



October 7, 2016

FOUNDATION INVESTIGATION REPORT

**NORAMI CREEK CULVERT - SITE NO. 48E-62
HIGHWAY 11, DISTRICT OF THUNDER BAY
McCOMBER TOWNSHIP
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6166-04-00 W.P. 6166-04-01**

Submitted to:

Hatch Ltd.
2800 Speakman Drive
Mississauga, ON
L5K 2R7



GEOCREs No.: 42E-26

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Distribution:

- 1 PDF Copy: Ministry of Transportation, Ontario, Downsview (Foundations Section)
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REPORT





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PART A

**DETAIL FOUNDATION INVESTIGATION REPORT
NORAMI CREEK CULVERT – SITE NO. 48E-62
HIGHWAY 11, DISTRICT OF THUNDER BAY
MCCOMBER TOWNSHIP
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 6166-04-00, W.P. 6166-04-01**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch Ltd. (Hatch), on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the replacement of the Norami Creek culvert (Site No. 48E-62). The Norami Creek culvert is located in the District of Thunder Bay in the Township of McComber on Highway 11 at STA 20+212, approximately 7.7 km west of the Highway 801 in Nezhah, Ontario. The key plan showing the general location of this section of Highway 11 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The Norami Creek culvert consists of a twin cell timber box, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purpose of this report, Highway 11 is oriented in a west-east direction (for this section of roadway) with the culvert perpendicular to the highway in a north-south orientation.

In general, the topography in the area of the culvert consists of low-lying swampy terrain on both sides of Highway 11. At the culvert location, the highway grade is at Elevation 318.8 m and the existing culvert invert, as provided by MTO, is at Elevation 315.7 m at the inlet (north end) and at Elevation 315.6 m at the outlet (south end). The creek ice/water level was measured by Golder on January 22, 2016, at Elevations 316.8 m and 316.2 m at the inlet and outlet ends, respectively. Surface conditions in the culvert inlet and outlet areas are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between January 22 and February 14, 2016, during which time six boreholes (Boreholes NR-1 to NR-6) were advanced at approximately the locations shown on Drawings 1 and 2. Boreholes NR-1, NR-2, NR-5 and NR-6 were advanced at the toe of slope near the culvert inlet/outlet and Boreholes NR-3 and NR-4 were advanced from the existing highway platform. Boreholes NR-1, NR-2 and NR-6 were advanced with a portable tripod using NW casing and wash boring techniques. The portable tripod was supplied and operated by Landcore Drilling of Chelmsford, Ontario. Borehole NR-3 was advanced using a truck mounted CME-55 drill rig and Boreholes NR-4 and NR-5 were advanced using a track mounted CME 850 drill rig. The CME-55 and CME-850 drill rigs, which were both equipped with 108 mm inside diameter hollow stem augers, were supplied and operated by Cartwright Drilling Ltd. of Thunder Bay, Ontario.

Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer or a cathead hammer (for boreholes advanced using the portable tripod), in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).



The field work was monitored on a full-time basis by members of Golder’s technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder’s geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions and Atterberg limits were carried out on selected soil samples. The geotechnical laboratory testing was completed according to MTO LS standards.

A sample of the creek water was obtained on January 27, 2016, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters including pH, resistivity, conductivity, sulphates and chlorides. The results of the analytical testing are presented in Table B1 in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the highway centerline and existing culvert and converted into northing/easting coordinates on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing provided by MTO (drawing bc04113.dwg). The MTM NAD83 Zone 14 northing and easting coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
NR-1	5503037.6	249433.2	316.7	9.8
NR-2	5503039.3	249442.4	316.8	9.8
NR-3	5503029.2	249444.7	318.8	12.8
NR-4	5503021.1	249430.4	318.8	12.8
NR-5	5503013.4	249445.6	316.7	9.8
NR-6	5503013.2	249437.6	316.8	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the Norami Creek culvert site is located within an outwash plain deposit consisting primarily of sand.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by metasedimentary rocks comprised of wacke, arkose, argillite, slate, marble, chert and iron formations.

¹ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42ENW

² Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542



4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N' values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawings 1 and 2 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment) or ice/water and/or sandy peat to peat (for boreholes advanced beyond the embankment toe of slope) underlain by a deposit of sand to silt and sand further underlain by a deposit of silt. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Surface Elevation (m)	Deposit Thickness (m)	N Values (blows)	Laboratory Testing
				Relative Density	
Ice/Water	NR-1, NR-2 and NR-6	316.8 – 316.7	0.1 – 0.8	n/a	n/a
Asphalt	NR-3, NR-4	318.8	0.100 – 0.125	n/a	n/a
(FILL) Gravelly sand and sand, trace to some silt, trace to some organics, brown; frozen/moist	NR-3, NR-4	318.7	2.9	N = 5 - 10 ¹ Loose to Compact	w = 2% – 16% ² 3 – M (Fig. B1)
Sandy Peat to Peat (Fibrous), some silt, trace gravel; brown to black, frozen/wet	NR1, NR-2, NR-4, NR-5 and NR-6	316.7 – 315.8	0.1 – 1.5	N = 2 – 4 Very Loose	w = 60% & 88%
Sand to Silt and Sand³, trace to some organics; brown to grey; wet	NR-2, NR-3, NR-5 and NR-6	316.1 – 315.4	0.7 – 2.3	N = 3 – 13 Very Loose to Compact	w = 20% – 31% 2 – M/MH (Fig. B2)
Silt, trace to some clay, trace to some sand; brown to grey; wet	NR-1 to NR-6	315.8 - 313.8	6.8 – 8.9 (boreholes terminated in this deposit)	N = 7 – 24 Loose to compact	w = 18% - 29% ⁴ 13 – MH (Fig. B3) 1 – AL (NP)

Where:

- N = SPT 'N' values; number of blows for 0.3 m of penetration
- M = Sieve analysis
- MH = Combined sieve and hydrometer analysis
- w = Natural moisture content (%)
- AL = Atterberg limits test
- NP = Non Plastic Atterberg limit test result



Notes:

- ¹ An SPT 'N' value of 44 blows per 0.3 m of penetration was measured in the sand fill deposit, however this value is likely due to the frozen state of the material and is not considered to be representative of the relative density of the granular fill.
- ² A moisture content of the 33 per cent was measured in one sample of the sand fill; however, this is likely due to the presence of organics within the sample.
- ³ An approximately 100 mm thick piece of wood was encountered within the silty sand deposit in Borehole NR-3.
- ⁴ A moisture content of the 34 per cent was measured in one sample of the silt deposit; however, this is likely due to the presence of a clay seam within the sample.

Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek ice/water level was surveyed at Elevation 316.8 m and 316.2 m at the inlet and outlet ends, respectively, on January 22, 2016. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
NR-1	0.0	316.4
NR-2	0.0	316.6
NR-3	2.5	316.3
NR-4	5.3	313.5
NR-5	0.9	315.8
NR-6	0.5	316.3*

*Borehole NR-6 were advanced using NW casing and wash boring techniques and as such, the measured groundwater level may not be representative of the in-situ groundwater condition.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mike Arthur, Mr. Shane Albert and Mr. Mathew Riopelle, under the overall direction of Mr. Adam Core, P.Eng. This Detail Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng., and Mr. David Muldowney, P.Eng., provided a technical review of the report. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.



Report Signature Page

GOLDER ASSOCIATES LTD.

Adam Core, P.Eng.
Geotechnical Engineer



David Muldowney, P.Eng.
Geotechnical Engineer



Jorge M. A. Costa, P.Eng.
Designated MTO Foundations Contact, Senior Consultant

AC/DAM/JMAC/kp

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DETAIL FOUNDATION REPORT NORAMI CREEK CULVERT - SITE NO. 48E-62

Table 1: Summary Details of Existing Culvert

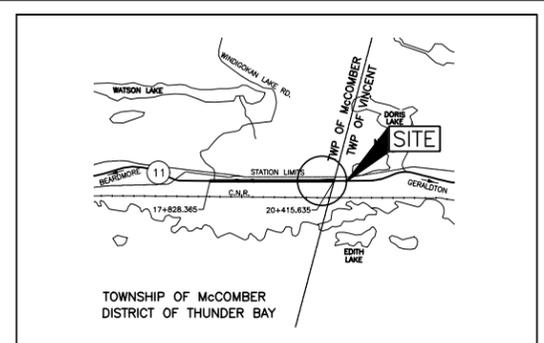
Culvert Location	Site #	Approximate Height of Embankment ¹ (m)	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length (m)	North End of Culvert (m)	South End of Culvert (m)
Hwy 11 STA 20+212	48E-62	2.9	Twin Cell Timber Box	2.1 m wide x 1.6 m high (each cell)	19	315.7	315.6

- Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the culvert invert.
 2. Culvert dimensions and invert elevations are based on the plan and profile drawings provided by MTO (Drawing bc904113.dwg).

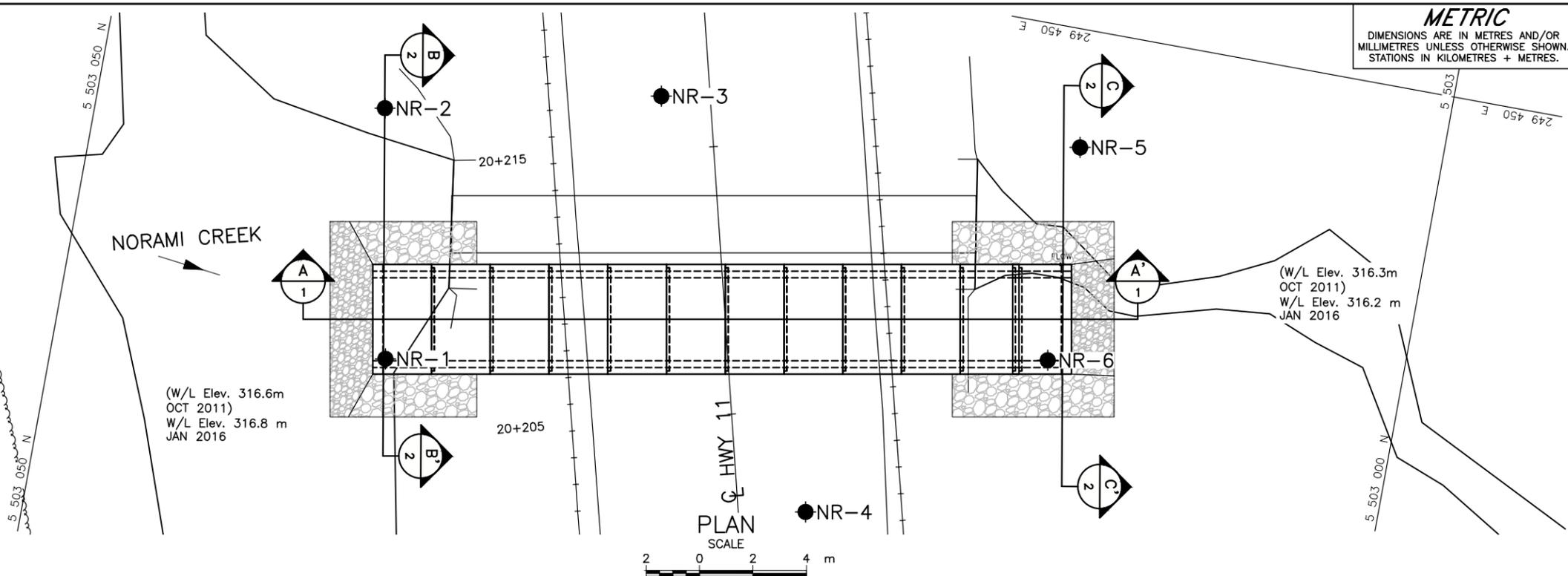
Prepared by: AC
Checked by: DAM
Reviewed by: JMAC

METRIC
 DIMENSIONS ARE IN METRES AND/OR
 MILLIMETRES UNLESS OTHERWISE SHOWN.
 STATIONS IN KILOMETRES + METRES.

