REPORT

July 16, 2013

FOUNDATION INVESTIGATION REPORT

HIGHWAY 17 - BIG CACHE CREEK CULVERT AT STATION 10+514
TOWNSHIP OF SPRINGER, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5106-08-00, WP 5013-10-01

Submitted to:
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GEOCRES NO. 41I-296

Report Number: 11-1191-0010-R01

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Golder Associates

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PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 17 – BIG CACHE CREEK CULVERT AT STATION 10+514

TOWNSHIP OF NIPISSING, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5106-08-00, WP 5013-10-01

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Golder Associates

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 rehabilitation of the Highway 17 Big Cache Creek culvert at STA 10+514 in Nipissing Township, 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 proposed culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Big Cache Creek culvert is located approximately 9 km west of Sturgeon Falls, Ontario and approximately 0.3 km east of the intersection of Highway 17 and Beaudry Road. In general, the topography in the area of the overall project limits consists of flat terrain utilized as farmland, with moderate tree cover. The existing highway grade is at about Elevation 208 m with the Big Cache Creek located about 9 m below the existing highway grade. The side slopes of the existing embankment are about 1.5 Horizontal to 1 Vertical (1.5H:1V). Rock fill was observed on the embankment side slopes, some pieces in excess of 1 m size. The existing culvert, which is presumed to be an open footing culvert and later a concrete invert slab was poured, is 37 m long with an inside width of 6.1 m. This inside height varies from 1.83 m at the ends to 1.1 m at the centre portion and the north and south inverts are at Elevation 199.6 and 199.3 m, respectively. Photographs 1 and 2 following the text of the report depict the embankment side slopes and culvert ends.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between June 18, 2012 and June 27, 2012, during which time a total of six (6) boreholes were advanced at the site: four (4) for the proposed culvert (Boreholes CC-2, CC-3, CC-5 and CC-6) as shown on Section A-A on Drawing 1; and two (2) for the proposed roadway protection (Boreholes CC-1 and CC-4) as shown on Section B-B on Drawing 1. The approximate locations of, and ground surface elevations at, the boreholes are shown on Drawing 1.

Boreholes CC-1 to CC-4, located on the existing highway embankment, were advanced using a truck-mounted CME 55 drill rig outfitted with 108 mm inside diameter continuous flight hollow-stem augers. Boreholes CC-5 and CC-6, located at the south and north toe of slope, respectively, were advanced by wash boring with portable equipment using HQ casing. A Dynamic Cone Penetration Test (DCPT) was advanced from the bottom of Borehole CC-2 from 23.5 m to 31.7 m depth (Elevation 176.5 m) and from the bottom of Borehole CC-5 from 15.8 m to 23.8 m depth (Elevation 175.4 m). 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 CC-1 to CC-4 and a manual hammer at Boreholes CC-5 and CC-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, 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. In addition, a one-dimensional consolidation (oedometer) test was carried out on one Shelby tube sample of the cohesive soil deposit from Borehole CC-6. 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 July 20, 2012, 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 staked stations and offsets on the highway. 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 (m)
	Northing	Easting		
CC-1	5140833.8	263625.8	208.4	15.8
CC-2	5140821.9	263643.2	208.2	23.5/31.7
CC-3	5140832.9	263638.8	208.5	18.9
CC-4	5140820.9	263657.8	208.4	15.8
CC-5	5140808.6	263625.0	199.2	15.8/23.8
CC-6	5140847.8	263655.0	199.9	15.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on terrain mapping (Ontario Geological Survey[1]), the site is located on a glaciolacustrine plain in an area of, sand, silt and/or clay deposits.

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

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. 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 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 and rock types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations and on the stratigraphic profile and cross-section shown on Drawing 1.

In general, the subsurface stratigraphy at the site consists of embankment fill underlain by a deposit of clayey silt to clay underlain by a deposit of 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

Boreholes CC-1 and CC-2 penetrated an upper and lower layer of asphalt 300 mm and 225 mm thick, respectively, separated by a layer of sand fill up to 100 mm thick. The surface of the asphalt was encountered at Elevation 208.4 m and 208.2 m at Boreholes CC-1 and CC-2, respectively.

Below the asphalt in Boreholes CC-1 and CC-2 and from ground surface in Boreholes CC-3 and CC-4, fill material was encountered consisting of sand and gravel to sand, some silt, with the surface of the deposit between Elevation 208.5 m and 207.6 m and the thickness between 0.8 m and 1.4 m.

Below the sand and gravel to sand fill in each of the four boreholes, a 5.6 m to 7.3 m deposit of sand and silt to clayey silt fill was encountered with the surface between Elevation 207.3 m and 206.4 m. In Borehole CC-2, wood fragments were noted in the bottom sample of fill at a depth of 7.6 m below roadway surface (Elevation 200.6 m). Peat and topsoil pockets were noted in the clayey silt fill sample in Borehole CC-4 at a depth of 4.6 m below ground surface (Elevation 203.8 m). An approximately 1.1 m thick layer of silty clay fill was encountered below the sand and silt to clayey silt fill in Borehole CC-4, at a depth of 5.9 m below ground surface (Elevation 202.5 m).

The augers were noted to be grinding in Borehole CC-4 within the fill at a depth between approximately 6.0 m and 7.0 m below ground surface.

The SPT ‘N’-values measured within the sand and gravel to sand fill range between 11 blows and 42 blows per 0.3 m of penetration indicating a compact to dense relative density. The SPT ‘N’-values within the sand and silt to clayey silt fill, range between 4 blows and 23 blows per 0.3 m of penetration, indicating a loose to compact relative density (or firm to very stiff consistency). One SPT ‘N’-value measured within the silty clay fill in Borehole CC-4 is 4 blows per 0.3 m of penetration suggesting a firm consistency.

Grain size distribution analyses were carried out on the following fill materials:

- one (1) sample of the sand and gravel fill and the results are presented on Figure B1-1 in Appendix B;
- seven (7) samples of the sand and silt to clayey silt fill and the results are presented on Figure B1-2; and

- one (1) sample of the silty clay fill and the results are presented on Figure B1-3.

Atterberg limits testing was carried out on six (6) samples of the sand and silt to clayey silt fill. Measured liquid limits range from 19 per cent to 29 per cent, plastic limits range from 15 per cent to 20 per cent and plasticity indices range from 4 per cent to 9 per cent. The results, which are plotted on a plasticity chart on Figure B1-4 in Appendix B, indicate that the tested samples consist of a silt of slight plasticity to clayey silt of low plasticity. The measured water contents are at, or near, the plastic limit. Further, an Atterberg limits test was carried out on the sample of silty clay fill in Borehole CC-4, and the measured liquid limit is 38 per cent, the plastic limit is 18 per cent and the plastic index is 20 per cent and the water content is near the liquid limit. The results are plotted on Figure B1-5 and indicate that the tested sample is a silty clay of intermediate plasticity.

The measured water content on a sample of the sand and gravel fill is 5 per cent and samples of the sand and silt to silty clay fill are between 17 per cent and 33 per cent. The organic content measured on a sample of the lower portion of the clayey silt fill deposit in Borehole CC-1 is about 2 per cent (slightly organic).

4.2.2 Sandy Silt to Sand

A 0.2 m thick layer of sand was encountered from ground surface (Elevation 199.2 m) in Borehole CC-5 and a 0.8 m thick layer of sandy silt to silty sand was encountered from ground surface (Elevation 199.9 m) in Borehole CC-6.

4.2.3 Clayey Silt to Clay

A deposit of clayey silt to clay was encountered below the embankment fill in Boreholes CC-1 to CC-4 at depths ranging between 7.0 m and 8.7 m below ground surface (Elevation 201.4 m and 199.5 m, respectively), below the sand deposit in Borehole CC-5 at a depth of 0.2 m (Elevation 199.0 m) and below the sandy silt to silty sand in Borehole CC-6 at a depth of 0.8 m (Elevation 199.1 m). In Boreholes CC-2, CC-5 and CC-6, the clayey silt to clay deposit was fully penetrated and is between 10.8 m and 13.2 m thick and was not fully penetrated in Boreholes CC-1, CC-3 and CC-4 after exploring the deposit for a thickness between 7.3 m and 10.4 m. The deposit generally consists of clay in the upper portion, transitioning to a silty clay in the middle of the deposit and a clayey silt in the lower portion. The deposit was noted to be varved, typically with approximately 10 mm to 50 mm thick silt to clayey silt laminae and approximately 10 mm to 25 mm thick clay laminae. Thicker silt seams (0.2 m or greater) were also observed within the deposit. Further, sand seams were noted within the lower clayey silt portion of the deposit, generally encountered below Elevation 193 m.

The SPT ‘N’-values measured within the clayey silt to clay deposit range between 0 blows (weight of hammer or rods) to 6 blows per 0.3 m of penetration. In situ field vane testing measured undrained shear strengths ranging from 43 kPa to 81 kPa, with a sensitivity between 2 and 12. The in situ vane test results indicate that the deposit has a firm stiff consistency.

Atterberg limits testing were carried out on fourteen (14) samples of the varved clayey silt to clay and the measured liquid limits range from 22 per cent to 76 per cent, the plastic limits range from 14 per cent to 25 per cent, and plasticity indices range from 8 per cent to 51 per cent. The results, which are plotted on a plasticity chart on Figures B2-1 and B2-2 in Appendix B, indicate that the tested samples of the overall deposit consist of a clayey silt of low plasticity to clay of high plasticity.

