11	TO	PM		192										
	Silt laminations below 10.7 m depth.		12	SS	3		191										
			13	SS	4		190										
			14	SS	8		189										
187.1							188										

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT		13-1184-0074				RECORD OF BOREHOLE No DE-4				2 OF 2 METRIC									
W.P.		5081-05-01		LOCATION		N 5144189.8; E 245653.0				ORIGINATED BY				MR					
DIST		HWY 17		BOREHOLE TYPE		NW Casing, Wash Boring				COMPILED BY				MT					
DATUM		GEODETIC		DATE		February 3 and 4, 2014				CHECKED BY				DAM					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)						
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100							
14.9	SILT, trace to some clay, trace sand		15	SS	28		186											NP	0 5 85 10
186.2	Compact Grey Wet																		
15.8	END OF BOREHOLE																		
185.2	END OF DYNAMIC CONE PENETRATION TEST																		
16.8	Note: 1. Water level at a depth of 1.9 m below ground surface (Elev. 200.1 m) upon completion of drilling. 2. DCPT advanced 0.5 m north of Borehole DE-4.																		

PROJECT		13-1184-0074		RECORD OF BOREHOLE No DE-5		1 OF 2 METRIC						
W.P.		5081-05-01		LOCATION		N 5144143.7; E 245655.8						
DIST		HWY 17		BOREHOLE TYPE		NW Casing, Wash Boring						
DATUM		GEODETIC		DATE		January 24 to 29, 2014						
				ORIGINATED BY		GM						
				COMPILED BY		MT						
				CHECKED BY		DAM						
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	"N" VALUES					
202.9	SNOW SURFACE											
0.0	SNOW/ICE											
202.6			1	SS	7							
0.3	Sandy SILT, some organics Very loose to loose Brown Moist		2	SS	2							
201.4			3	SS	7							
1.5	Sandy SILT to Silty SAND Very loose to loose Brown Moist to wet		4	SS	5							
			5	SS	2							
	Approximately 0.6 m thick silt layer at 3.8 m depth.		6	SS	2							
	Approximately 0.1 m thick sand layer at 4.6 m.		7A 7B	SS	12							
			8A 8B	SS	2							
196.5	CLAYEY SILT Firm to stiff Brown Wet		9	SS	4							
6.4			10	SS	7							
	Silt laminations at 9.1 m depth.		11	SS	6							
	Approximately 0.3 m thick silty sand layer encountered at 10.7 m depth.		12	SS	3							
189.5	SILT, trace to some clay Compact Grey Wet		13	SS	24							
13.4												

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

Continued Next Page

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

PROJECT		13-1184-0074				RECORD OF BOREHOLE No DE-5				2 OF 2 METRIC							
W.P.		5081-05-01		LOCATION		N 5144143.7; E 245655.8				ORIGINATED BY		GM					
DIST		HWY 17		BOREHOLE TYPE		NW Casing, Wash Boring				COMPILED BY		MT					
DATUM		GEODETIC		DATE		January 24 to 29, 2014				CHECKED BY		DAM					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---																
	SILT, trace to some clay Compact Grey Wet		14	SS	18											NP	0 0 90 10
185.5			15	SS	23												
17.4	END OF BOREHOLE Note: 1. Water level at a depth of 2.6 m below ground surface (Elev. 200.3 m) upon completion of drilling. 2. DCPT advanced 1 m west of Borehole DE-5.																


SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No DE-6			1 OF 2 METRIC															
W.P. 5081-05-01			LOCATION N 5144137.3; E 245674.8			ORIGINATED BY GM															
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT															
DATUM GEODETIC			DATE January 30, 2014			CHECKED BY DAM															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
202.7	SNOW SURFACE							20 40 60 80 100	20 40 60	W _p W W _L											
0.0	SNOW/ICE							20 40 60 80 100	20 40 60												
202.4			1	SS	2		202														
0.3	SILT and SAND, some organics Very loose Brown Moist		2	SS	4		201														
201.2	Casing refusal at 1.5 m depth below the ice surface on probable cobble or boulder (hammer bouncing). Moved borehole 0.3 m east and advanced casing to 1.5 m depth without sampling.		3	SS	7		200														
1.5	SAND and SILT to Silty SAND, trace to some clay Very loose to compact Grey Wet		4	SS	7		199														
	Approximately 0.6 m thick sand layer at 3.0 m depth.		5	SS	4		198														
			6	SS	9		197														
			7	SS	16		196														
197.2			8	SS	1		195														
5.5	SILTY CLAY Firm to stiff Grey Wet		9	SS	WH		194														
			10	TO	PH		193														
			11	SS	3		192														
	Approximately 1.5 m thick silt layer at 10.7 m depth.		12	SS	17		191														
			13	SS	4		190														
			14	SS	3		189														
187.8							188														

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No DE-6				2 OF 2 METRIC											
W.P. <u>5081-05-01</u>		LOCATION <u>N 5144137.3; E 245674.8</u>				ORIGINATED BY <u>GM</u>											
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>NW Casing, Wash Boring</u>				COMPILED BY <u>MT</u>											
DATUM <u>GEODETIC</u>		DATE <u>January 30, 2014</u>				CHECKED BY <u>DAM</u>											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> W_p W W_L </div>					
14.9	Sandy SILT		15	SS	21												
186.9	Compact Grey Wet																
15.8	END OF BOREHOLE																
	Note: 1. Water level at a depth of 1.3 m below ground surface (Elev. 201.4 m) upon completion of drilling.																

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 02/05/14 DATA INPUT:



APPENDIX B

Laboratory Test Results



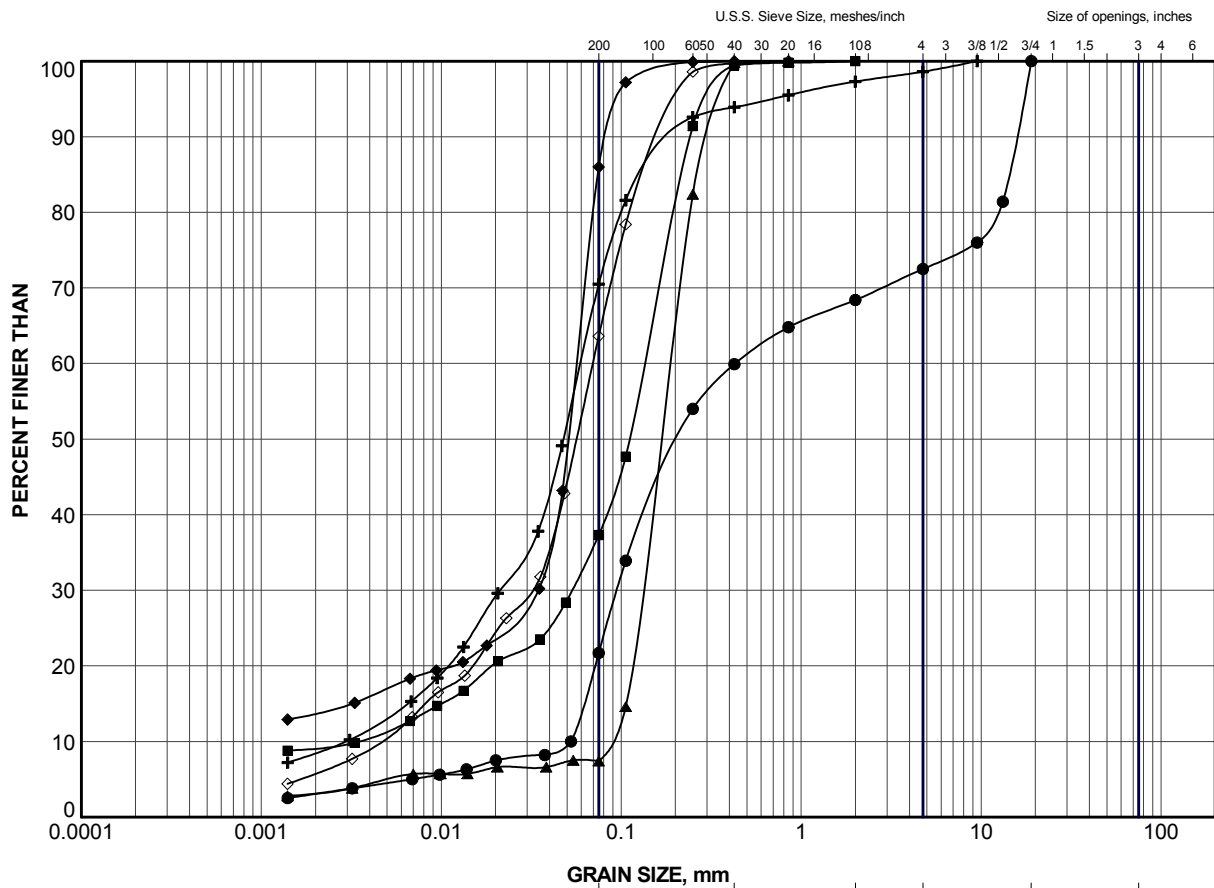
FOUNDATION INVESTIGATION AND DESIGN REPORT HIGHWAY 17 DEER CREEK CULVERT, SITE 43-165/C