CONT No. GWP No. 6166-04-00
HIGHWAY 11
 NORAMI CREEK CULVERT STA 20+212
BOREHOLE LOCATIONS AND SOIL STRATA



KEY PLAN
 SCALE
 1.5 0 1.5 3 km



PLAN
 SCALE
 2 0 2 4 m

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
NR-1	316.7	5503037.6	249433.2
NR-2	316.8	5503039.3	249442.4
NR-3	318.8	5503029.2	249444.7
NR-4	318.8	5503021.1	249430.4
NR-5	316.7	5503013.4	249445.6
NR-6	316.8	5503013.2	249437.6

NOTES

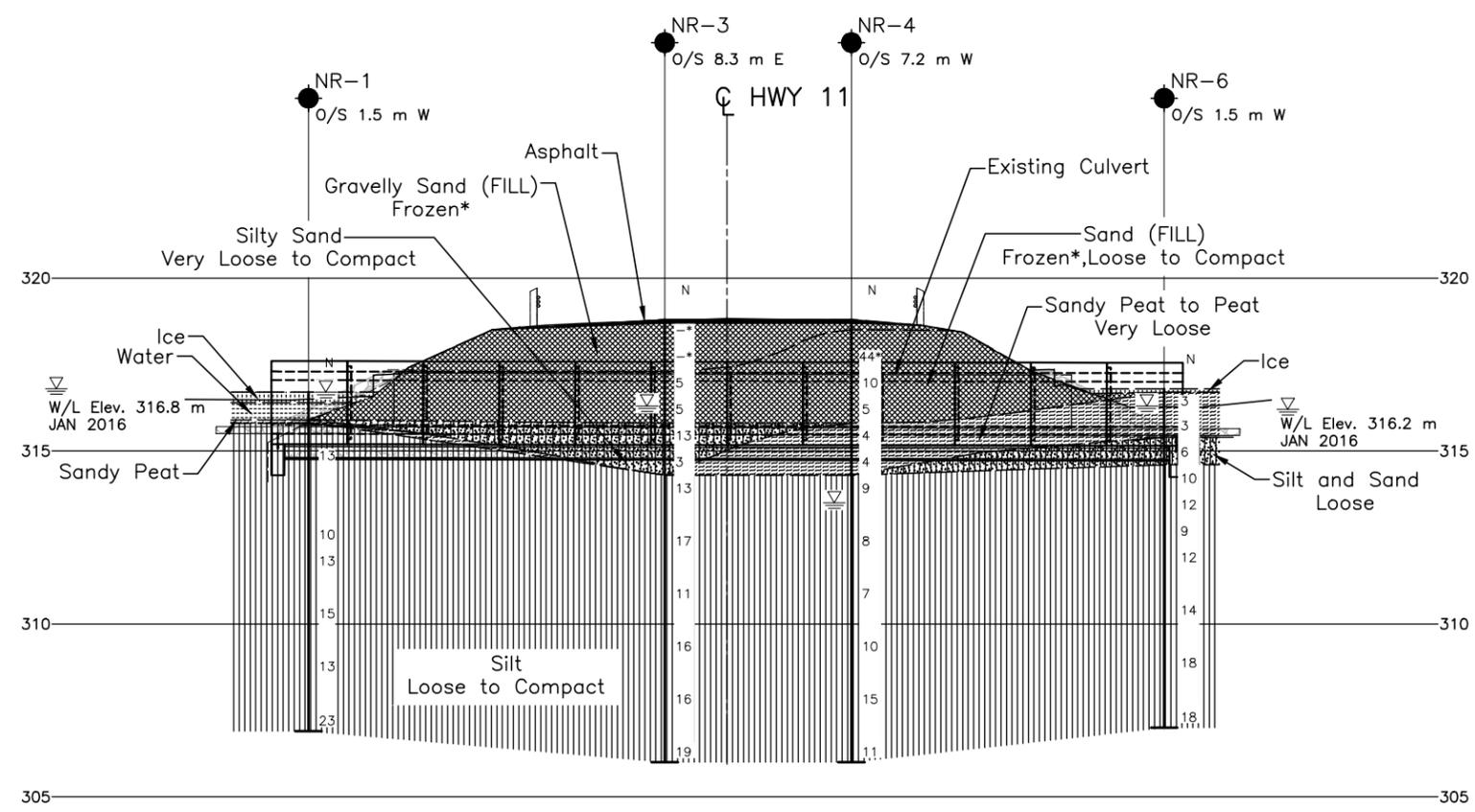
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

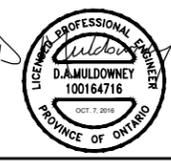
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

REFERENCE

Base plans provided in digital format by MTO, drawing file nos. BC904113.dwg received Dec. 11, 2015. GA received in digital format by MTO, drawing file nos. ST-358767-NORAMI CREEK CULVERT-01-GENERAL ARRANGEMENT.dwg received June 27, 2016.