Atterberg limits tests were also carried out on four (4) samples of the deposit separated into the clayey silt laminae and clay laminae and the test results are shown on Figure B2-3. The test results on the three (3) clay laminae samples indicate liquid limits ranging from 54 per cent to 84 per cent, plastic limits ranging from 24 per cent to 33 per cent and plasticity indices ranging from 30 per cent to 51 per cent. For the single clayey silt lamina sample, the liquid limit is 29 per cent, plastic limit is 17 per cent and plasticity index is 13 per cent. The test results confirm that the 'silty' varves are classified as clayey silt of low plasticity and the clayey varves are classified as clay of high plasticity.

The results of grain size distribution testing completed on samples of the clayey silt and clay laminae are shown on Figure B3 in Appendix B and the results of grain size distribution testing completed on a sample of the silty sand seam in Borehole CC-2 is shown on Figure B4.

The natural moisture content measured on the overall varved clayey silt to clay deposit range from 34 per cent to 55 per cent, on samples of the clayey silt laminae range from 30 per cent to 44 per cent and on the clay laminae range from 58 per cent to 71 per cent. The natural moisture content measured on the silty sand seam in Borehole CC-2 is 26 per cent.

One laboratory consolidation (oedometer) test was carried out on a specimen of the clayey silt to clay obtained from Borehole CC-6 and the test results are shown on Figure B5 in Appendix B. The preconsolidation stress was estimated from the Void Ratio versus logarithmic Pressure plot using the Casagrande method as well as from the Total Work versus Pressure plot. The relevant consolidation test results are summarized below:

Borehole/ Sample Number	Elevation (m)	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	e_o	C_r	C_c	c_v^* (cm^2/s)
CC-6/6	195.1	34	270	236	7.9	1.634	0.09	0.90	0.022

Note: *For approximate stress range of $35 \leq \sigma_v' \leq 285$ kPa
where: σ_{vo}' effective overburden stress in kPa
σ_p' preconsolidation stress in kPa
OCR overconsolidation ratio
e_o initial void ratio
C_c compression index (based on void ratio)
C_r recompression index (based on void ratio)
c_v coefficient of consolidation in cm^2/s in the normally consolidated range

4.2.4 Sandy Silt to Sand and Silt

A deposit of sandy silt to sand and silt with clay seams was encountered below the clayey silt to clay deposit at a depth between 11.6 m and 20.1 m below ground surface (between Elevation 188.3 m and 185.8 m) in Boreholes CC-2, CC-5 and CC-6. The sampled boreholes did not fully penetrate the deposit after exploring for thicknesses of between approximately 2.4 m and 4.2 m. As discussed in Section 3.0, a DCPT was advanced from the bottom of Borehole CC-2 from a depth of 23.5 m to a depth of 31.7 m and from the bottom of sampled Borehole CC-5 from a depth of 15.8 m to a depth of 23.8 m, potentially not penetrating this deposit based on a review of the results of the DCPT.

The SPT 'N'-values measured within this deposit range between 0 blows (weight of hammer) and 32 blows per 0.3 m of penetration, indicating a very loose to dense relative density.

Grain size analyses were carried out on three (3) samples of this deposit and the results are represented on Figure B6 in Appendix B.

The measured water content on samples of the deposit is between 28 per cent and 33 per cent.

4.2.5 Groundwater Conditions

Unstabilized water levels in Boreholes CC-1 to CC-4 upon completion of drilling ranged from 6.7 m to 12.8 m below roadway level, corresponding to Elevation 201.7 m and 195.6 m. The unstabilized water levels in Boreholes CC-5 and CC-6 upon completion of drilling are at ground surface, corresponding to Elevation 199.2 m and 199.9 m, respectively.

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 field drilling program was carried out under the supervision of Mr. Shane Albert, under the overall direction of Mr. André Bom, P.Eng. This report was prepared by Mr. Nicholas Kicz, Geotechnical Engineering Student and the technical aspects were reviewed by Mr. André Bom, P.Eng. with input by Mr. Fintan J. Heffernan, P.Eng., a specialist consultant with Golder. 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.

Report Signature Page

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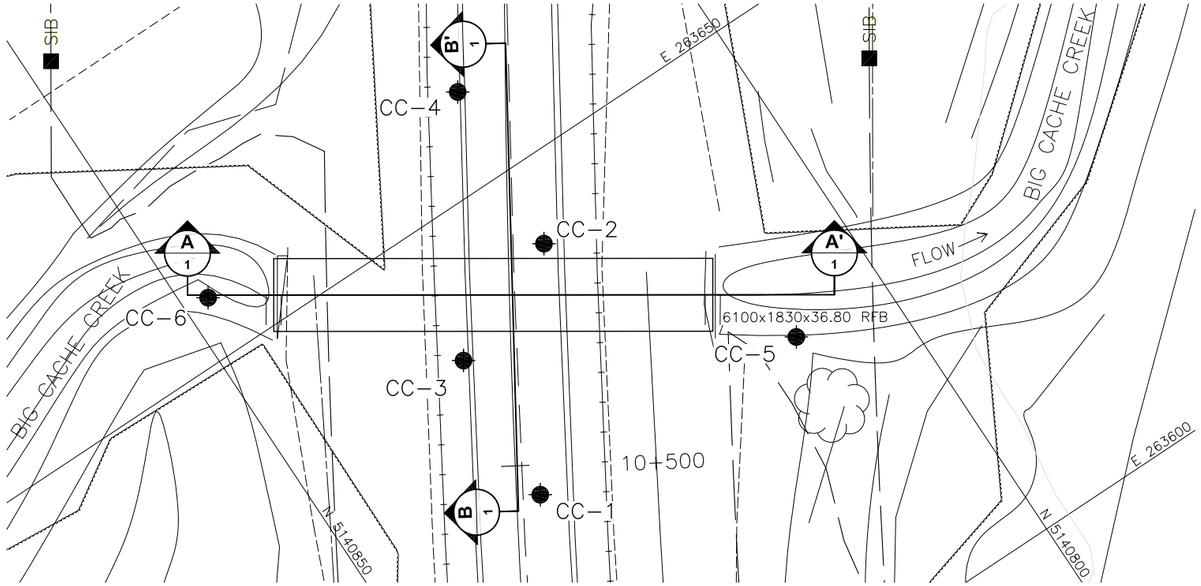
NK/AB/FJH/JMAC/kp

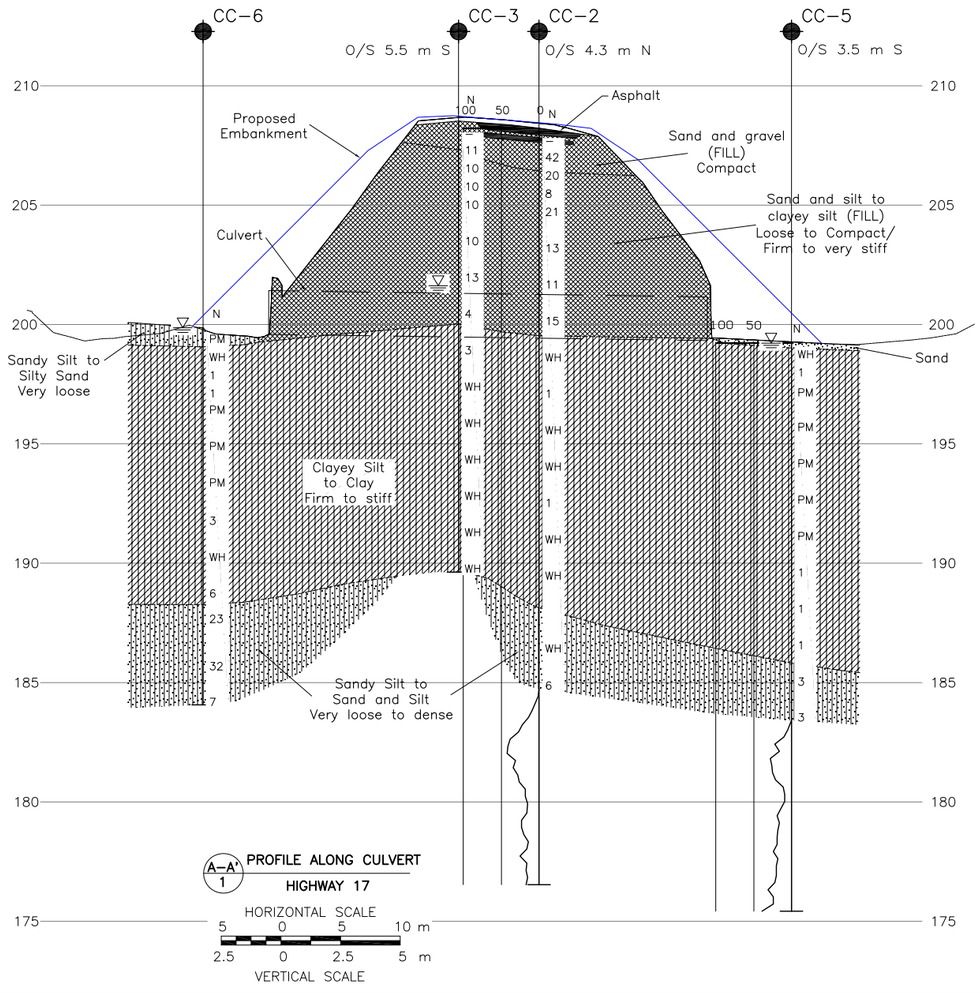
http://capws.golder.com/sites/capws2/p111910010mtohighway17rehabsturgeonfalls/reports/big cache/final/11-1191-0010-1 fir 13july16 big cache.docx

