



February 25, 2014

FOUNDATION INVESTIGATION REPORT

**HIGHWAY 11 - ARMSTRONG CREEK CULVERT AT STATION 23+879
TOWNSHIP OF DEVITT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 164-98-00**

Submitted to:
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GEOCRES NO. 42G-49

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REPORT





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**FOUNDATION REPORT
HIGHWAY 11 ARMSTRONG CREEK CULVERT**

PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 11 – ARMSTRONG CREEK CULVERT AT STATION 23+879

TOWNSHIP OF DEVITT, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 164-98-00



FOUNDATION REPORT HIGHWAY 11 ARMSTRONG CREEK CULVERT

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Limited (MMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the Highway 11 Armstrong Creek Culvert at STA 23+879 in the Township of Devitt, 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. The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Armstrong Creek culvert is located to the east of Val Côté, Ontario, approximately 27.0 km east of the east junction of Highway 583. In general, the topography in the area of the overall project limits consists of flat terrain utilized as farmland. The existing highway grade is at about Elevation 228 m with the water surface at the culvert outlet was measured by Golder at Elevation 223.8 m on September 24, 2013. The existing crossing consists of two Corrugated Steel Pipe (CSP) culverts, each 2 m in diameter and 27 m long.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between August 26 and 27 and September 23, 2013, during which time a total of five (5) boreholes (AC-1 to AC-5) were advanced for the proposed culvert replacement, as shown on Drawing 1. Boreholes AC-2, AC-4 and AC-5 were advanced using a track-mounted CME 55 supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. Boreholes AC-1 and AC-3 were advanced using a skid-mounted D25 supplied and operated by Walker Drilling Ltd. of Barrie, Ontario. The Record of Boreholes sheets are provided in Appendix A.

The boreholes were advanced to depths ranging between 8.2 m and 15.8 m below existing ground. Each of the boreholes for the investigation were advanced using 108 mm or 76 mm inner diameter continuous flight hollow stem augers except below a depth of 11.4 m in Borehole AC-2, below which NW casing and NQ coring were used to advance the borehole from 11.4 m to the bottom of the borehole at 15.8 m depth. Soil samples were generally obtained at intervals of depth of about 0.75 m to 1.5 m, using a 50 mm outer diameter split-spoon sampler, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Field vane shear tests were carried out in cohesive soils for assessment of undrained shear strengths (ASTM D2573) using an MTO Standard 'N' size vane. 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. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The fieldwork was supervised throughout by a member 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 Geotechnical 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



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limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

A sample of soil was obtained near the founding elevation of the culvert in Borehole AC-3 on September 23, 2013, and a sample of the creek water was obtained on September 27, 2013. The samples were obtained 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 Tables B1 and B2 in Appendix B, together with the detailed analytical laboratory test results.

The as-drilled borehole locations for the current investigation were measured in the field relative to stakes installed by MMM. Golder referenced as-drilled borehole ground surface elevations to the stakes. The ground surface elevations at the borehole locations are referenced to Geodetic datum. The as-drilled borehole locations for the investigation, the ground elevations and borehole depths at the drilled locations are shown in the table below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
AC-1	5 498 435.7	355 641.9	224.6	8.2
AC-2	5 498 445.1	355 654.7	227.7	15.8
AC-3	5 498 462.7	355 658.5	225.1	8.2
AC-4	5 498 454.0	355 639.3	227.7	12.8
AC-5	5 498 446.8	355 665.3	227.9	12.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Published literature indicates that the site is located in the Quetico Subprovince of the Superior Province (Geology of Ontario; OGS Special Volume 4)¹. The bedrock in a large area within and surrounding the Town of Hearst consists of muscovite-bearing granitic rocks (peraluminous), and may include biotite granite. Beyond the muscovite-bearing granitic boundary, bedrock consists of metasedimentary rocks.

Based on terrain mapping by the Ontario Geological Survey², the site is in a transition between an esker with subsurface soils consisting of silt and a ground moraine with subsurface soils consisting of clayey till.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions, as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the Record of Boreholes sheets attached in Appendix A. Detailed results of the laboratory testing of the soil

¹ Geology of Ontario, 1991. Ontario Geological Survey, Special Volume 4, Part 1. Eds P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott, Ministry of Northern Development and Mines, Ontario.

² Northern Ontario Engineering Geology Terrain Study, OGS Electronic Map, printed July 2011



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samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling progress and cuttings. 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. The inferred soil stratigraphy based on the results of the boreholes at the culvert location is shown on Drawing 1.

In general, the subsoils at the structure site consist of fill underlain by peat (where encountered) and by clay to silty clay, clayey silt and/or sandy silt to sand and silt. Instances of auger grinding and a boulder were encountered during drilling within the sandy silt to sand and silt. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

A 150 mm thick layer of asphalt was encountered from ground surface in Boreholes AC-2, AC-4 and AC-5 between Elevation 227.7 m and Elevation 227.9 m and was underlain by brown sand and gravel to sand fill with thicknesses of 5.4 m, 3.5 m and 3.8 m, respectively. In Borehole AC-1 sand fill was encountered from ground surface at Elevation 224.6 m with a thickness of 0.3 m. In Borehole AC-3, a 100 mm thick layer of topsoil fill was encountered from ground surface at Elevation 225.1 m and was underlain by brown sand fill with a thickness of 1.3 m.

SPT 'N'-values measured within the upper portion of the fill in Boreholes AC-2, AC-4 and AC-5 range between 36 blows and 73 blows per 0.3 m of penetration, indicating a dense to very dense relative density. SPT 'N'-values measured within the fill in Boreholes AC-1 and AC-3 and the lower portion of the fill in Boreholes AC-2, AC-4 and AC-5 range between 1 blow and 23 blows per 0.3 m of penetration, indicating a very loose to compact relative density. One SPT 'N'-value measured in the upper portion of the fill in Borehole AC-4 is 75 blows per 0.25 m of penetration.

Grain size distribution tests were carried out on three samples of the sand fill and the results are shown on Figure B1 in Appendix B.

The natural water content measured on samples of the fill range between about 2 per cent and 18 per cent.

4.2.2 Peat

A deposit of black amorphous peat was encountered beneath the sand fill in Borehole AC-3 at a depth of 1.4 m (Elevation 223.7 m) with a thickness of 0.8 m.

One SPT 'N'-value measured within the peat was 3 blows per 0.3 m of penetration, suggesting a soft consistency.

4.2.3 Organic Clayey Silt

A deposit of brown to grey organic clayey silt was encountered beneath the sand fill in Borehole AC-1 at a depth of 0.3 m (Elevation 224.3 m) with a thickness of 1.2 m.



One SPT 'N'-value measured within the organic clayey silt was 5 blows per 0.3 m of penetration, suggesting a firm consistency.

4.2.4 Clay to Silty Clay

A deposit of brown to grey clay to silty clay was encountered below the fill in Boreholes AC-4 and AC-5 at depths of 3.7 m (Elevation 224.0 m) and 4.0 m (Elevation 223.9 m), respectively. In Boreholes AC-1 and AC-3 the clay to silty clay deposit was encountered beneath the peat and organic clayey silt, at depths of 1.5 m (Elevation 223.1 m) and 2.2 m (Elevation 222.9 m), respectively. The thickness of the deposit is between 2.6 m and 5.3 m in Boreholes AC-1, AC-3 and AC-4 and 0.6 m in Borehole AC-5.