PROFILE
 A-A
 HORIZ. SCALE 1:200
 VERT. SCALE 1:200
 SCALE
 2 0 2 4 m



NO.	DATE	BY	REVISION

Geocres No. 42E-26

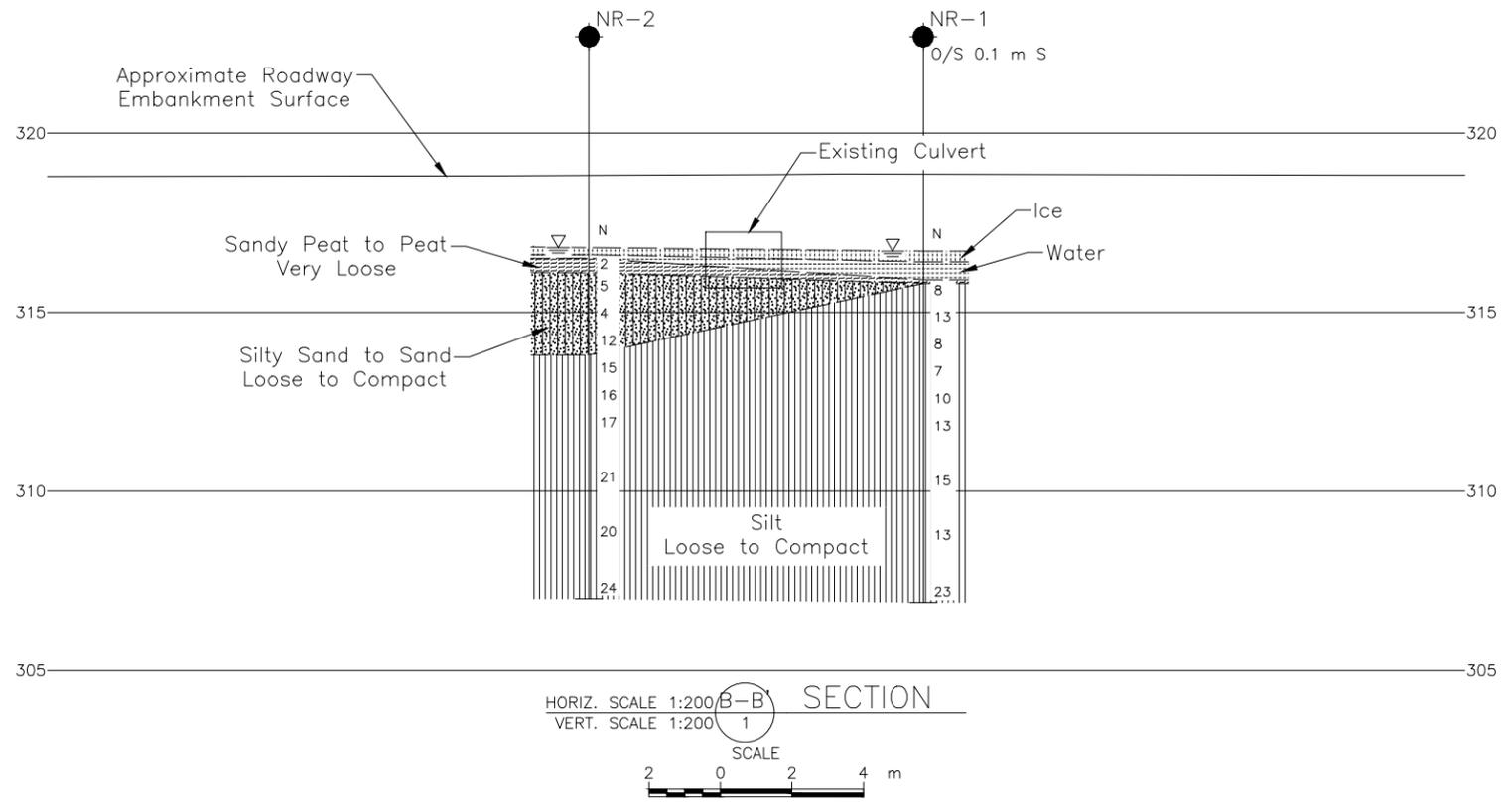
HWY. 11	PROJECT NO. 1533879	DIST. .
SUBM'D. AC	CHKD. .	DATE: 10/7/2016
DRAWN: JJJ	CHKD. DAM	APPD. JMAC
		SITE: 48E-62
		DWG. 1

METRIC
 DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. GWP No. 6166-04-00

HIGHWAY 11
 NORAMI CREEK CULVERT STA 20+212
 SOIL STRATA

SHEET



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
NR-1	316.7	5503037.6	249433.2
NR-2	316.8	5503039.3	249442.4
NR-5	316.7	5503013.4	249445.6
NR-6	316.8	5503013.2	249437.6

NOTES

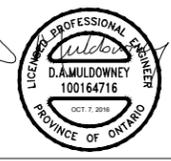
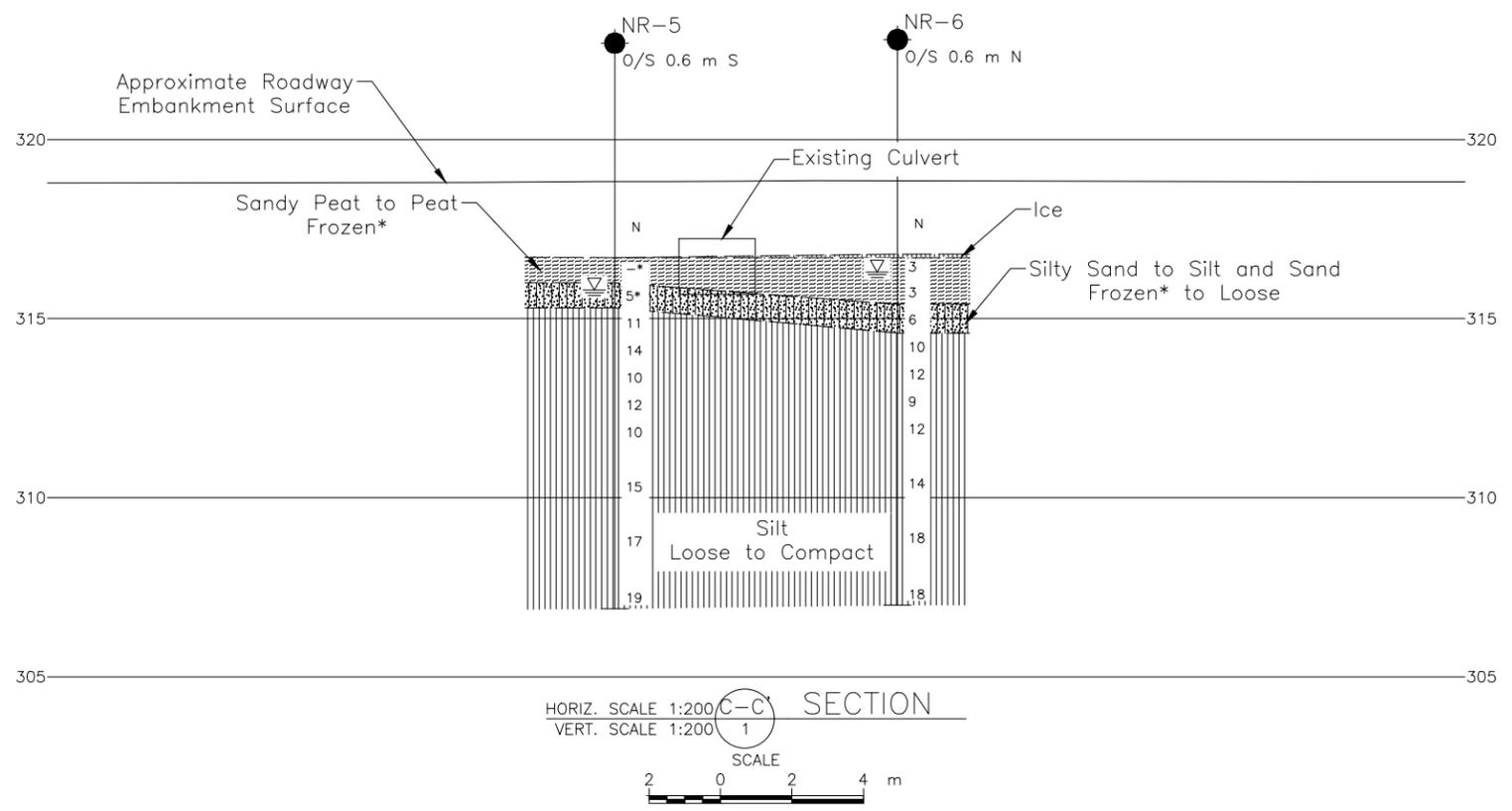
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NO.	DATE	BY	REVISION