MINISTRY OF TRANSPORTATION, ONTARIO



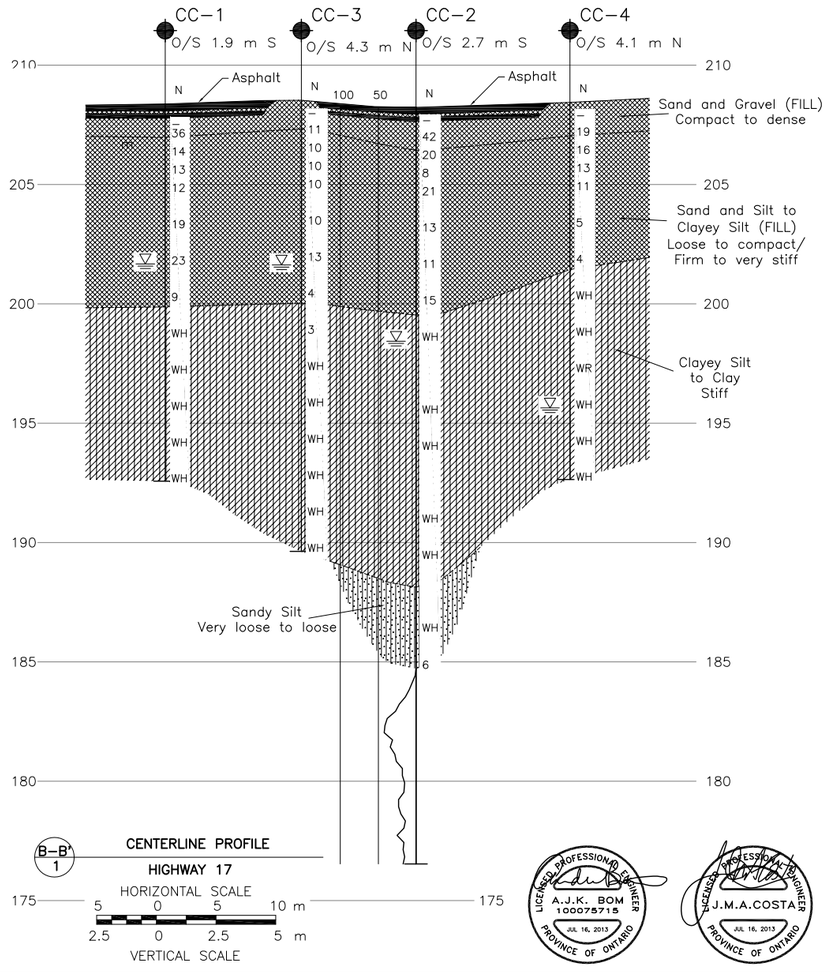
PLAN

SCALE
5 0 5 10 m



A-A' 1 PROFILE ALONG CULVERT
HIGHWAY 17

HORIZONTAL SCALE
5 0 5 10 m
2.5 0 2.5 5 m
VERTICAL SCALE



B-B' 1 CENTERLINE PROFILE
HIGHWAY 17

HORIZONTAL SCALE
5 0 5 10 m
2.5 0 2.5 5 m
VERTICAL SCALE

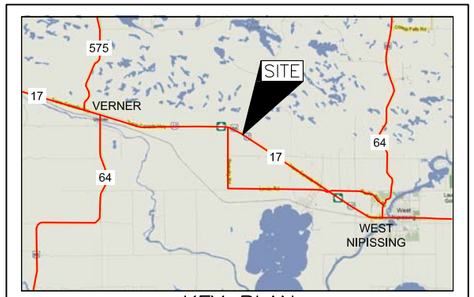
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5106-08-00

SHEET

HIGHWAY 17
BIG CACHE CREEK CULVERT AT STA 10+514
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN
SCALE
3 0 3 km

LEGEND

- Borehole
- 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
CC-1	208.4	5140833.8	263625.8
CC-2	208.2	5140821.9	263643.2
CC-3	208.5	5140832.9	263638.8
CC-4	208.4	5140820.9	263657.8
CC-5	199.2	5140808.6	263625.0
CC-6	199.9	5140847.8	263655.0

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 name "Cont1-Culvert Sections.dwg", received on JULY 16, 2012.
Key plan based on Google Maps.

LICENCED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 JUL 16, 2013 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA JUL 16, 2013 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 41I-296

HWY. 17	PROJECT NO. 11-1191-0010		DIST. 43-265
SUBM'D.	CHKD.	DATE: JUL 2013	SITE:
DRAWN: TB	CHKD. AB	APPD. JMAC	DWG. 1

PLOT DATE: July 12, 2013
FILENAME: \\golder.gds\GAL\Sudbury\CAD-GIS\CAD\Projects\2011\11-1191-0010 Rehab Sturgeon Falls\Caldwell Township (Unnamed and Big Cache Creeks)\11119100\0A0002.dwg

Photograph 1: Embankment north slope and culvert inlet (received from MMM December 2012).

Photograph 2: Embankment north slope and culvert outlet (received from MMM December 2012).

APPENDIX A

Record of Boreholes

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
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
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, 60º 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 cm^2 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) Cohesionless Soils

Density Index / Relative Density	N 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	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

Percent 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 (cohesionless) or With (cohesive)	Sand and Gravel / Silty Clay with sand / Clayey Silt with sand

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

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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

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

(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 δ
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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

Golder Associates

RECORD OF BOREHOLE No CC-1

1 OF 2 **METRIC**

PROJECT 11-1191-0010
W.P. 5013-10-01
LOCATION N 5140833.8; E 263625.8
ORIGINATED BY SA
DIST HWY 17
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY TB
DATUM GEODETIC
DATE June 19, 2012
CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
208.4	GROUND SURFACE										
0.0 / 208.1	ASPHALT (300 mm)										
	Sand, some gravel (75 mm) (FILL)										
	ASPHALT (225 mm)										
0.6	Sand, some gravel, some silt (FILL) Dense Brown		1	AS	-						
			2	SS	36						
207.0	Moist										
1.4	Sand and silt to clayey silt (FILL) Compact/Stiff to very stiff Brown to grey Moist		3	SS	14				○		0 33 47 20
			4	SS	13						
			5	SS	12						
			6	SS	19				⊢○		0 7 76 17
			7	SS	23	▽					
			8	SS	9				○		OC=1.8%
199.9											
8.5	CLAYEY SILT to CLAY, varved Stiff Grey Wet		9	SS	WH			3	⊢○		
			10	SS	WH						
			11	SS	WH			6 3	⊢○		
			12	SS	WH			3			

ELEVATION SCALE: 208, 207, 206, 205, 204, 203, 202, 201, 200, 199, 198, 197, 196, 195, 194

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

Golder Associates

PROJECT 11-1191-0010

RECORD OF BOREHOLE No CC-1

2 OF 2 **METRIC**

W.P. 5013-10-01 LOCATION N 5140833.8; E 263625.8 ORIGINATED BY SA

DIST HWY 17 BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY TB

DATUM GEODETIC DATE June 19, 2012 CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	CLAYEY SILT to CLAY, varved Stiff Grey Wet										
192.6	Sand seams noted at 15.4 m depth.		13	SS	WH		193				
15.8	END OF BOREHOLE										
	Note: 1. Water level at a depth of 6.7 m below ground surface (Elev. 201.7 m) upon completion of drilling.										