The SPT 'N'-values recorded within this deposit range from 1 blow to 7 blows per 0.3 m of penetration. In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from about 31 kPa to greater than 90 kPa. The field vane test suggests the deposit is generally very stiff to firm with depth.

Atterberg limits testing carried out on six samples of the clay to silty clay deposit yielded liquid limits ranging from about 34 per cent to 62 per cent, plastic limits from about 17 per cent to 25 per cent and plasticity indices from about 17 per cent to 38 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B2 in Appendix B and indicate that the deposit consists of clay of high plasticity to silty clay of intermediate plasticity.

Grain size distribution tests carried out on three samples of the clay to silty clay deposit are shown on Figure B3, in Appendix B.

The natural water content measured on samples of the clay to silty clay range from about 29 per cent to 38 per cent.

4.2.5 Sandy Silt to Sand and Silt

A deposit of brown to grey sandy silt to sand and silt, trace to some gravel, trace to some clay was encountered below the fill in Borehole AC-2 at a depth of 5.6 m (Elevation 222.1 m) and below the silty clay deposit in Borehole AC-5 at a depth of 4.6 m (Elevation 223.3 m). The thickness of the sandy silt is 9.2 m in Borehole AC-2 was not penetrated in Borehole AC-5 after exploring the deposit for 8.2 m. A boulder was encountered in Borehole AC-2 from a depth of 11.4 m to 11.8 m. In Borehole AC-5 the augers were observed to be grinding from a depth of 6.9 m to 7.3 m, which could be indicative of cobbles and/or boulders within this deposit.

SPT 'N'-values recorded within the sandy silt range from 0 blows (weight of hammer) to 23 blows per 0.3 m of penetration, indicating the deposit has a very loose to compact relative density.

Grain size distribution tests carried out on four samples of the sandy silt to sand and silt deposit are shown on Figure B4, in Appendix B.

Atterberg limits testing carried out on four samples of the sandy silt to sand and silt deposit yielded liquid limits ranging from about 16 per cent to 17 per cent, plastic limits from about 8 per cent to 13 per cent and plasticity



FOUNDATION REPORT HIGHWAY 11 ARMSTRONG CREEK CULVERT

indices from about 4 per cent to 8 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B5 in Appendix B and indicate that the deposit consists of clayey silt to silt of low plasticity.

The natural water content measured on seven samples of the sandy silt range from about 11 per cent to 13 per cent.

4.2.6 Clayey Silt

A deposit of grey clayey silt was encountered below the clay to silty clay in Boreholes AC-1, AC-3 and AC-4 at depths of 4.9 m (Elevation 219.7 m), 4.8 m (Elevation 220.3 m) and 9.0 m (Elevation 218.7 m), respectively. In Borehole AC-2 the clayey silt deposit was encountered beneath the sandy silt at a depth of 14.8 m (Elevation 212.9 m).

The SPT 'N'-values recorded within this deposit range from 3 blows to 15 blows per 0.3 m of penetration with one value of 0 blows (weight of hammer). In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from about 38 kPa to 50 kPa. The SPT tests together with the field vane test suggest the deposit is generally firm to stiff.

Atterberg limits testing carried out on five samples of the clayey silt deposit yielded liquid limits ranging from about 22 per cent to 26 per cent, plastic limits from about 12 per cent to 16 per cent and plasticity indices from about 9 per cent to 14 per cent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure B6 in Appendix B and indicate that the deposit consists of clayey silt of low plasticity.

Grain size distribution tests carried out on four samples of the clayey silt deposit are shown on Figure B7, in Appendix B.

The natural water content measured on samples of the clayey silt range from about 16 per cent to 27 per cent.

4.2.7 Groundwater Conditions

Boreholes AC-1, AC-4 and AC-5 were dry upon completion of drilling. In Boreholes AC-2 and AC-3, unstabilized water levels measured upon the completion of drilling were at depths of 3.0 m (Elevation 224.7 m) and 3.5 m (Elevation 221.6 m). On September 24, 2013, the water level in Armstrong Creek was surveyed by Golder to be at Elevation 223.8 m. Groundwater and creek water levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The drilling program was supervised by Mr. Shane Albert. This report was prepared by Mr. Matthew Thibeault, EIT, and was reviewed by Mr. Andre Bom, P.Eng. A quality control review of the report was provided by Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project.