Geocres No. 42E-26

HWY. 11	PROJECT NO. 1533879	DIST. .
SUBM'D. AC	CHKD. .	DATE: 10/7/2016
DRAWN: JJJ	CHKD. DAM	APPD. JMAC
		SITE: 48E-62
		DWG: 2



PHOTOGRAPHS

**Photograph 1: Norami Creek Culvert
Looking West at Inlet (December 2015)**



**Photograph 2: Norami Creek Culvert
Looking East at Outlet (December 2015)**





PHOTOGRAPHS

**Photograph 3: Norami Creek Culvert
Looking West at Inlet (February 2016)**



**Photograph 4: Norami Creek Culvert
Looking West at Outlet (February 2016)**





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I.	GENERAL	(a)	Index Properties (continued)
π	3.1416	w	water content
$\ln x$,	natural logarithm of x	w_l or LL	liquid limit
\log_{10}	x or log x, logarithm of x to base 10	w_p or PL	plastic limit
g	acceleration due to gravity	I_p or PI	plasticity index = $(w_l - w_p)$
t	time	w_s	shrinkage limit
FoS	factor of safety	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)
II.	STRESS AND STRAIN	(b)	Hydraulic Properties
γ	shear strain	h	hydraulic head or potential
Δ	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
ε	linear strain	v	velocity of flow
ε_v	volumetric strain	i	hydraulic gradient
η	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
ν	Poisson's ratio	j	seepage force per unit volume
σ	total stress		
σ'	effective stress ($\sigma' = \sigma - u$)	(c)	Consolidation (one-dimensional)
σ'_{vo}	initial effective overburden stress	C_c	compression index (normally consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)	C_r	recompression index (over-consolidated range)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$	C_s	swelling index
τ	shear stress	C_α	secondary compression index
u	porewater pressure	m_v	coefficient of volume change
E	modulus of deformation	C_v	coefficient of consolidation (vertical direction)
G	shear modulus of deformation	C_h	coefficient of consolidation (horizontal direction)
K	bulk modulus of compressibility	T_v	time factor (vertical direction)
		U	degree of consolidation
		σ'_p	pre-consolidation stress
		OCR	over-consolidation ratio = σ'_p / σ'_{vo}
III.	SOIL PROPERTIES	(d)	Shear Strength
(a)	Index Properties	τ_p, τ_r	peak and residual shear strength
$\rho(\gamma)$	bulk density (bulk unit weight)*	ϕ'	effective angle of internal friction
$\rho_d(\gamma_d)$	dry density (dry unit weight)	δ	angle of interface friction
$\rho_w(\gamma_w)$	density (unit weight) of water	μ	coefficient of friction = $\tan \delta$
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	c'	effective cohesion
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)	C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)	p	mean total stress $(\sigma_1 + \sigma_3)/2$
e	void ratio	p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
n	porosity	q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
S	degree of saturation	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

$\tau = c' + \sigma' \tan \phi'$
shear strength = (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.

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

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

	<u>kPa</u>	<u>C_u, S_u</u>	<u>psf</u>
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.

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-1	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503037.6; E 249433.2</u>	ORIGINATED BY <u>SA</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>NW Casing and Wash Boring</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 1 and 2, 2016</u>	CHECKED BY <u>DAM</u>

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	NUMBER	TYPE	"N" VALUES			20	40	60	80	100						20	40	60
316.7	GROUND SURFACE																		
0.0	ICE (300 mm)				∇														
316.4																			
0.3	WATER (500 mm)																		
315.9																			
0.9	Sandy PEAT (fibrous) (100 mm) Black Wet SILT, trace to some clay, trace to some sand, trace to some gravel Loose to compact Brown to grey Wet	1	SS	8															
		2	SS	13							○					0	3	95	2
		3	SS	8															
		4	SS	7															
		5	SS	10															
		6	SS	13							○			NP		0	4	93	3
		7	SS	15															
	Approximately 100 mm to 150 mm of heave encountered between 6.1 m and 9.1 m depth.																		
		8	SS	13							○					13	8	73	6
		9	SS	23															
306.9	END OF BOREHOLE																		
9.8																			

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-2	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503039.3; E 249442.4</u>	ORIGINATED BY <u>SA</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>NW Casing and Wash Boring</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 1, 2016</u>	CHECKED BY <u>DAM</u>

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	20	40	60	80						100	20
316.8	GROUND SURFACE																	
0.0	ICE (200 mm)																	
0.3	WATER (100 mm)																	
316.1	PEAT (Fibrous), trace sand Very loose Black Wet		1	SS	2													
0.7	SILTY SAND to SAND, trace to some gravel, trace organics Loose to compact Brown to grey Wet		2	SS	5							○				8	82	(10)
			3	SS	4													
			4	SS	12													
313.8	SILT, trace to some clay, trace to some sand Compact Grey Wet		5	SS	15													
3.0			6	SS	16							○				0	8	88 4
			7	SS	17													
			8	SS	21													
			9	SS	20							○				0	3	90 7
	A 25 mm clay seam was noted at 8.1 m depth.																	
			10	SS	24													
307.0	END OF BOREHOLE																	
9.8																		

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-3	2 OF 2 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503029.2; E 249444.7</u>	ORIGINATED BY <u>MR</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 14, 2016</u>	CHECKED BY <u>DAM</u>

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W		
306.0	--- CONTINUED FROM PREVIOUS PAGE --- SILT, trace to some clay, trace to some sand Compact Grey Wet		12	SS	19											
12.8	END OF BOREHOLE Note: 1. Water level at a depth of 2.5 m below ground surface (Elev. 316.3 m) upon completion of drilling.					306										

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 12/07/16 DATA INPUT:

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



RECORD OF BOREHOLE No NR-4 2 OF 2 **METRIC**

PROJECT 1533879

G.W.P. 6166-14-00 LOCATION N 5503021.1; E 249430.4 ORIGINATED BY MA

DIST HWY 11 BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers COMPILED BY AC

DATUM GEODETIC DATE January 22, 2016 CHECKED BY DAM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W			W _L	20	40	60	GR
306.0	--- CONTINUED FROM PREVIOUS PAGE --- SILT, trace clay, trace sand Loose to compact Grey Wet	11	SS	11																	
12.8	END OF BOREHOLE Note: 1. Water level at a depth of 5.3 m below ground surface (Elev. 313.5 m) upon completion of drilling.																				