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

Golder Associates

RECORD OF BOREHOLE No CC-2

1 OF 3 **METRIC**

PROJECT 11-1191-0010 | W.P. 5013-10-01 | LOCATION N 5140821.9; E 263643.2 | ORIGINATED BY SA

DIST | HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY TB

DATUM GEODETIC | DATE June 18, 2012 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
208.2	GROUND SURFACE								
0.0 / 207.9	ASPHALT (300 mm)								
	Sand, some gravel (100 mm) (FILL)		1	AS	-				
	ASPHALT (225 mm)								
0.6	Sand, some gravel, some silt (FILL) Dense Brown Moist		2	SS	42				
206.4			3	SS	20				
1.8	Sand and silt to clayey silt (FILL) Compact/Stiff to very stiff Grey to brown Moist		4	SS	8				0 37 51 12
			5	SS	21				
			6	SS	13				
			7	SS	11				0 5 78 17
	Wood fragments in Sample 8.		8	SS	15				
199.5									
8.7	CLAYEY SILT to CLAY, varved Stiff Grey Wet		9	SS	WH	▽			
			10	SS	1				
			11	SS	WH				
			12	SS	WH				

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

ELEVATION SCALE: 208 207 206 205 204 203 202 201 200 199 198 197 196 195 194

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

Continued Next Page

Golder Associates

RECORD OF BOREHOLE No CC-2

2 OF 3 **METRIC**

PROJECT 11-1191-0010
W.P. 5013-10-01
LOCATION N 5140821.9; E 263643.2
ORIGINATED BY SA
DIST HWY 17
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY TB
DATUM GEODETIC
DATE June 18, 2012
CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---											
	CLAYEY SILT to CLAY, varved Stiff Grey Wet		13	SS	1		193					
	0.1 m silty sand seam at bottom of Sample 13.						192	7				
	0.3 m silty sand seam at top of Sample 14.		14	SS	WH		191	4				0 66 28 6
			15	SS	WH		190					
188.1							189					
20.1	Sandy SILT, clay seams Very loose to loose Grey Wet		16	SS	WH		188					
			17	SS	6		187					
184.7							186					
23.5	START OF DCPT						185					0 29 56 15
							184					
							183					
							182					
							181					
							180					
							179					

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No CC-2

3 OF 3 **METRIC**

PROJECT 11-1191-0010
W.P. 5013-10-01
LOCATION N 5140821.9; E 263643.2
ORIGINATED BY SA
DIST HWY 17
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY TB
DATUM GEODETIC
DATE June 18, 2012
CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	START OF DCPT						178				
							177				
176.5											
31.7	END OF DCPT END OF BOREHOLE Note: 1. Water level at a depth of 9.8 m below ground surface (Elev. 198.4 m) upon completion of drilling.										

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

Golder Associates

RECORD OF BOREHOLE No CC-3

1 OF 2 **METRIC**

PROJECT 11-1191-0010 | W.P. 5013-10-01 | LOCATION N 5140832.9; E 263638.8 | ORIGINATED BY SA

DIST ____ HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY TB

DATUM GEODETIC | DATE June 20 and 21, 2012 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
208.5	GROUND SURFACE										
0.0	Sand and gravel (FILL) Compact Brown Moist		1	AS	-		208				
207.3			2	SS	11						
1.2	Sand and silt to clayey silt (FILL) Loose to compact/Firm to stiff Brown to grey Moist		3	SS	10		207				
	Augers grinding at 2.3 m depth.		4	SS	10		206				0 17 63 20
			5	SS	10		205				
			6	SS	10		204				
			7	SS	13	▽	203				0 12 73 15
			8	SS	4		202				
200.0							201				
8.5	CLAYEY SILT to CLAY, varved Stiff Grey Wet		9	SS	3		200				
			10	SS	WH		199	3			
			11	SS	WH		198	4			
			12	SS	WH		197	3			
							196	4			
							195				
							194				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No CC-3

2 OF 2 **METRIC**

PROJECT 11-1191-0010 | W.P. 5013-10-01 | LOCATION N 5140832.9; E 263638.8 | ORIGINATED BY SA

DIST | HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY TB

DATUM GEODETIC | DATE June 20 and 21, 2012 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	20 40 60		
	CLAYEY SILT to CLAY, varved Stiff Grey Wet		13	SS	WH		193				
								3			
							192				
			14	SS	WH						
							191	2			
	Sand seams noted at 18.5 m depth.		15	SS	WH		190				
189.6											
18.9	END OF BOREHOLE										
	Note: 1. Water level at a depth of 6.9 m below ground surface (Elev. 201.6 m) upon completion of drilling.										

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

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No CC-4

1 OF 2 **METRIC**

PROJECT 11-1191-0010
W.P. 5013-10-01
LOCATION N 5140820.9; E 263657.8
ORIGINATED BY SA
DIST HWY 17
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY TB
DATUM GEODETIC
DATE June 19 and 20, 2012
CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
208.4	GROUND SURFACE								
0.0	Sand and gravel, some silt, trace to some clay (FILL) Compact Brown Moist		1	AS	-		208		
			2	SS	19				30 46 18 6
207.0							207		
1.4	Sand and silt to clayey silt (FILL) Loose to compact/Firm to very stiff Brown Moist		3	SS	16				
			4	SS	13		206		
			5	SS	11		205		0 13 69 18
	Peat / topsoil pockets in Sample 6.		6	SS	5		204		
202.5							203		
5.9	Silty Clay (FILL) Firm Brown Moist		7	SS	4		202		0 0 55 45
201.4	Augers grinding between about 6 m and 7 m depth.								
7.0	CLAYEY SILT to CLAY, varved Stiff Grey Wet		8	SS	WH		201		
	Auger grinding at 7.6 m depth.						200		
			9	SS	WH		199		
			10	SS	WR		198		
							197		
			11	SS	WH	▽	196		
							195		
			12	SS	WH		194		

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

+^{3}, ×^{3}: Numbers refer to Sensitivity

○$^{3\%}$ STRAIN AT FAILURE

Continued Next Page

Golder Associates

RECORD OF BOREHOLE No CC-4

2 OF 2 **METRIC**

PROJECT 11-1191-0010 | W.P. 5013-10-01 | LOCATION N 5140820.9; E 263657.8 | ORIGINATED BY SA

DIST _____ HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY TB

DATUM GEODETIC | DATE June 19 and 20, 2012 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	CLAYEY SILT to CLAY, varved Stiff Grey Wet										
192.6	Sand seams noted at 15.4 m depth.		13	SS	WH		193				
15.8	END OF BOREHOLE										
	Note: 1. Water level at a depth of 12.8 m below ground surface (Elev. 195.6 m) upon completion of drilling.										

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

Golder Associates

RECORD OF BOREHOLE No CC-5

1 OF 2 **METRIC**

PROJECT 11-1191-0010
W.P. 5013-10-01
DIST ____ HWY 17
DATUM GEODETIC
LOCATION N 5140808.6; E 263625.0
BOREHOLE TYPE Portable Equipment, HQ Casing, Wash Boring
DATE June 24 and 25, 2012
ORIGINATED BY SA
COMPILED BY TB
CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
199.2	GROUND SURFACE							
0.0	SAND, some gravel, some silt Grey Wet	1	SS	WH				
0.2	CLAYEY SILT to CLAY, varved Firm to stiff Grey Wet	2	SS	1				
		3	TO	PM				
	Sample 4: Light grey silt to clayey silt laminae 10 mm to 25 mm thick Dark grey clay laminae 25 mm thick	4	TO	PM	0	1	73	26
	Sample 5 top 0.2 m: Light grey clayey silt	5	TO	PM	0	1	85	14
	Sample 6 bottom 0.4 m: Light grey silt laminae 25 mm thick Dark grey clayey silt laminae 10 mm thick	6	TO	PM				
	Sand seams noted below 7.2 m depth.	7	SS	1				
		8	SS	1				
		9	SS	1				
		10	SS	1				
185.8								
13.4	SAND and SILT, clay seams Very loose Grey Wet	11	SS	3	0	38	48	14

ELEVATION SCALE: 199, 198, 197, 196, 195, 194, 193, 192, 191, 190, 189, 188, 187, 186, 185

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%)
20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Continued Next Page

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

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No CC-5

2 OF 2 **METRIC**

PROJECT 11-1191-0010 | W.P. 5013-10-01 | LOCATION N 5140808.6; E 263625.0 | ORIGINATED BY SA

DIST | HWY 17 | BOREHOLE TYPE Portable Equipment, HQ Casing, Wash Boring | COMPILED BY TB

DATUM GEODETIC | DATE June 24 and 25, 2012 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---									
183.4	SAND and SILT, clay seams Very loose Grey Wet		12	SS	3		184 183 182 181 180 179 178 177 176			
15.8	START OF DCPT									
175.4										
23.8	END OF DCPT END OF BOREHOLE Note: 1. Water level at ground surface (Elev. 199.2 m) upon completion of drilling.									

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

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

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No CC-6

1 OF 2 **METRIC**

PROJECT 11-1191-0010 | W.P. 5013-10-01 | LOCATION N 5140847.8; E 263655.0 | ORIGINATED BY SA

DIST | HWY 17 | BOREHOLE TYPE Portable Equipment, HQ Casing, Wash Boring | COMPILED BY TB

DATUM GEODETIC | DATE June 27, 2012 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
199.9	GROUND SURFACE										
0.0	Sandy SILT to Silty SAND Very loose Grey Wet		1	SS	PM						
199.1											
0.8	CLAYEY SILT to CLAY, varved Stiff Grey Wet		2	SS	WH		199				
			3	SS	1		198				
			4	SS	1		197				
	Sample 5: Light grey silt to clayey silt laminae 10 mm to 25 mm thick Dark grey clay laminae 10 mm to 25 mm thick		5	TO	PM						0 0 80 20
							196	9			
	Sample 6: Light grey silt to clayey silt laminae 25 mm to 50 mm thick Dark grey clay laminae 10 mm to 25 mm thick		6	TO	PM		195	6		16.7	0 1 71 28
			7	TO	PM		194				
							193	5			
	Sand seams noted below 7.9 m depth.		8	SS	3		192				
			9	SS	WH		191				
							190	5			
			10	SS	6		189				
188.3								5			
11.6	Sandy SILT, clay seams Loose to dense Grey Wet		11	SS	23		188				0 29 50 21
							187				
			12	SS	32		186				
							185				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No CC-6

2 OF 2 **METRIC**

PROJECT 11-1191-0010 | W.P. 5013-10-01 | LOCATION N 5140847.8; E 263655.0 | ORIGINATED BY SA

DIST ____ HWY 17 | BOREHOLE TYPE Portable Equipment, HQ Casing, Wash Boring | COMPILED BY TB

DATUM GEODETIC | DATE June 27, 2012 | CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
184.1	Sandy SILT, clay seams Loose to dense Grey Wet		13	SS	7						
15.8	END OF BOREHOLE										
	Note: 1. Water level at ground surface (Elev. 199.9 m) upon completion of drilling.										