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Report Signature Page

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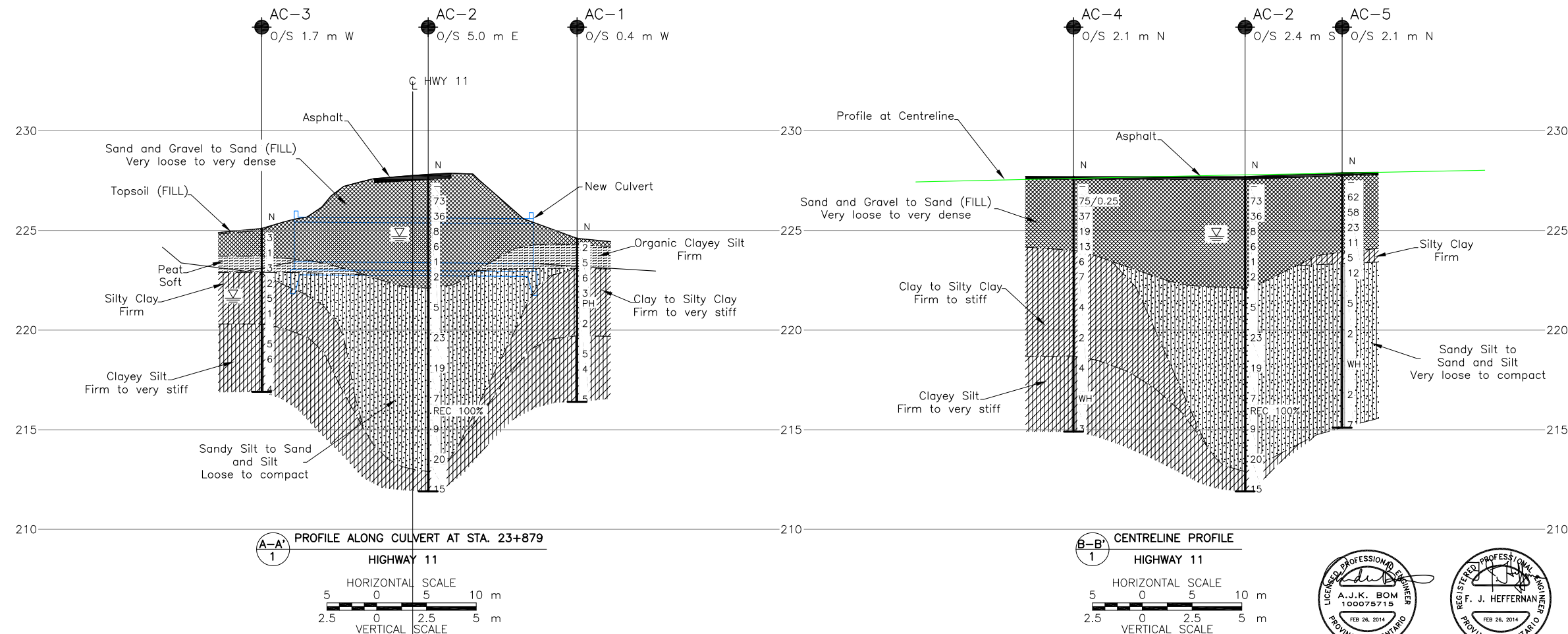
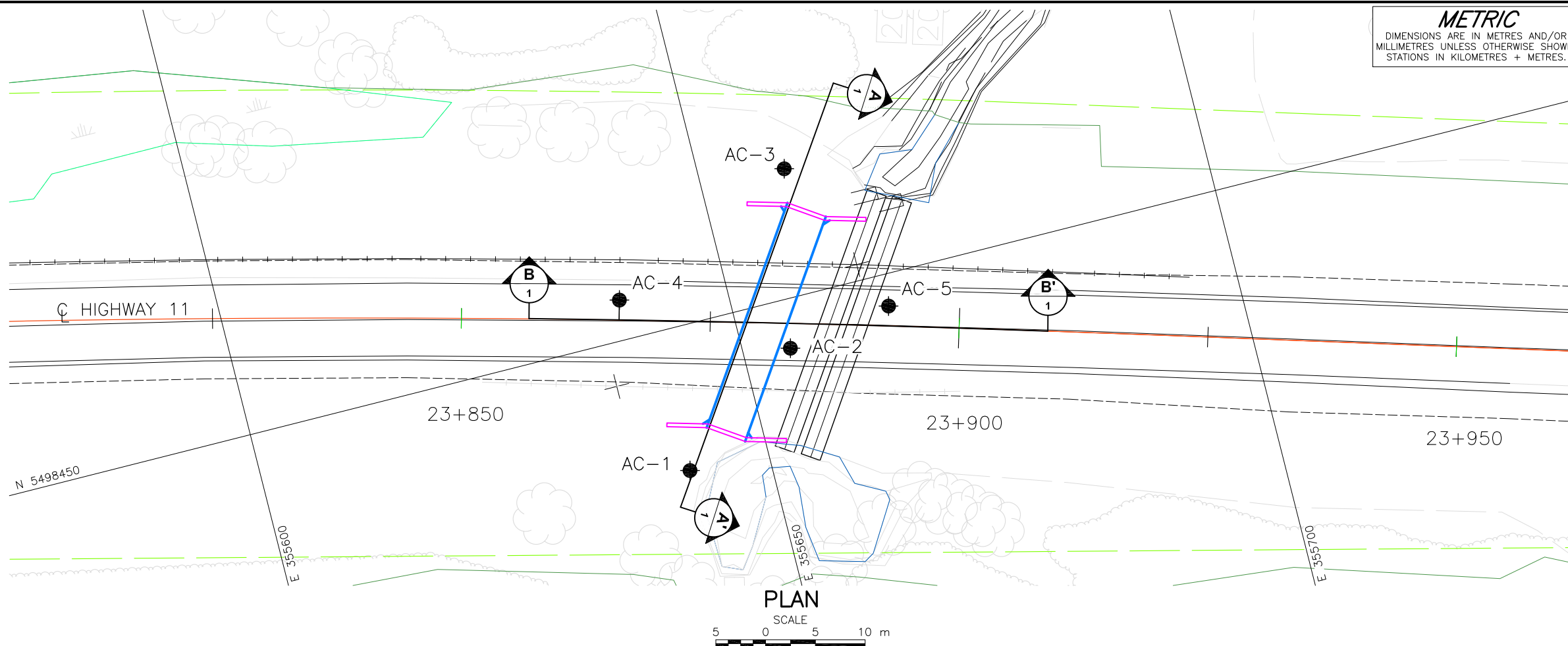


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Designated MTO Contact

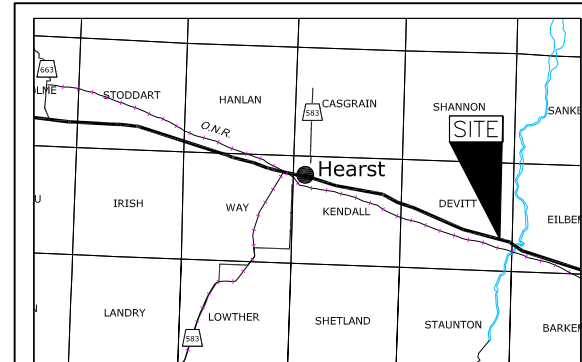
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CONT No.
GWP No.164-98-00HIGHWAY 11
ARMSTRONG CREEK CULVERT AT STA. 23+879
BOREHOLE LOCATIONS AND
SOIL STRATA

SHEET

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA

KEY PLAN

SCALE
0 10 km

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- 100% Recovery
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
AC-1	224.6	5498435.7	355641.9
AC-2	227.7	5498445.1	355654.7
AC-3	225.1	5498462.7	355658.5
AC-4	227.7	5498454.0	355639.3
AC-5	227.9	5498446.8	355665.3

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 MMM, drawing file BASE-PLAN.dwg and Hwy 11 - Align-C2.dwg, received NOV 2013.
Culvert plan and profile provided in digital format by MMM, drawing file GENERAL ARRANGEMENT- Armstrong Creek.dwg, received FEB 19, 2014.



NO.	DATE	BY	REVISION
1			
Geocres No. 42G-49			
HWY. 11	PROJECT NO. 10-1191-0038		DIST.
SUBM'D. MT	CHKD.	DATE: FEB 2014	SITE:
DRAWN: JJJ	CHKD. AB	APPD. FJH	DWG. 1



**FOUNDATION REPORT
HIGHWAY 11 ARMSTRONG CREEK CULVERT**

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

	kPa	C_u, S_u	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 10-1191-0038		RECORD OF BOREHOLE No AC-1				1 OF 1 METRIC								
W.P. 164-98-00		LOCATION N 5498435.7; E 355641.9				ORIGINATED BY SA								
DIST _____ HWY 11		BOREHOLE TYPE 76 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY DAM								
DATUM Geodetic		DATE September 23, 2013				CHECKED BY AB								
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						
224.6	GROUND SURFACE													
0.0	Sand, trace to some silt, trace organics (FILL)		1	SS	2									
224.3	Very loose													
0.3	Brown													
	Moist													
223.1	ORGANIC CLAYEY SILT, trace to some sand, trace gravel		2	SS	5									
1.5	Firm													
	Brown/Grey													
	Moist to wet													
	CLAY to SILTY CLAY, trace to some sand, trace gravel		3	SS	6									
	Firm to very stiff													
	Grey													
	Wet		4	SS	3									
	Silt seams encountered between 3.0 m and 4.4 m depth.		5	VS	PH									
			6	SS	2									
219.7	CLAYEY SILT, some sand, trace gravel		7	SS	5									
4.9	Firm													
	Grey													
	Wet													
			8	SS	4									
			9	SS	5									
216.4	END OF BOREHOLE													
8.2	Note: 1. Borehole dry upon completion of drilling. 2. Sample 5 taken from vane tip at a depth of 3.0 m to 3.2 m.													