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-5	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503013.4; E 249445.6</u>	ORIGINATED BY <u>MR</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>February 13, 2016</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	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W			W _L	20	40	60	GR	SA
316.7	GROUND SURFACE																					
0.0	Sandy PEAT (Fibrous) Brown Frozen*		1	AS	-*																	
316.0																						
0.7	SILTY SAND, trace organics Grey Frozen*		2	SS	5*																	
315.3																						
1.4	SILT, trace to some clay, trace sand Compact Grey Wet		3	SS	11																	
			4	SS	14																	0 4 90 6
			5	SS	10																	
			6	SS	12																	
			7	SS	10																	
			8	SS	15																	0 4 88 8
			9	SS	17																	
			10	SS	19																	
306.9	END OF BOREHOLE																					
9.8	Note: 1. Water level at a depth of 0.9 m below ground surface (Elev. 315.8 m) upon completion of drilling.																					

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:

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

PROJECT <u>1533879</u>	RECORD OF BOREHOLE No NR-6	1 OF 1 METRIC
G.W.P. <u>6166-14-00</u>	LOCATION <u>N 5503013.2; E 249437.6</u>	ORIGINATED BY <u>SA</u>
DIST <u> </u> HWY <u>11</u>	BOREHOLE TYPE <u>NW Casing and Wash Boring</u>	COMPILED BY <u>AC</u>
DATUM <u>GEODETIC</u>	DATE <u>January 31, 2016</u>	CHECKED BY <u>DAM</u>

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 (%)		
						20	40	60	80	100	20	40	60		GR	SA	SI	CL	
316.8	GROUND SURFACE																		
0.0	ICE (100 mm)																		
0.1	PEAT (Fibrous), some sand, trace gravel Very loose Dark brown to black Wet		1	SS	3														
315.4			2	SS	3														
315.4	SILT and SAND, trace clay, trace organics Loose Grey Wet		3	SS	6										0	40	58	2	
314.6																			
2.2	SILT, trace to some clay, trace sand Loose to compact Grey Wet		4	SS	10														
			5	SS	12														
			6	SS	9										0	3	95	2	
			7	SS	12														
			8	SS	14														
			9	SS	18										0	3	91	6	
			10	SS	18														
307.0	END OF BOREHOLE																		
9.8	Note: 1. Water level at a depth of 0.5 m below ground surface (Elev. 316.3 m) upon completion of drilling.																		

SUD-MTO 001 1533879.GPJ GAL=MISS.GDT 12/07/16 DATA INPUT:



APPENDIX B

Laboratory Test Results



**DETAIL FOUNDATION REPORT
NORAMI CREEK CULVERT - SITE NO. 48E-62**

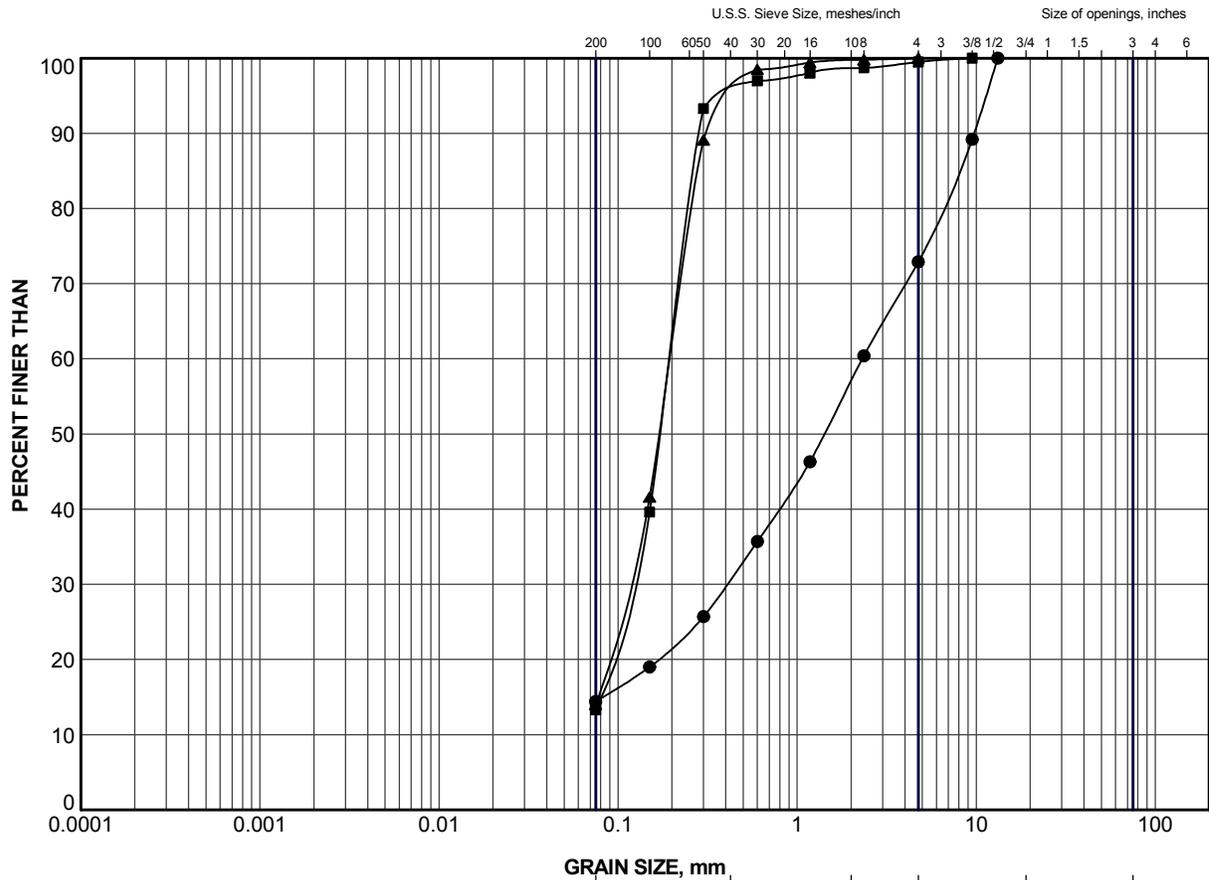
Table B1: Summary of Analytical Testing of Norami Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	21.4
Sulphate (SO4)	mg/L	0.82
Conductivity (EC)	µS/cm	230
Resistivity	ohm-cm	4350
pH	n/a	7.22