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

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

APPENDIX B

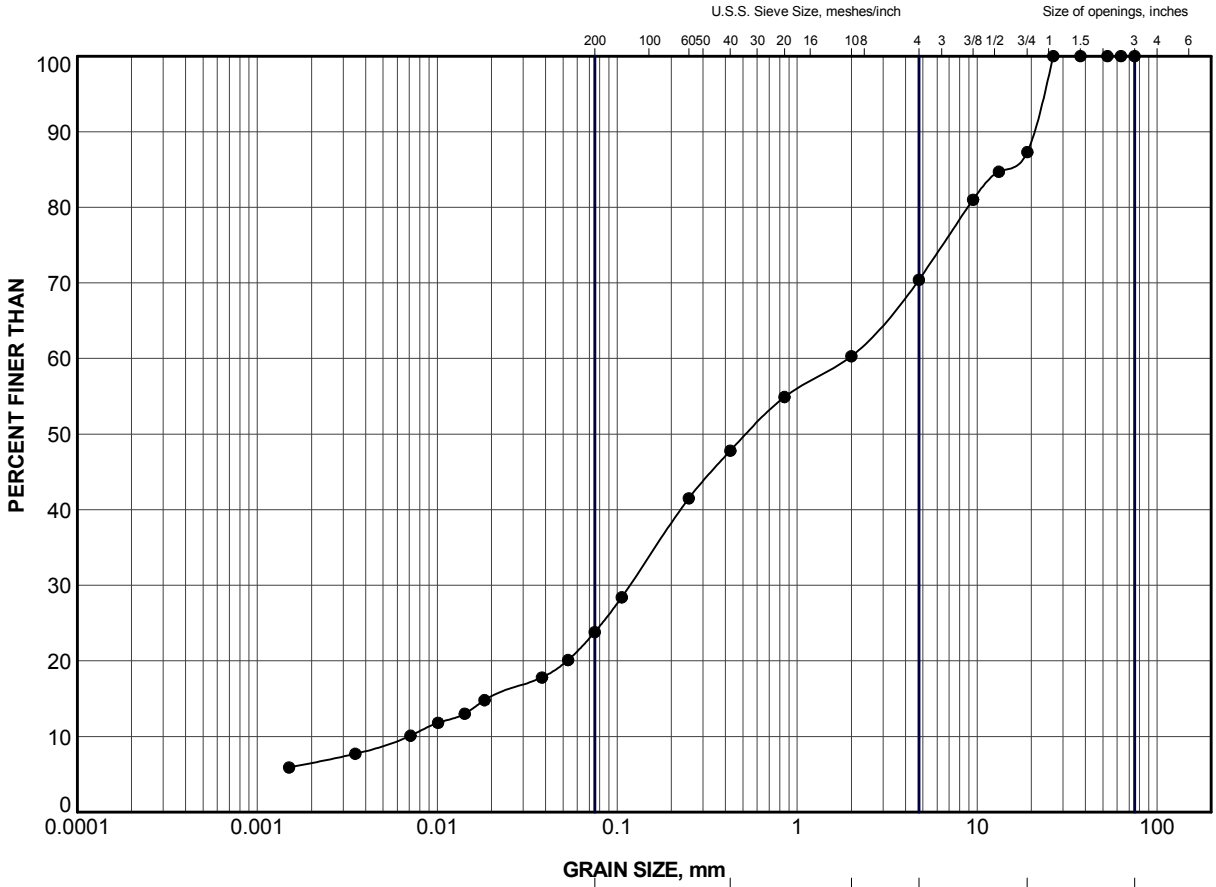
Laboratory Test Results

Table B1 - Summary of Analytical Testing of Big Cache Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	4
Dissolved Sulphate	mg/L	1	Not Detected
Conductivity	µohm/cm	1	150
Resistivity	ohm-cm	n/a	6900
pH	n/a	n/a	7.82

Checked by: AB

Notes: 1. Sample obtained on July 20, 2012.
2. Analytical testing carried out by Maxxam Analytics.



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-4	2	207.3

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

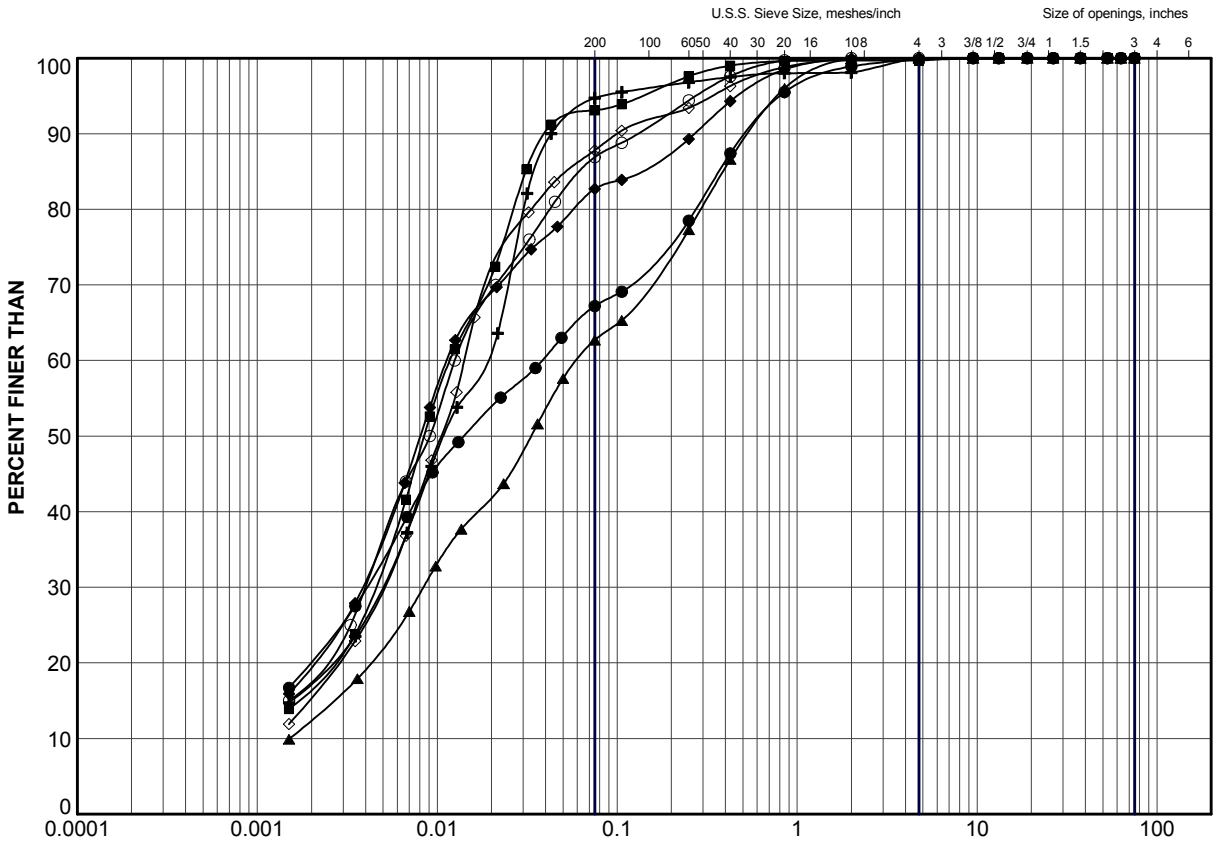
GRAIN SIZE DISTRIBUTION

SAND AND GRAVEL (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Dec 2012	SCALE N/A	REV.
CHECK	AB	Dec 2012		
APPR		Dec 2012	**FIGURE B1-1**	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-1	3	206.6
■	CC-1	6	203.5
▲	CC-2	4	205.6
+	CC-2	7	201.8
◆	CC-3	4	205.9
◇	CC-3	7	202.1
○	CC-4	5	205.1