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 30/10/13 DATA INPUT:


PROJECT <u>10-1191-0038</u>		RECORD OF BOREHOLE No AC-2		1 OF 2 METRIC	
W.P. <u>164-98-00</u>		LOCATION <u>N 5498445.1; E 355654.7</u>		ORIGINATED BY <u>SA</u>	
DIST <u> </u> HWY <u>11</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring</u>		COMPILED BY <u>MT</u>	
DATUM <u>Geodetic</u>		DATE <u>August 26, 2013</u>		CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			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					
227.7	GROUND SURFACE																			
0.0	ASPHALT (150 mm)		1	AS	-															
0.2	Sand and gravel to sand, trace to some silt, trace clay (FILL) Very loose to very dense Brown to grey Moist to wet		2	SS	73															
			3	SS	36															
			4	SS	8															
			5	SS	6															
			6	SS	1															
			7	SS	2															
222.1																				
5.6	Sandy SILT to SAND and SILT, trace to some clay, trace to some gravel Loose to compact Grey Wet		8	SS	5															
			9	SS	23															
			10	SS	19															
			11	SS	7															
			12	RC	REC 100%															
			13	SS	9															
			14	SS	20															
212.9	Augers grinding between 14.6 m and 15.1 m depth.																			
14.8																				





SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 30/10/13 DATA INPUT:

Continued Next Page

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

PROJECT 10-1191-0038			RECORD OF BOREHOLE No AC-2				2 OF 2 METRIC									
W.P. 164-98-00		LOCATION N 5498445.1; E 355654.7				ORIGINATED BY SA										
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY MT										
DATUM Geodetic		DATE August 26, 2013				CHECKED BY AB										
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								
	--- CONTINUED FROM PREVIOUS PAGE ---															
211.9 15.8	CLAYEY SILT, some sand, trace gravel Stiff to very stiff Grey Wet END OF BOREHOLE Note: 1. Water level at a depth of 3.0 m below ground surface (Elev. 224.7 m) upon completion of drilling.		15	SS	15											4 22 51 23

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 30/10/13 DATA INPUT:

PROJECT 10-1191-0038			RECORD OF BOREHOLE No AC-3			1 OF 1 METRIC											
W.P. 164-98-00			LOCATION N 5498462.7; E 355658.5			ORIGINATED BY SA											
DIST _____ HWY 11			BOREHOLE TYPE 76 mm I.D. Continuous Flight Hollow Stem Augers			COMPILED BY DAM											
DATUM Geodetic			DATE September 23, 2013			CHECKED BY AB											
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 (%)
225.1	GROUND SURFACE							20	40	60	80	100					
0.9	Topsoil (FILL) Sand, some gravel, some silt, trace organics (FILL) Very loose Brown Moist		1	SS	3												18 64 (18)
223.7			2	SS	1												
1.4	PEAT (Amorphous), some sand Soft Black Wet		3	SS	3												
222.9																	
2.2	SILTY CLAY, some sand Firm Grey Wet		4	SS	2												0 10 40 50
			5	SS	5												
			6	SS	1												
220.3																	
4.8	CLAYEY SILT, trace sand Firm Grey Wet		7	SS	5												0 5 62 33
			8	SS	6												
216.9			9	SS	4												
8.2	END OF BOREHOLE																
	Note: 1. Water level at a depth of 3.5 m (Elev. 221.6 m) below ground surface upon completion of drilling.																

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 30/10/13 DATA INPUT:

PROJECT		10-1191-0038		RECORD OF BOREHOLE No AC-4		1 OF 1 METRIC	
W.P.		164-98-00		LOCATION		N 5498454.0; E 355639.3	
DIST				BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers	
DATUM		Geodetic		DATE		August 27, 2013	
ORIGINATED BY		SA		COMPILED BY		MT	
CHECKED BY		AB					
SOIL PROFILE				SAMPLES		DYNAMIC CONE PENETRATION RESISTANCE PLOT	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
227.7	GROUND SURFACE						
0.0	ASPHALT (150 mm)						
0.2	Sand and gravel to sand, trace clay, trace to some silt (FILL) Compact to very dense Brown Moist		1	AS	-		
			2	SS	75/0.25		
			3	SS	37		
			4	SS	19		
			5	SS	13		
224.0							
3.7	CLAY to SILTY CLAY Firm to stiff Grey Wet Silt seams encountered between 4.6 m and 5.2 m depth.		6	SS	6		
			7	SS	7		
			8	SS	4		
			9	SS	2		
218.7							
9.0	CLAYEY SILT, some sand, trace gravel Firm to stiff Grey Wet		10	SS	4		
			11	SS	WH		
			12	SS	3		
214.9							
12.8	END OF BOREHOLE						
Note: 1. Borehole dry upon completion of drilling							

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

PROJECT 10-1191-0038			RECORD OF BOREHOLE No AC-5			1 OF 1 METRIC														
W.P. 164-98-00			LOCATION N 5498446.8; E 355665.3			ORIGINATED BY SA														
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers			COMPILED BY MT														
DATUM Geodetic			DATE August 27, 2013			CHECKED BY AB														
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
227.9	GROUND SURFACE							20	40	60	80	100	20	40	60	kN/m ³				
0.0	ASPHALT (150 mm)		1	AS	-		227													
0.2	Sand and gravel to sand, trace to some silt, trace clay (FILL) Compact to very dense Brown Moist		2	SS	62		226													
			3	SS	58		225													
			4	SS	23		224													
			5	SS	11		223													
223.9	SILTY CLAY Firm Brown Moist to wet		6	SS	5		222													
223.3	Sandy SILT, some clay, trace to some gravel Very loose to compact Brown to grey Wet		7	SS	12		221													
4.6			8	SS	5		220													
			9	SS	2		219													
			10	SS	WH		218													
			11	SS	2		217													
			12	SS	7		216													
215.1	END OF BOREHOLE																			
12.8	Note: 1. Borehole dry upon completion of drilling																			

SUD-MTO 001 1011910038 BH LOGS.GPJ GAL-MISS.GDT 30/10/13 DATA INPUT:



APPENDIX B

Laboratory Test Results



DRAFT FOUNDATION REPORT HIGHWAY 11 ARMSTRONG CREEK CULVERT

Table B1 - Summary of Analytical Testing of Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	9
Dissolved Sulphate	mg/L	5	Not Detected
Conductivity	umho/cm	1	160
Resistivity	ohm-cm	n/a	6200
pH	n/a	n/a	7.71

Notes: 1. Sample obtained on September 27, 2013.
2. Analytical testing carried out by Maxxam Analytics.