Notes:

1. Sample obtained on January 27, 2016.
2. Analytical testing carried out by ALS Canada Ltd.

Prepared by: AC
Checked by: DAM
Reviewed by: JMAC



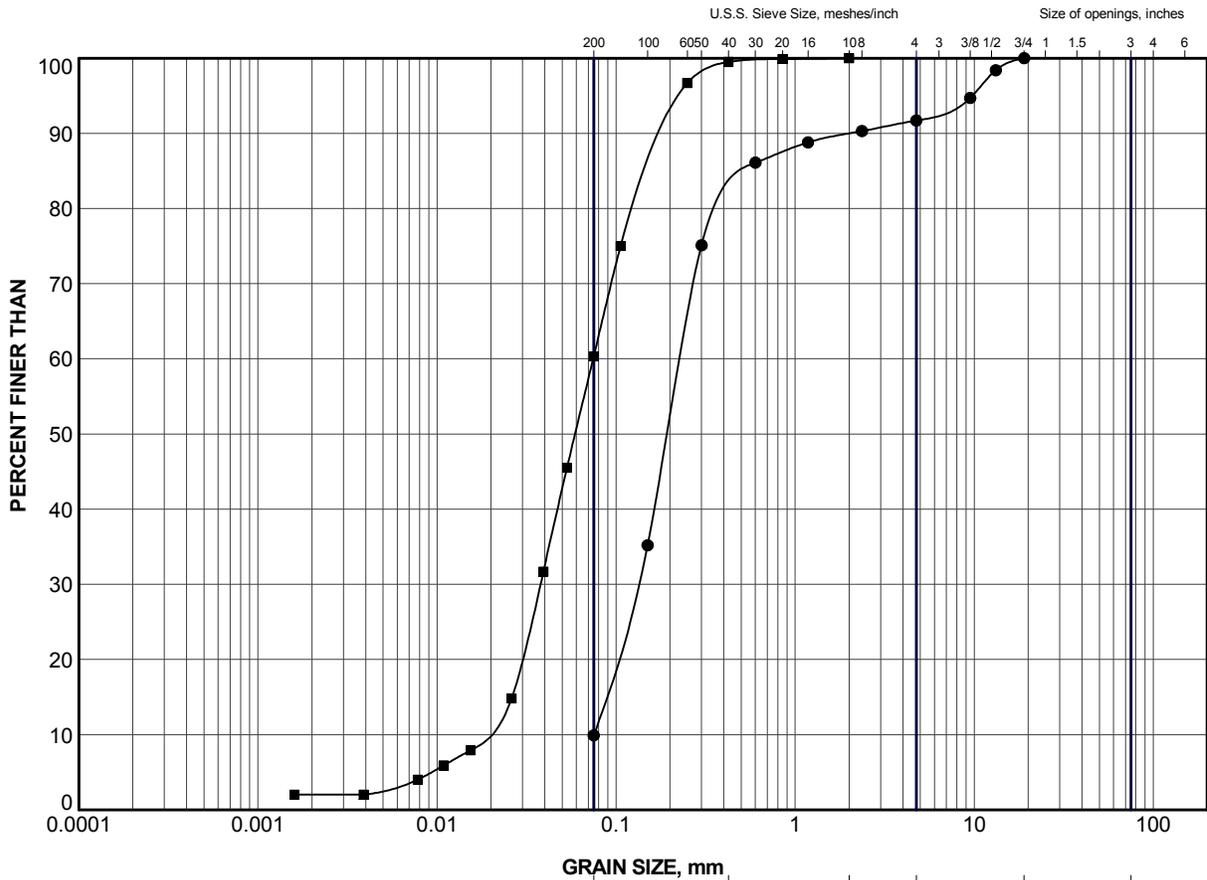
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-3	2	317.7
■	NR-3	4	316.2
▲	NR-4	2	317.0

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SAND to GRAVELLY SAND (FILL)					
PROJECT No.		1533879		FILE No.	1533879.GPJ
DRAWN	JJL	Jun 2016	SCALE	N/A	REV.
CHECK	DAM	Jun 2016	FIGURE B1		
APPR	JMAC	Jun 2016			