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

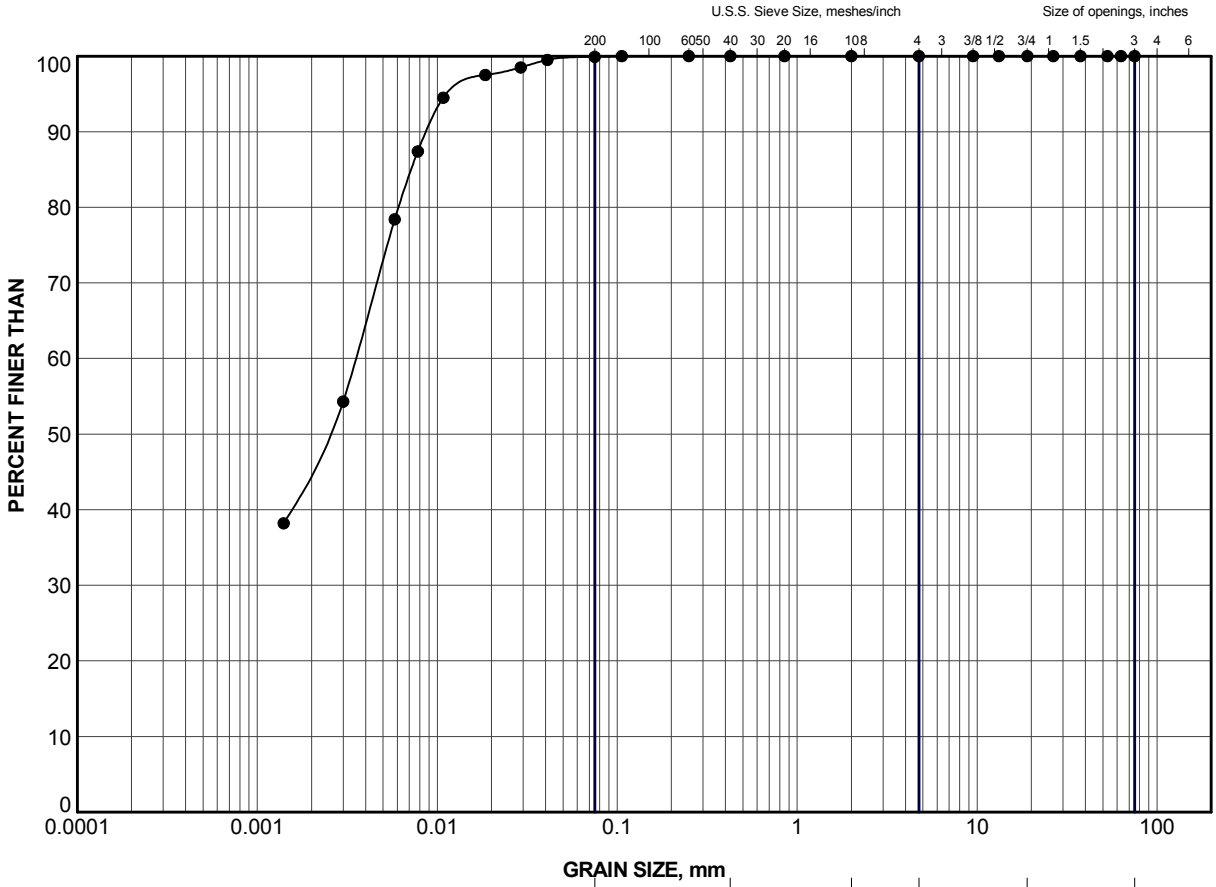
GRAIN SIZE DISTRIBUTION

SAND AND SILT TO CLAYEY SILT (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Jan 2013	SCALE	N/A REV.
CHECK	AB	Jan 2013		
APPR	JMAC	Jan 2013		**FIGURE B1-2**

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-4	7	202.0

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

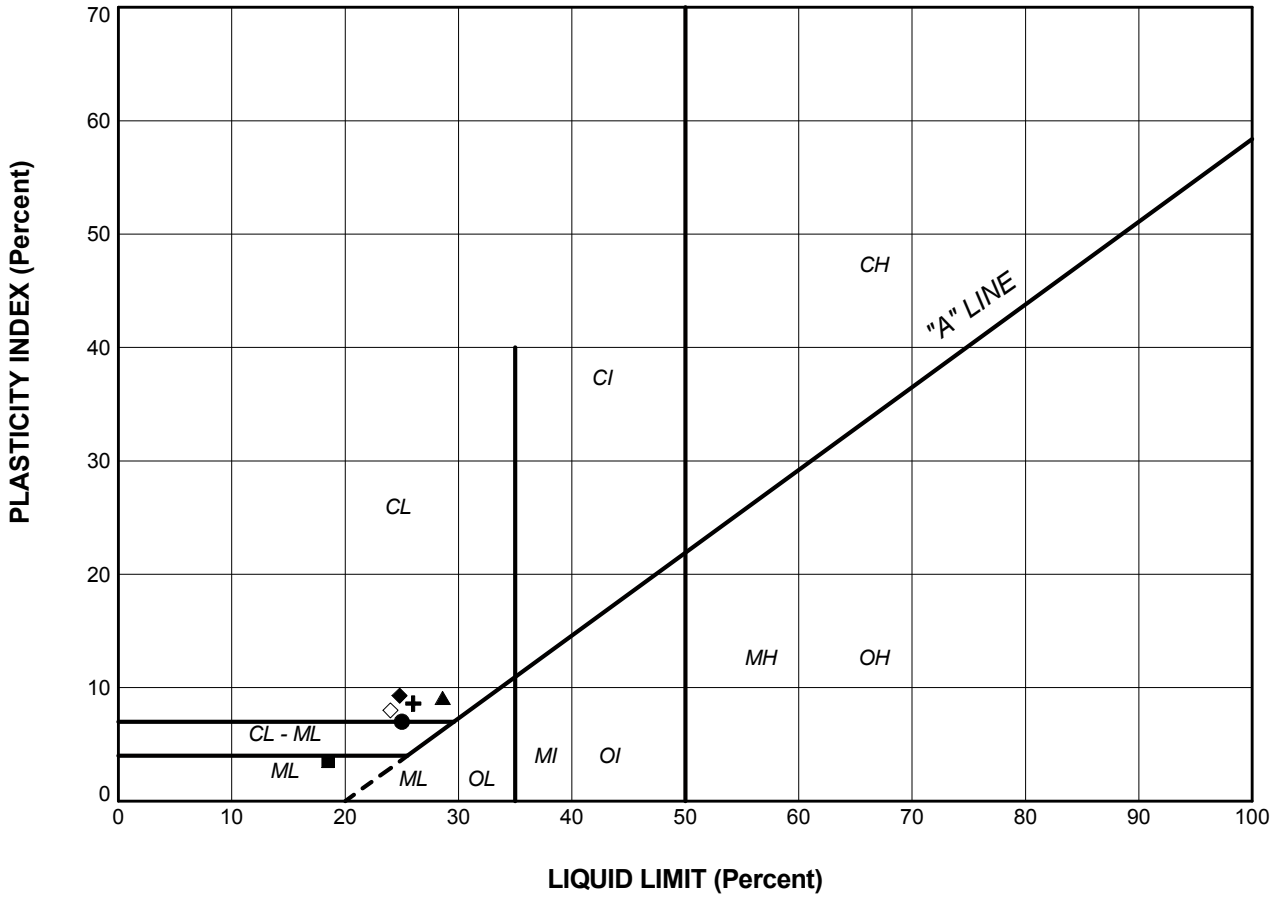
GRAIN SIZE DISTRIBUTION

SILTY CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Dec 2012	SCALE N/A	REV.
CHECK	AB	Dec 2012		
APPR		Dec 2012	**FIGURE B1-3**	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-1	6	25	18	7
■	CC-2	4	19	15	4
▲	CC-2	7	29	20	9
+	CC-3	4	26	17	9
◆	CC-3	7	25	16	9
◇	CC-4	5	24	16	8