Table B1 - Summary of Analytical Testing of Deer Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	11
Dissolved Sulphate	mg/L	1	8
Conductivity	µohm/cm	1	230
Resistivity	ohm-cm	n/a	4300
pH	n/a	n/a	7.51

- Notes:
1. Sample obtained on March 10, 2014.
 2. Analytical testing carried out by Maxxam Analytics.

Checked by: AB



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	DE-1	6	198.8
■	DE-2	8	200.5
▲	DE-3	6	198.3
+	DE-4	2	200.9
◆	DE-5	6	198.8
◇	DE-6	2	201.6

PROJECT

HIGHWAY 17
DEER CREEK CULVERT STA 11+815

TITLE

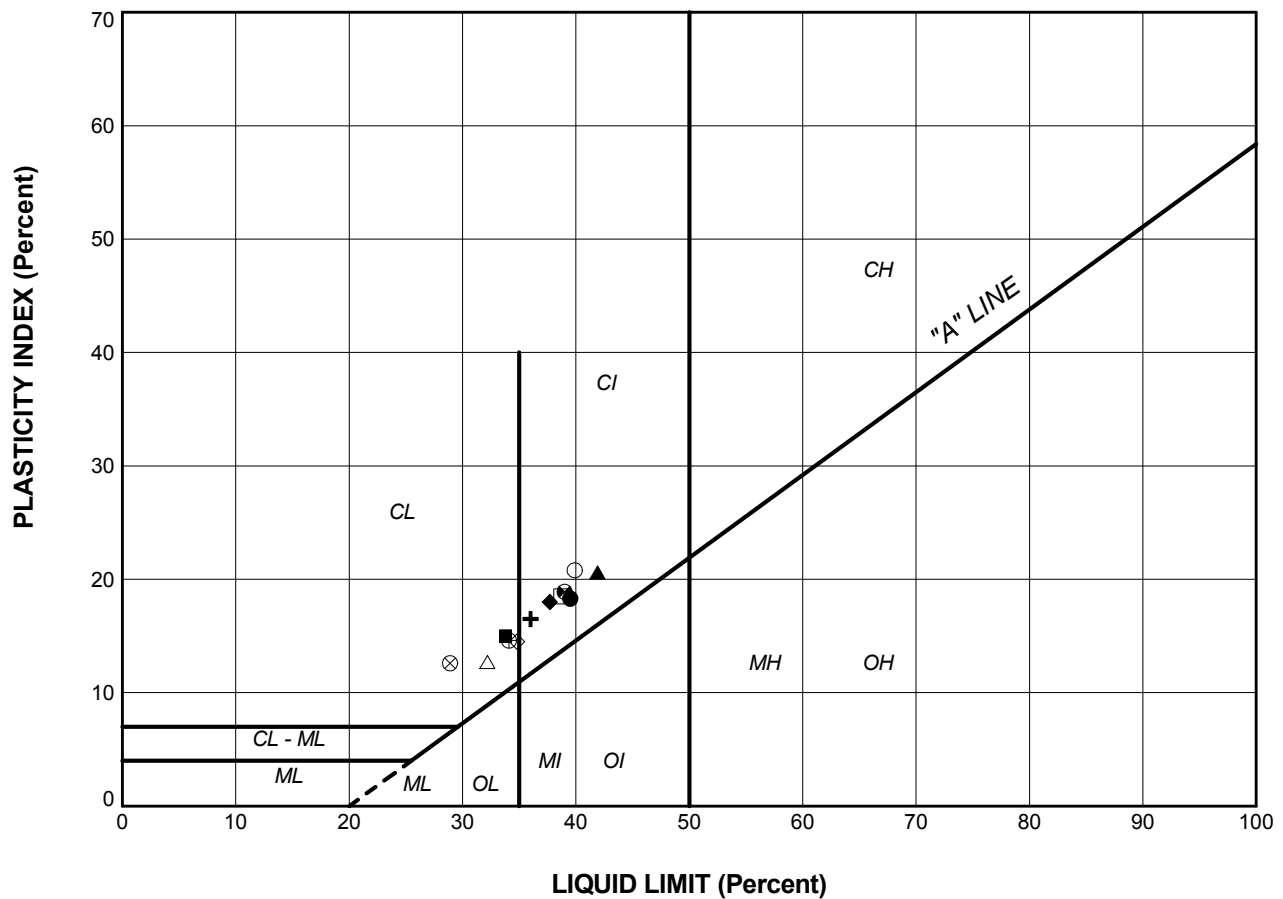
GRAIN SIZE DISTRIBUTION
SANDY SILT to GRAVELLY SAND