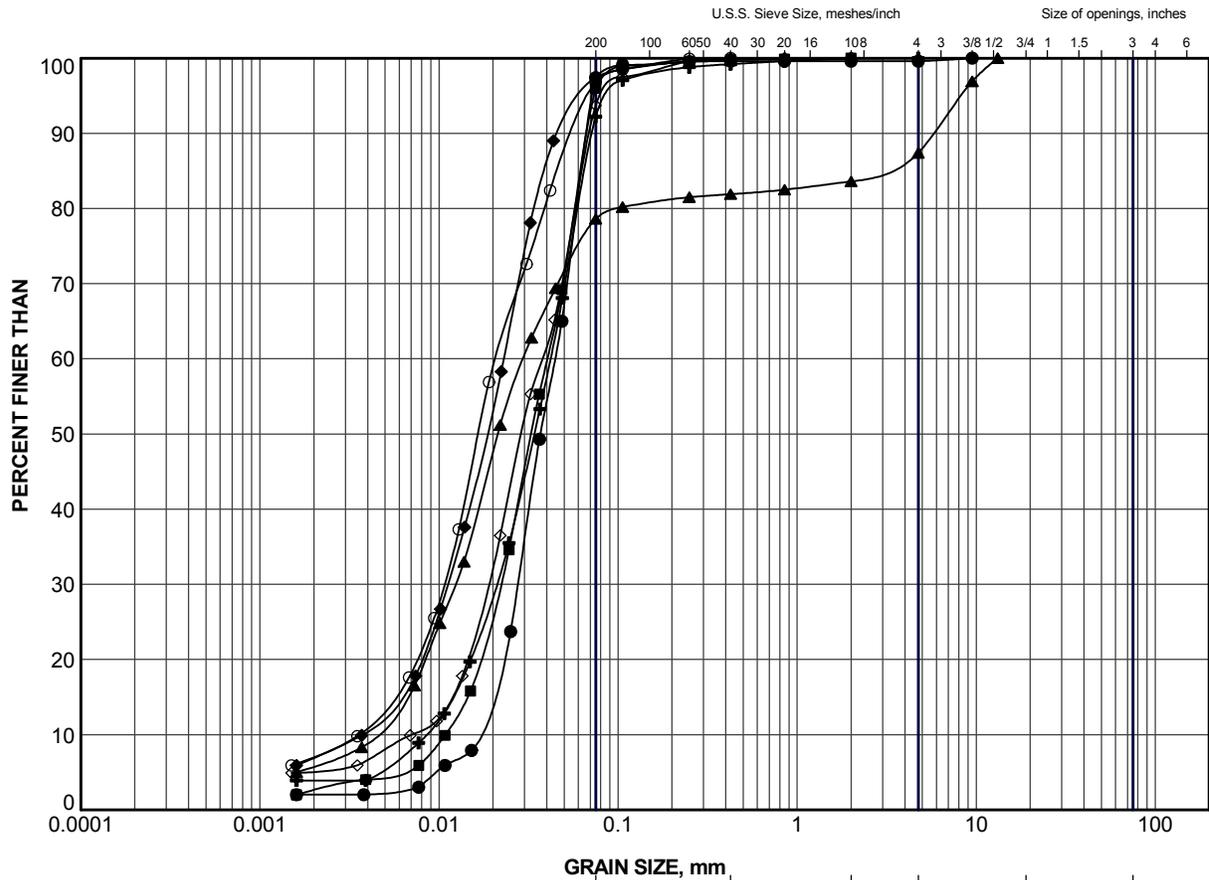


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-2	2	315.7
■	NR-6	3	315.0

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SAND to SILT and SAND					
PROJECT No.		1533879		FILE No.	1533879.GPJ
DRAWN	JJL	Jul 2016	SCALE	N/A	REV.
CHECK	DAM	Jul 2016	FIGURE B2		
APPR	JMAC	Jul 2016			
 Golder Associates SUDBURY, ONTARIO					



CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

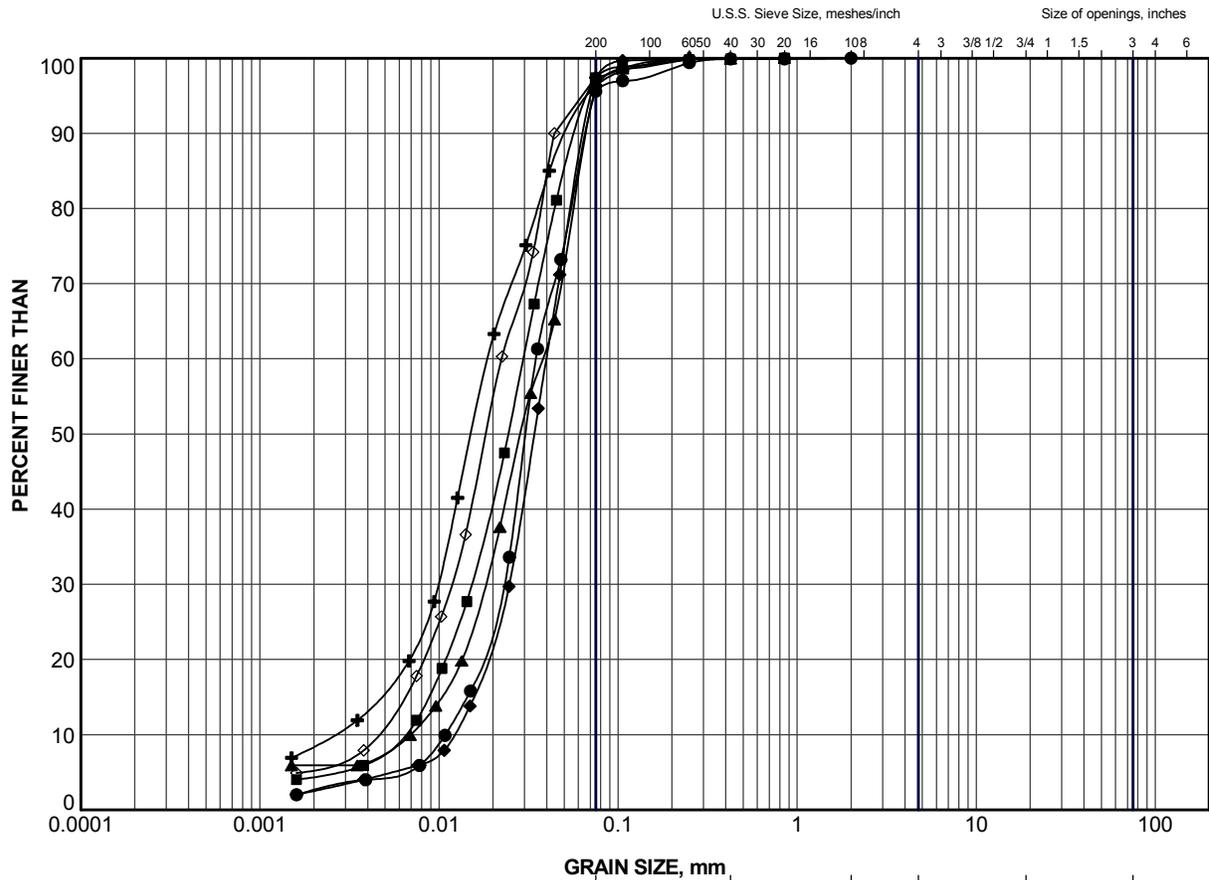
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-1	2	314.9
■	NR-1	6	311.8
▲	NR-1	8	308.8
+	NR-2	6	312.7
◆	NR-2	9	308.9
◇	NR-3	7	313.9
○	NR-3	10	309.4

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		1533879		FILE No.	1533879.GPJ
DRAWN	JJL	Jun 2016	SCALE	N/A	REV.
CHECK	DAM	Jun 2016	FIGURE B3.1		
APPR	JMAC	Jun 2016			



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CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	NR-4	6	313.9
■	NR-4	9	309.4
▲	NR-5	4	314.1
+	NR-5	8	310.3
◆	NR-6	6	312.7
◇	NR-6	9	308.9

PROJECT HIGHWAY 11 NORAMI CREEK CULVERT STA 20+212					
TITLE GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		1533879		FILE No. 1533879.GPJ	
DRAWN	JJL	Jun 2016	SCALE	N/A	REV.
CHECK	DAM	Jun 2016	FIGURE B3.2		
APPR	JMAC	Jun 2016			



SUD-MTO GSD (2016) GLDR_LDN.GDT

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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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
33 Mackenzie Street, Suite 100
Sudbury, Ontario, P3C 4Y1
Canada
T: +1 (705) 524 6861