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

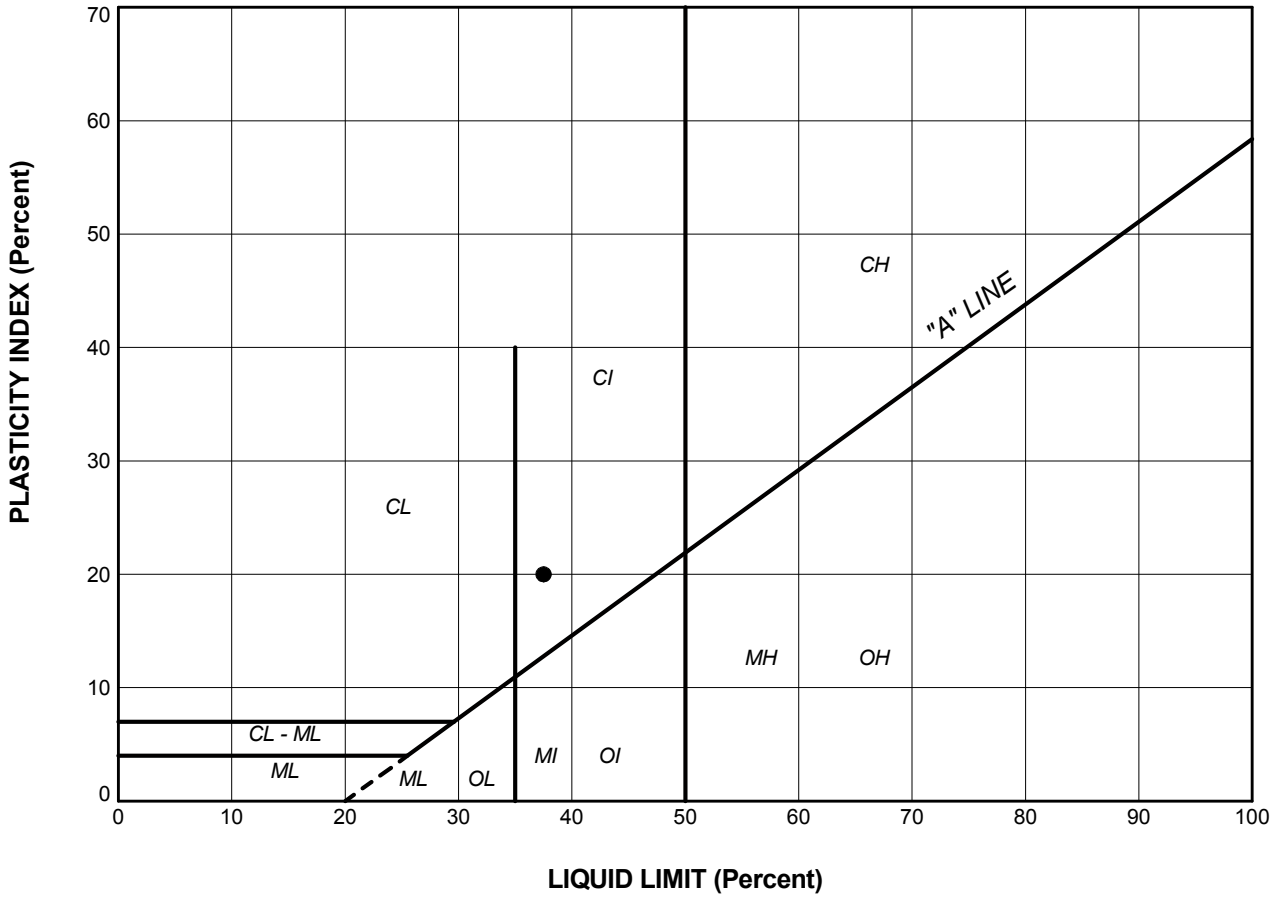
PLASTICITY CHART

SAND AND SILT TO CLAYEY SILT (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Dec 2012	SCALE N/A	REV.
CHECK	AB	Dec 2012		
APPR		Dec 2012	**FIGURE B1-4**	

SUD-MTO PL (NEW) GLDR_LDN.GDT



LIQUID LIMIT (Percent)

SOIL TYPE	**PLASTICITY**
C = Clay	L = Low
M = Silt	I = Intermediate
O = Organic	H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-4	7	38	18	20

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

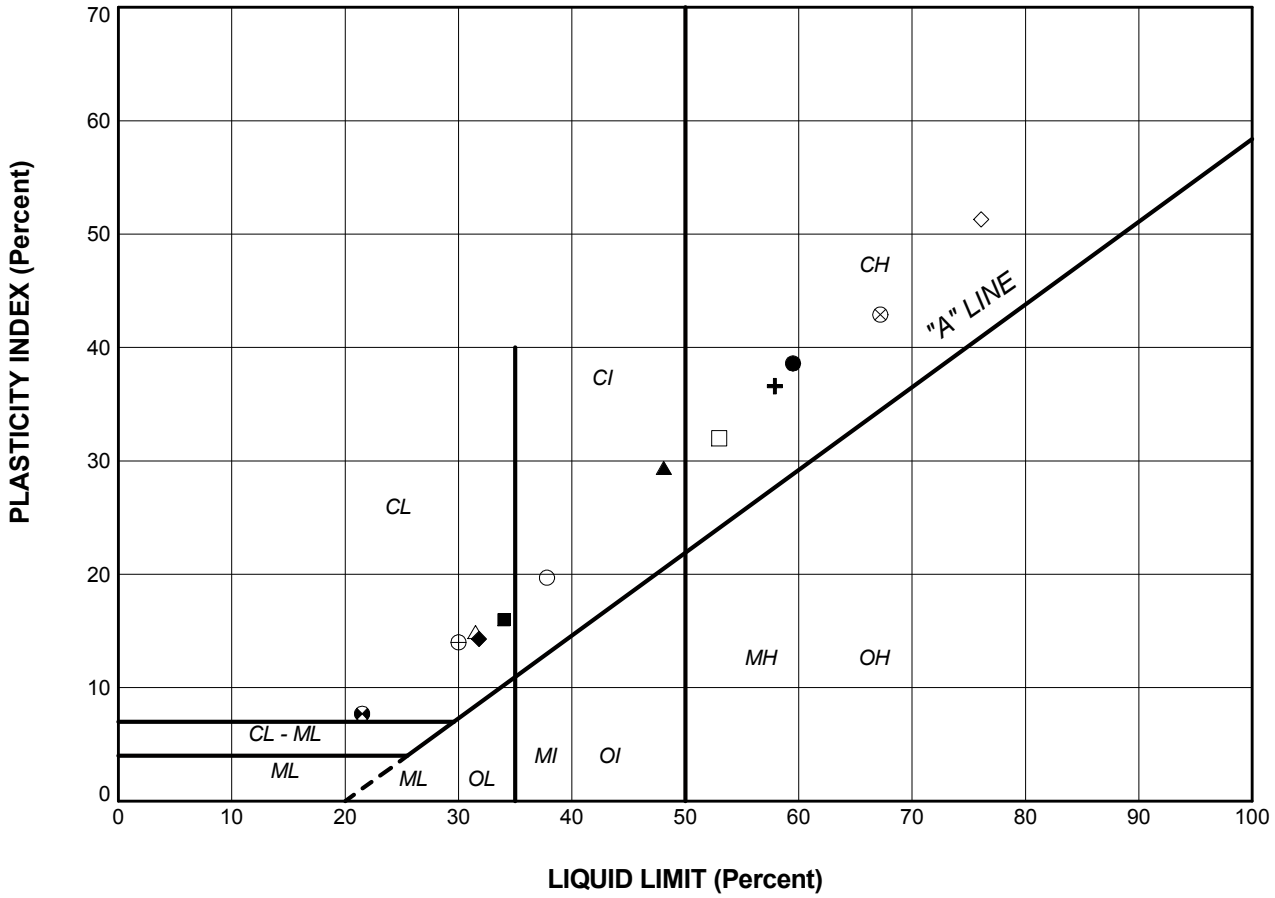
PLASTICITY CHART

SILTY CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Dec 2012	SCALE N/A	REV.
CHECK	AB	Dec 2012		
APPR		Dec 2012	**FIGURE B1-5**	

SUD-MTO PL (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-1	9	60	21	39
■	CC-1	11	34	18	16
▲	CC-2	10	48	19	29
+	CC-2	12	58	21	37
◆	CC-2	15	32	18	14
◇	CC-3	9	76	25	51
○	CC-3	11	38	18	20
△	CC-3	13	32	17	15
⊗	CC-4	9	67	24	43
⊕	CC-4	11	30	16	14
□	CC-5	2	53	21	32
☢	CC-5	7	22	14	8

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

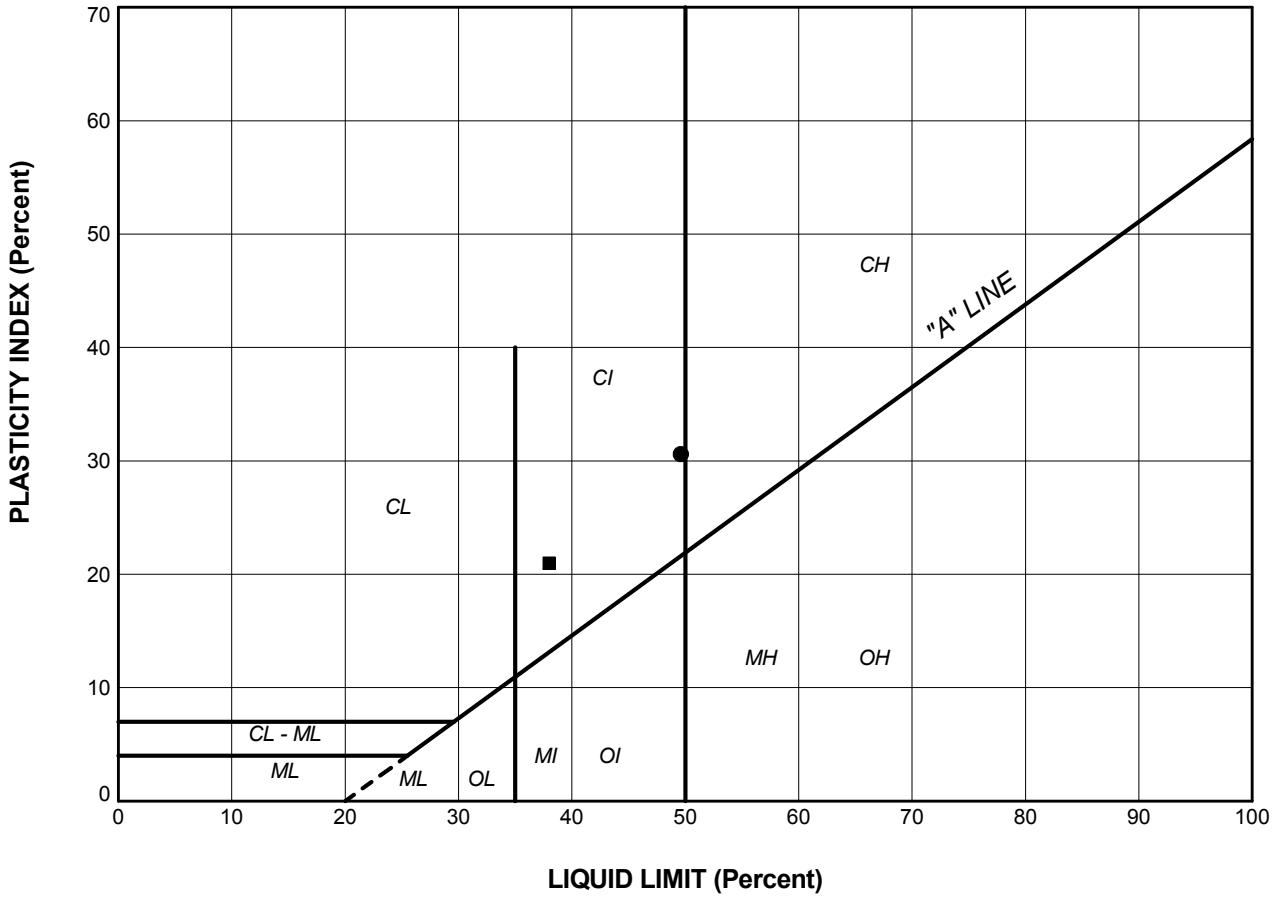
PLASTICITY CHART

CLAYEY SILT TO CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Jan 2013	SCALE N/A	REV.
CHECK	AB	Jan 2013		
APPR	JMAC	Jan 2013	**FIGURE B2-1**	