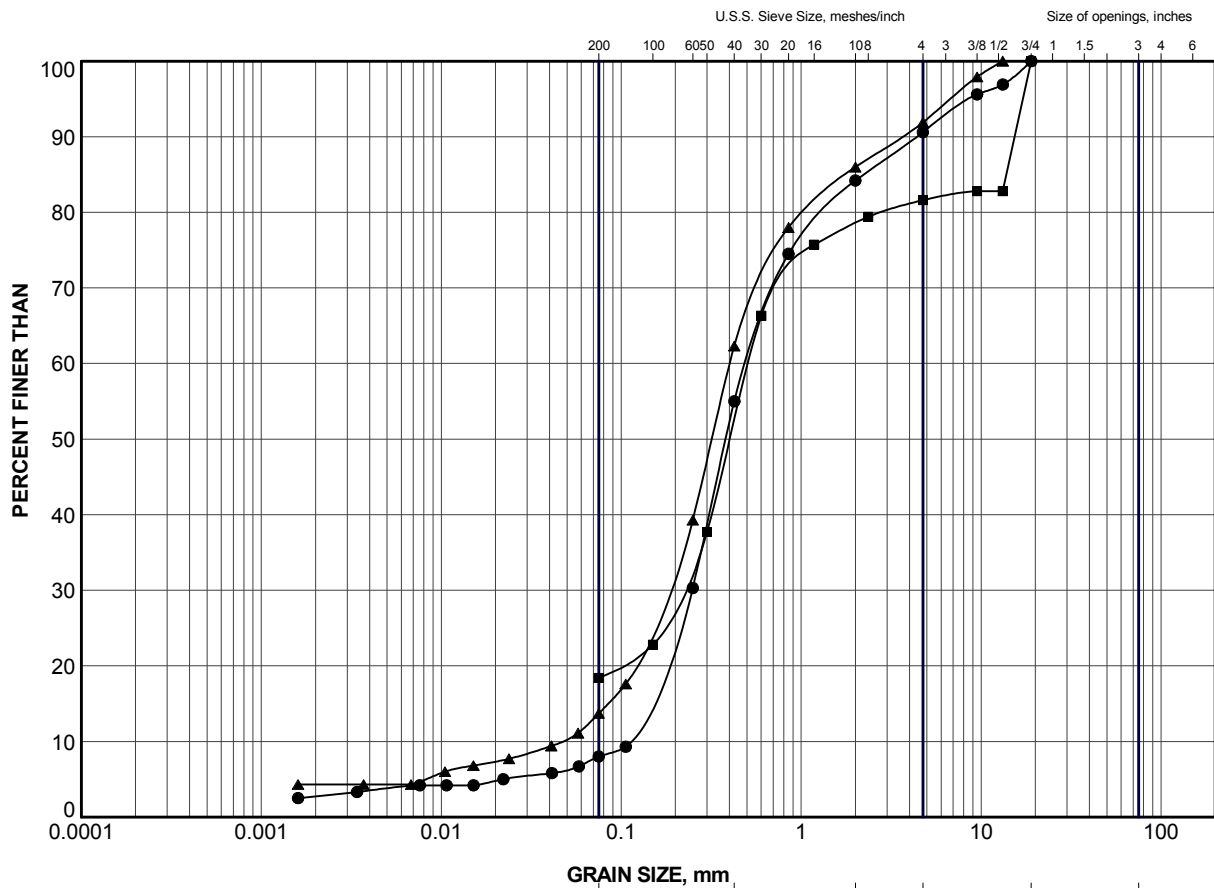
Checked by: AB

Table B2 - Summary of Analytical Testing of Soil Sample

Parameter	Units	Reportable Detection Limit	Result
Soluble (20:1) Chloride	ug/g	20	490
Soluble (20:1) Sulphate	ug/g	20	Not Detected
Conductivity	umho/cm	1	1070
Resistivity	ohm-cm	n/a	940
Available (CaCl2) pH	n/a	n/a	8.11


Notes: 1. Sample obtained on September 23, 2013.
2. Analytical testing carried out by Maxxam Analytics.

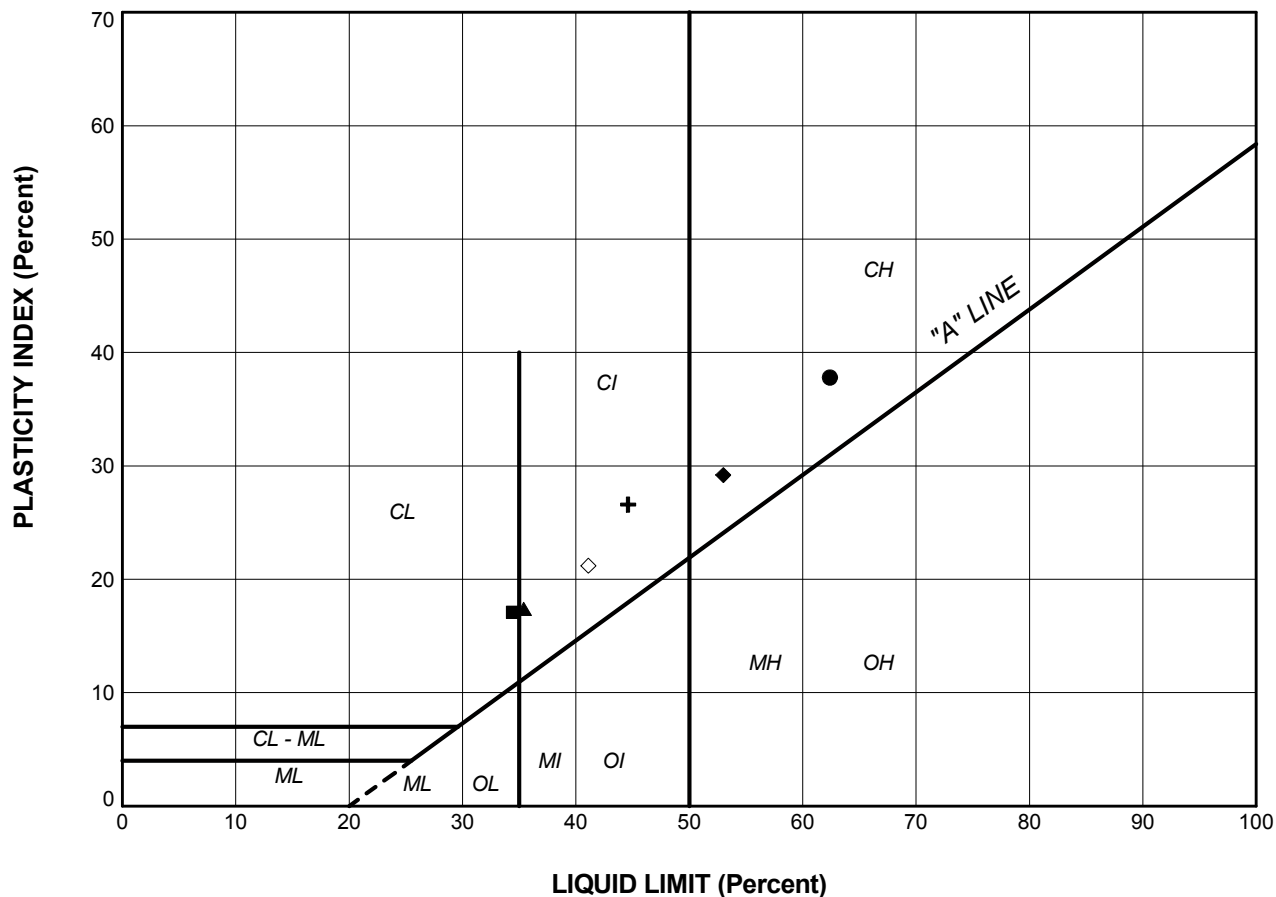
Checked by: AB



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	AC-2	6	223.6
■	AC-3	1b	224.8
▲	AC-5	4	225.3

PROJECT					HIGHWAY 11 ARMSTRONG CREEK CULVERT				
TITLE					GRAIN SIZE DISTRIBUTION SAND (FILL)				
PROJECT No.		10-1191-0038		FILE No		1910038 BH LOGS.GPJ			
DRAWN	JJL	Oct 2013	SCALE	N/A	REV.				
CHECK	AB	Oct 2013							
APPR		Oct 2013							
 Golder Associates SUDBURY, ONTARIO			FIGURE B1						