**Golder
Associates**
SUDBURY, ONTARIO

PROJECT No.	13-1184-0074	FILE No.	13-1184-0074.GPJ
DRAWN	TB	May 2014	SCALE N/A
CHECK	AB	May 2014	REV.
APPR	JMAC	May 2014	

FIGURE B1




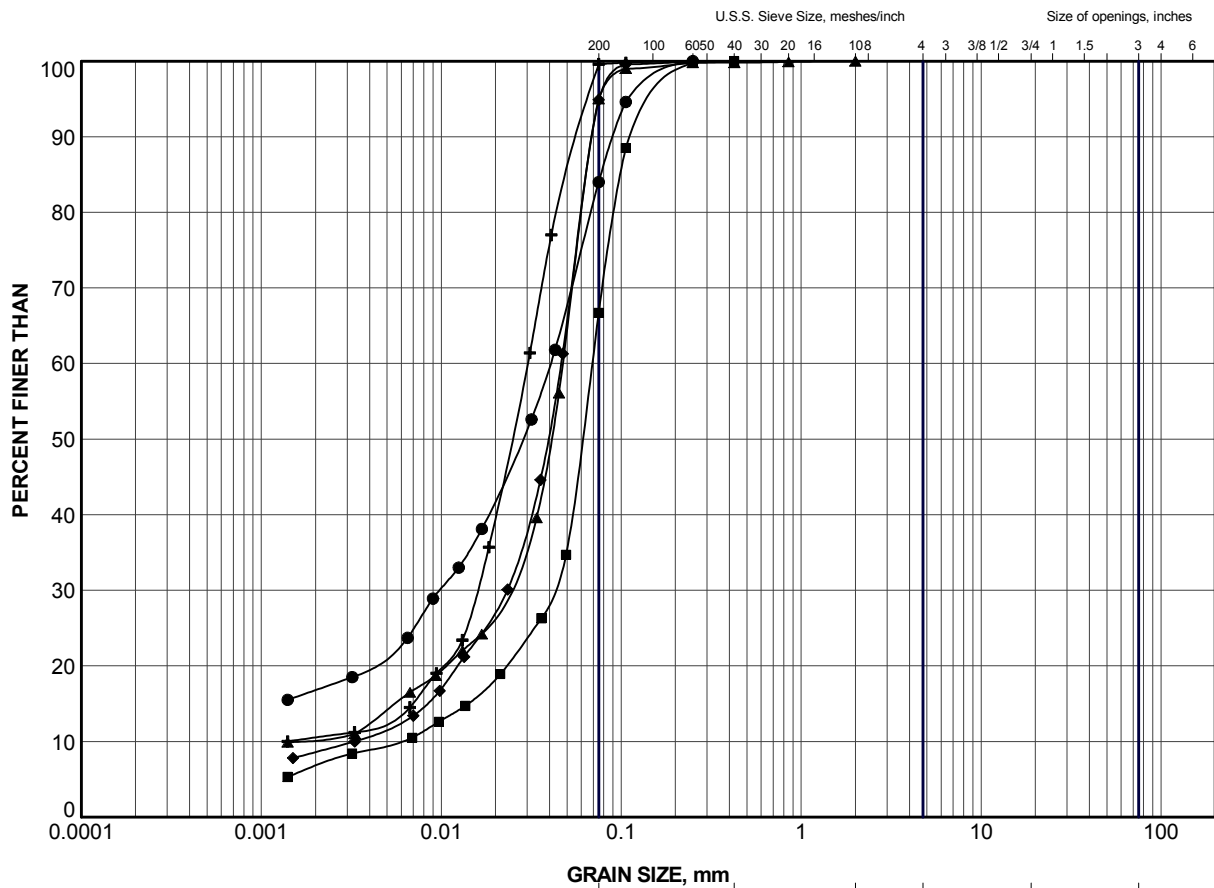
SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	DE-1	11	39.5	21.2	18.3
■	DE-1	12A	33.8	18.8	15.0
▲	DE-2	11	41.9	21.3	20.6
+	DE-2	12	36.0	19.5	16.5
◆	DE-3	8B	37.7	19.7	18.0
◇	DE-3	12	34.8	20.3	14.5
○	DE-4	10	39.9	19.1	20.8
△	DE-4	13	32.2	19.5	12.7
⊗	DE-5	10	28.9	16.3	12.6
⊕	DE-5	12	34.1	19.5	14.6
□	DE-6	11	38.7	20.2	18.5
⊗	DE-6	13	39.0	20.1	18.9

PROJECT					
HIGHWAY 17 DEER CREEK CULVERT STA 11+815					
TITLE					
PLASTICITY CHART CLAYEY SILT to SILTY CLAY					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		May 2014	
CHECK		AB		May 2014	
APPR		JMAC		May 2014	
 Golder Associates SUDBURY, ONTARIO				SCALE N/A REV.	
FIGURE B2					



GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	DE-1	13	188.1
■	DE-3	15	186.9
▲	DE-4	15	186.5
+	DE-5	14	187.4
◆	DE-6	12	191.7

PROJECT					
HIGHWAY 17 DEER CREEK CULVERT STA 11+815					
TITLE					
GRAIN SIZE DISTRIBUTION SILT to SILT and SAND					
PROJECT No.		13-1184-0074		FILE No. 13-1184-0074.GPJ	
DRAWN	TB	May 2014	SCALE	N/A	REV.
CHECK	AB	May 2014	FIGURE B3		
APPR	JMAC	May 2014			



As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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