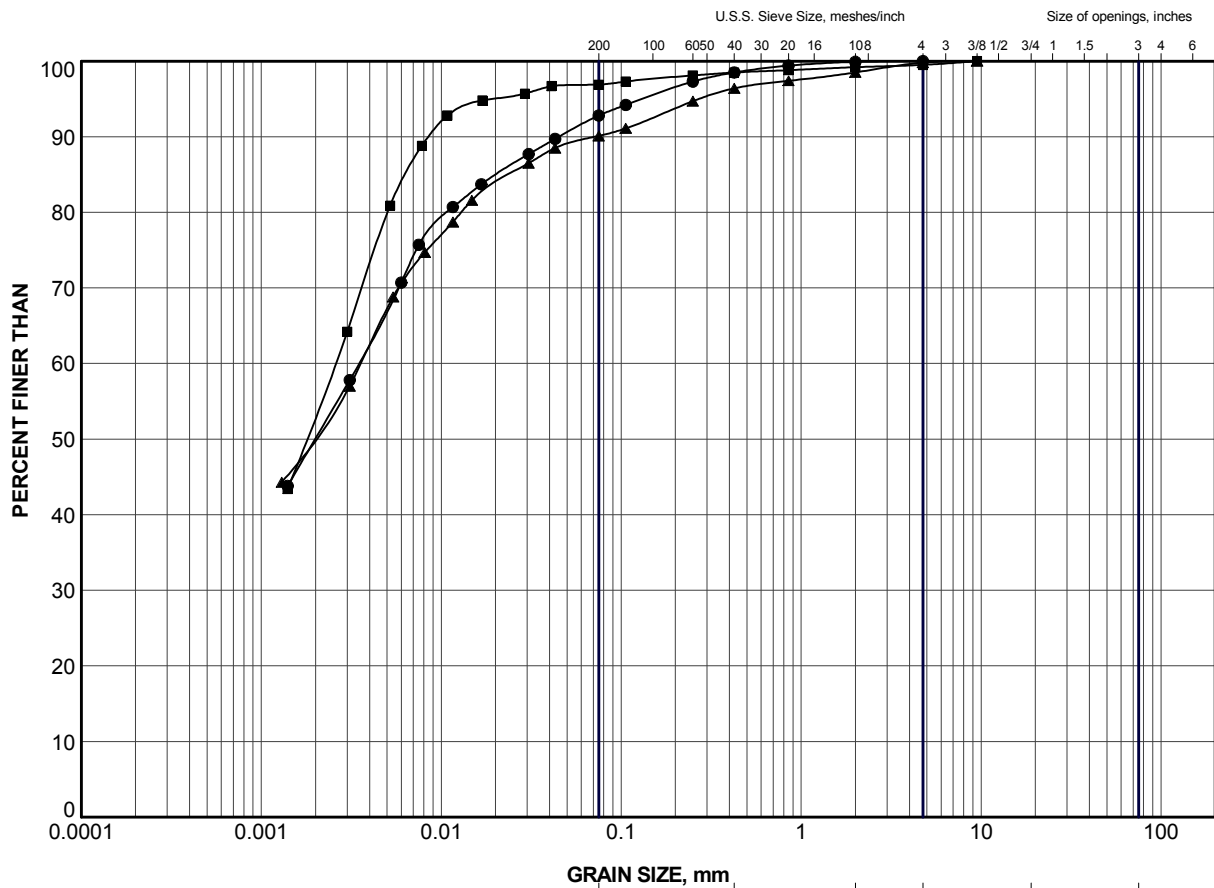
LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	AC-1	3	62.4	24.6	37.8
■	AC-1	4	34.4	17.3	17.1
▲	AC-1	6	35.4	18.0	17.4
+	AC-3	4	44.6	18.0	26.6
◆	AC-4	7	53.0	23.8	29.2
◇	AC-4	9	41.1	19.9	21.2

PROJECT					HIGHWAY 11 ARMSTRONG CREEK CULVERT				
TITLE					PLASTICITY CHART CLAY to SILTY CLAY				
PROJECT No.			10-1191-0038		FILE No.1011910038 BH LOGS.GPJ				
DRAWN	JJL	Oct 2013	SCALE	N/A	REV.				
CHECK	AB	Oct 2013							
APPR		Oct 2013							




FIGURE B2

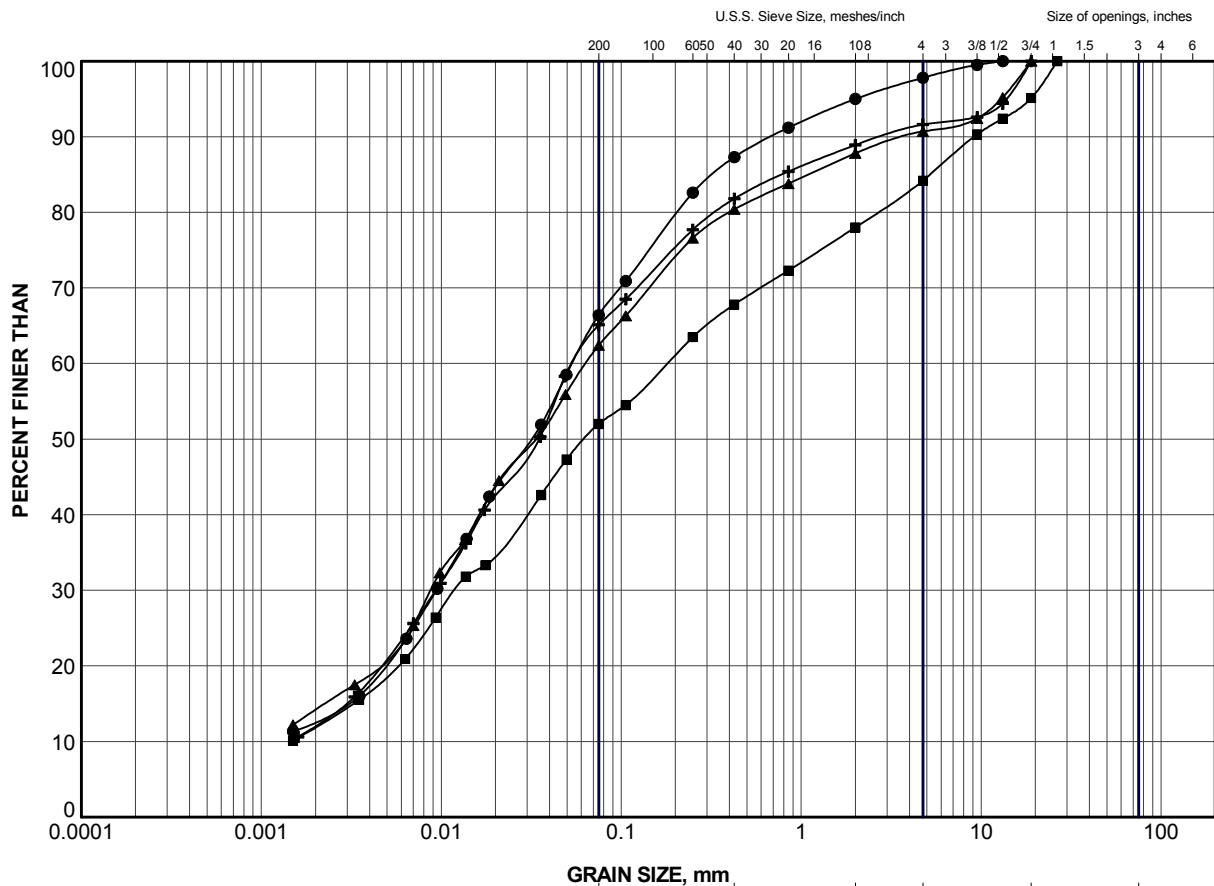


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	AC-1	3	222.8
■	AC-1	6	220.5
▲	AC-3	4	222.5


PROJECT						HIGHWAY 11 ARMSTRONG CREEK CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION CLAY to SILTY CLAY					
PROJECT No.			10-1191-0038			FILE No			1910038 BH LOGS.GPJ		
DRAWN	JJL	Oct 2013	SCALE	N/A	REV.						
CHECK	AB	Oct 2013									
APPR		Oct 2013				FIGURE B3					
 Golder Associates SUDBURY, ONTARIO											

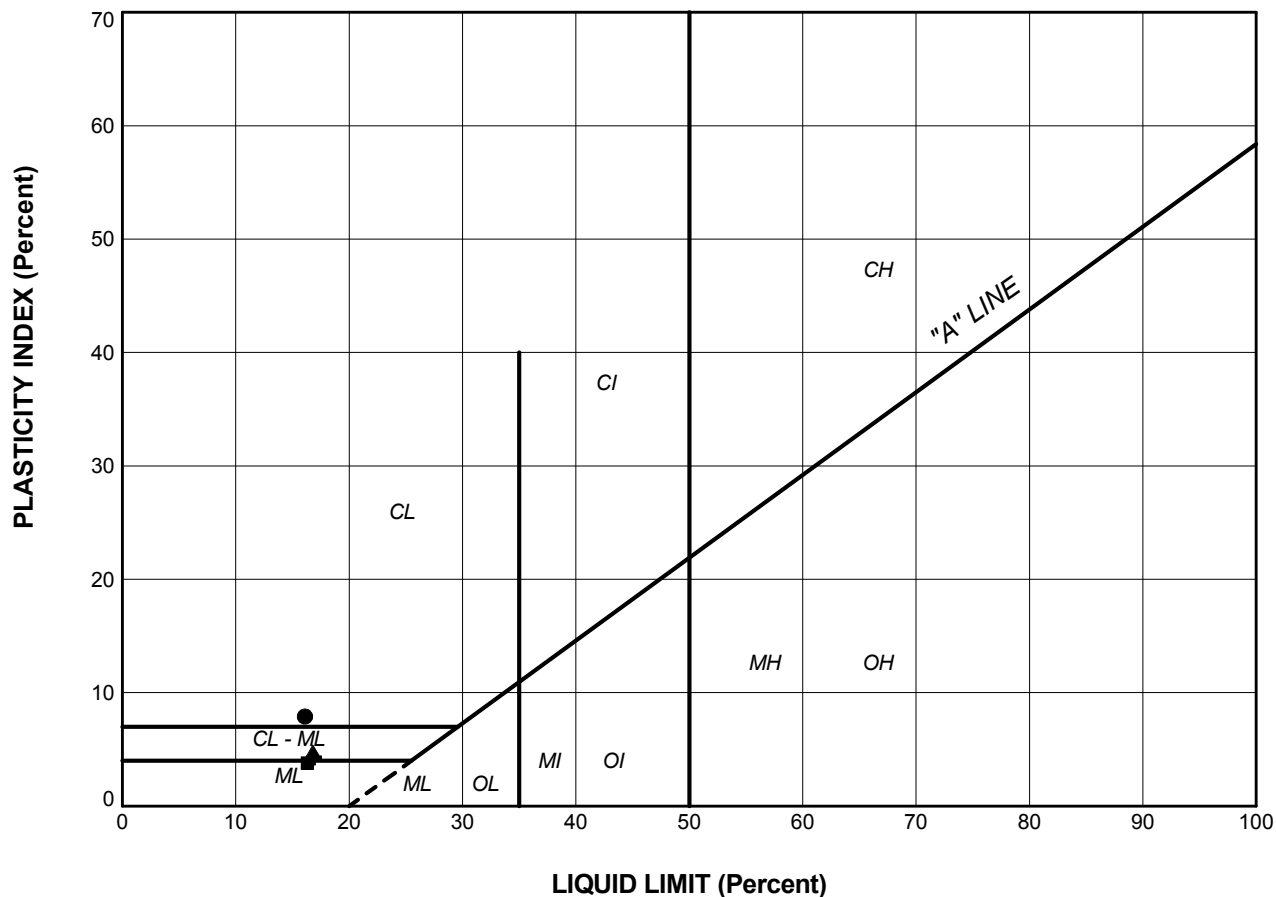


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	AC-2	10	218.3
■	AC-2	13	215.2
▲	AC-5	8	221.5
+	AC-5	11	216.9

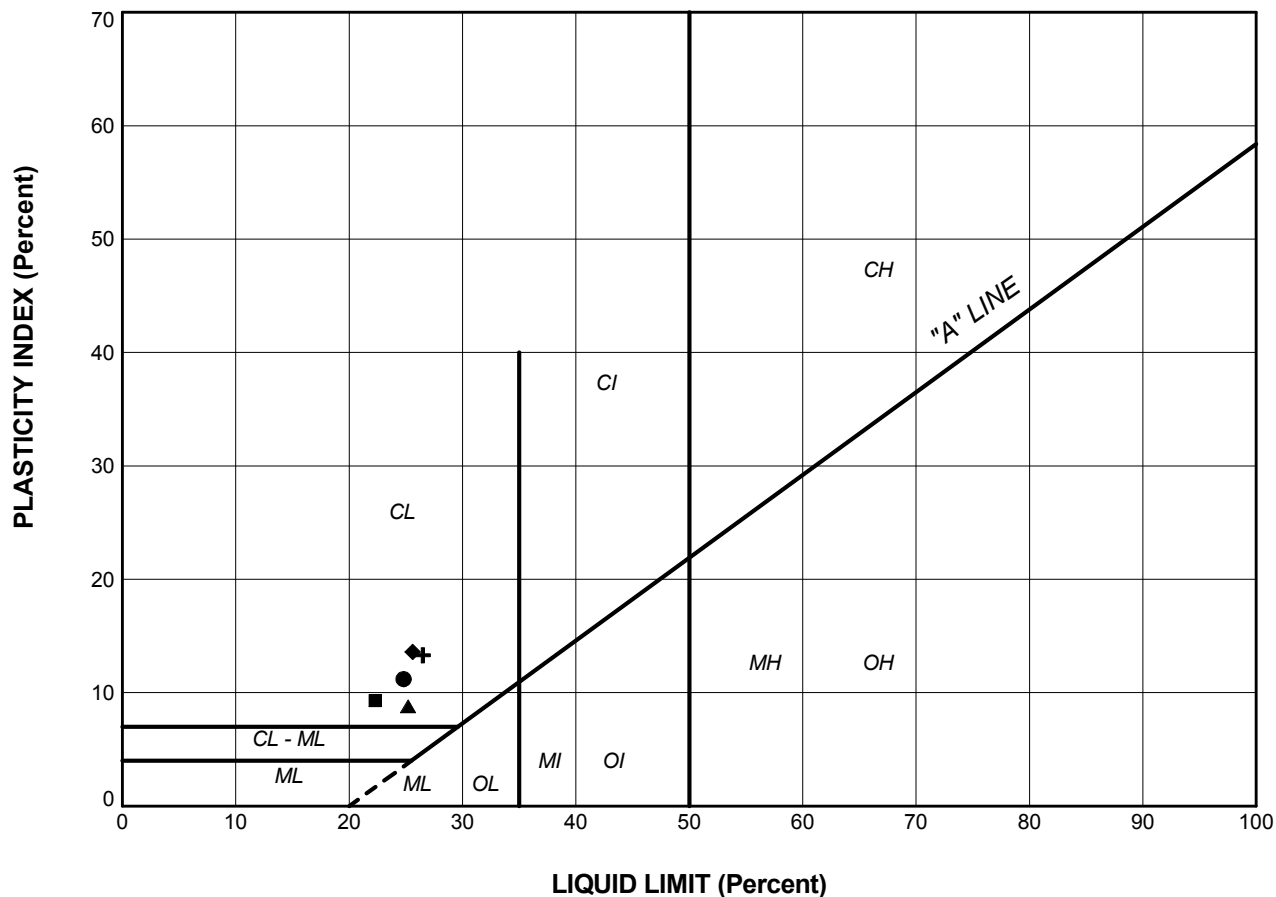
PROJECT					
HIGHWAY 11 ARMSTRONG CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION SANDY SILT to SAND and SILT					
PROJECT No.		10-1191-0038		FILE No. 1910038 BH LOGS.GPJ	
DRAWN	JJL	Oct 2013	SCALE	N/A	REV.
CHECK	AB	Oct 2013			
APPR		Oct 2013			
 Golder Associates SUDBURY, ONTARIO			FIGURE B4		



LEGEND

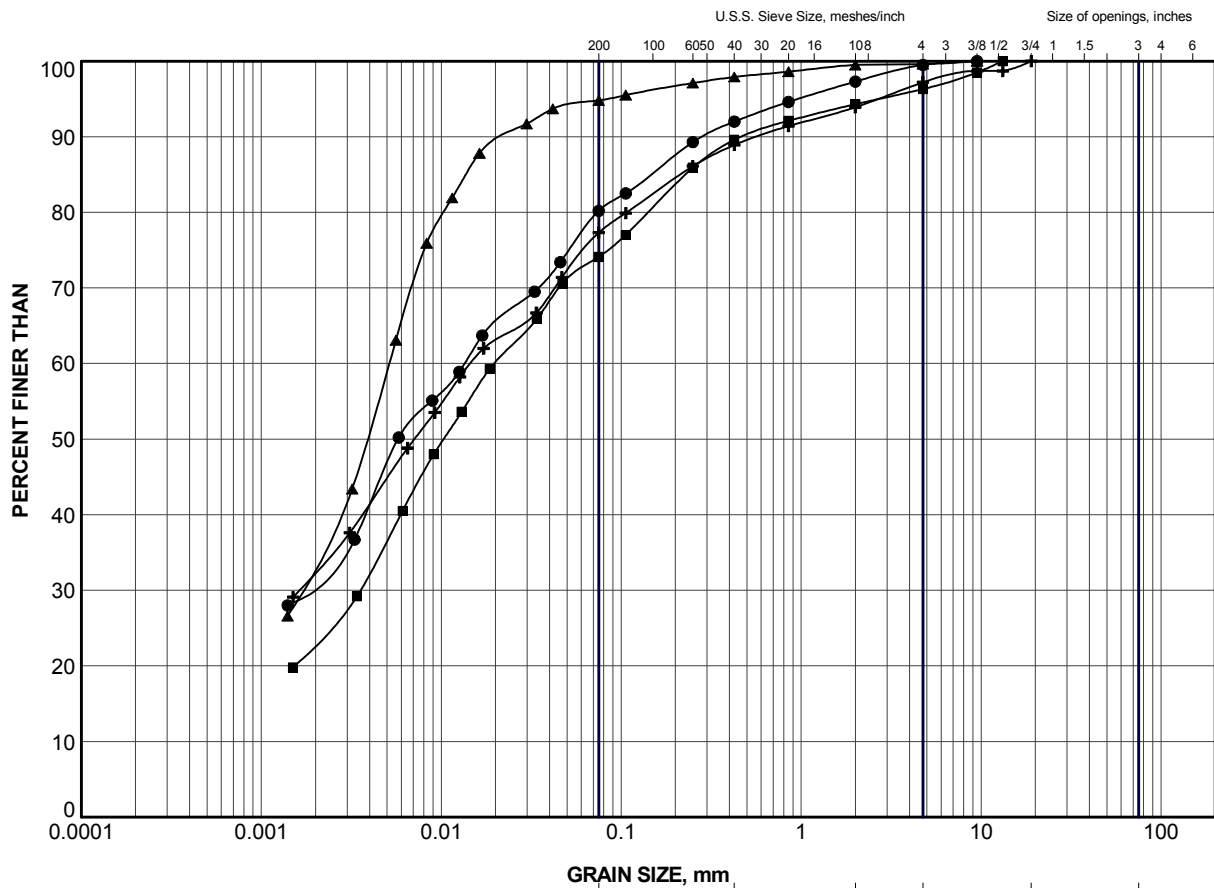
SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	AC-2	10	16.1	8.2	7.9
■	AC-2	13	16.3	12.5	3.8
▲	AC-5	8	16.8	12.0	4.8
+	AC-5	11	16.9	12.6	4.3

PROJECT					
HIGHWAY 11 ARMSTRONG CREEK CULVERT					
TITLE					
PLASTICITY CHART SANDY SILT to SAND and SILT					
PROJECT No.		10-1191-0038		FILE No.1011910038 BH LOGS.GPJ	
DRAWN	JJL	Oct 2013	SCALE	N/A	REV.
CHECK	AB	Oct 2013			
APPR		Oct 2013			
 Golder Associates SUDBURY, ONTARIO			FIGURE B5		



PROJECT				
HIGHWAY 11 ARMSTRONG CREEK CULVERT				
TITLE				
PLASTICITY CHART CLAYEY SILT				
PROJECT No.		10-1191-0038		FILE No.1011910038 BH LOGS.GPJ
DRAWN	JJL	Oct 2013	SCALE	N/A
CHECK	AB	Oct 2013	REV.	
APPR		Oct 2013	FIGURE B6	





LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	AC-1	8	218.2
■	AC-2	15	212.2
▲	AC-3	7	219.5
+	AC-4	11	216.7

PROJECT

HIGHWAY 11
ARMSTRONG CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION
CLAYEY SILT



Golder Associates
SUDBURY, ONTARIO

PROJECT No.	10-1191-0038	FILE No.	1910038 BH LOGS.GPJ
DRAWN	JJL	Oct 2013	SCALE N/A REV.
CHECK	AB	Oct 2013	
APPR		Oct 2013	

FIGURE B7

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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