SUD-MTO PL (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-6	3	50	19	31
■	CC-6	9	38	17	21

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

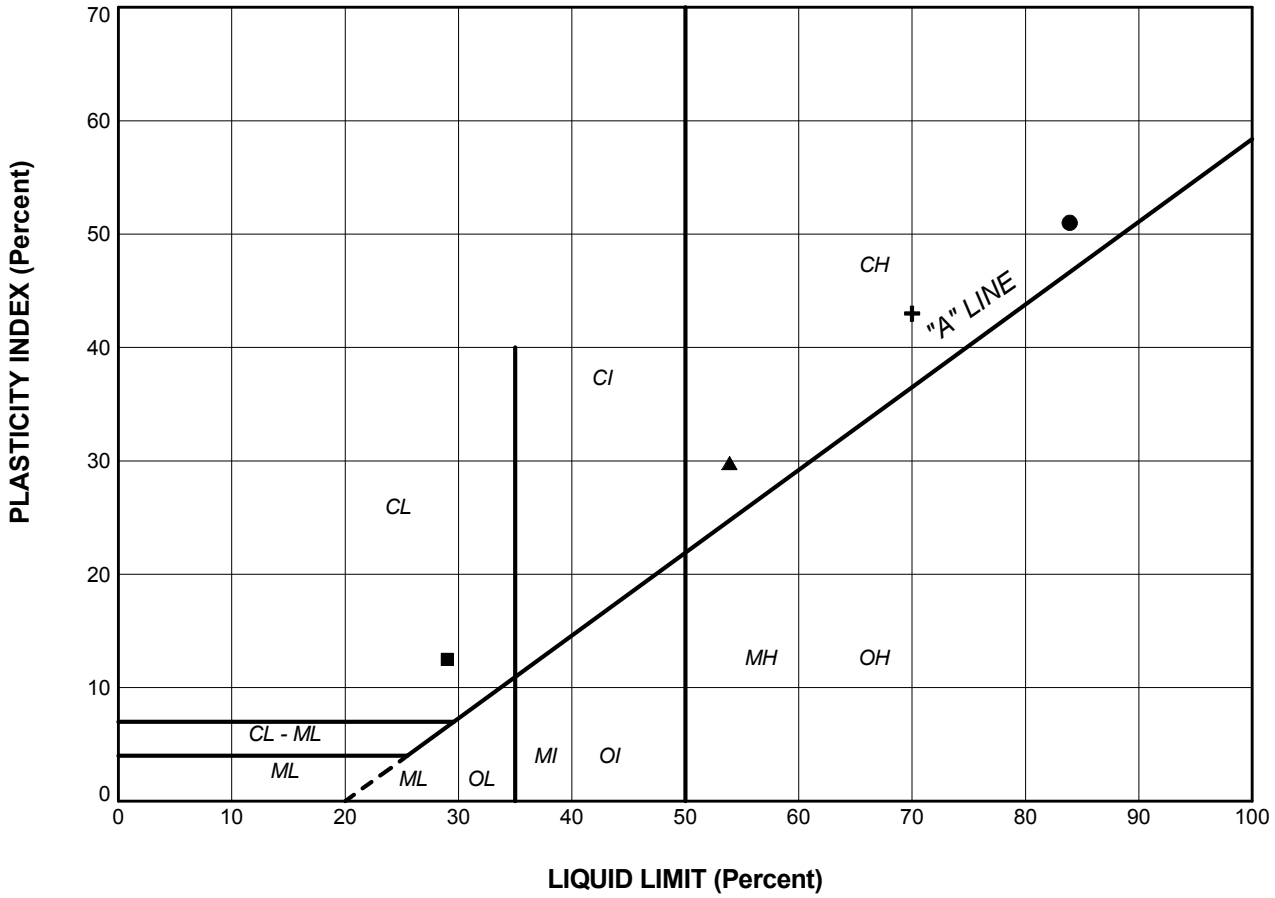
PLASTICITY CHART

SILTY CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Jan 2013	SCALE N/A	REV.
CHECK	AB	Jan 2013		
APPR	JMAC	Jan 2013	**FIGURE B2-2**	

SUD-MTO PL (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-5	4	84	33	51
■	CC-5	5	29	17	13
▲	CC-6	5	54	24	30
+	CC-6	6	70	27	43

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

PLASTICITY CHART

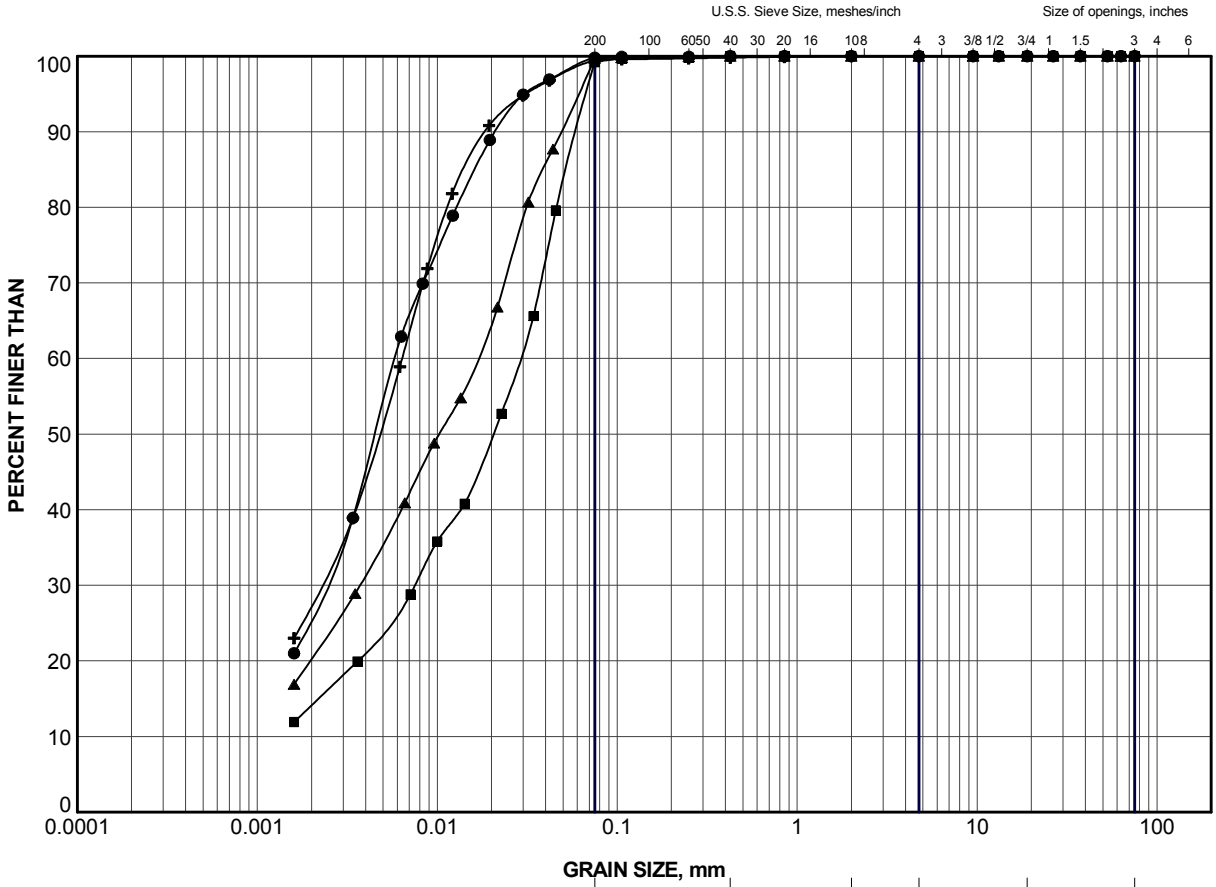
CLAYEY SILT AND CLAY LAMINAE

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Jan 2013	SCALE	N/A
CHECK	AB	Jan 2013	REV.	
APPR	JMAC	Jan 2013		

FIGURE B2-3

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-5	4	195.8
■	CC-5	5	194.3
▲	CC-6	5	196.6
+	CC-6	6	195.1

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

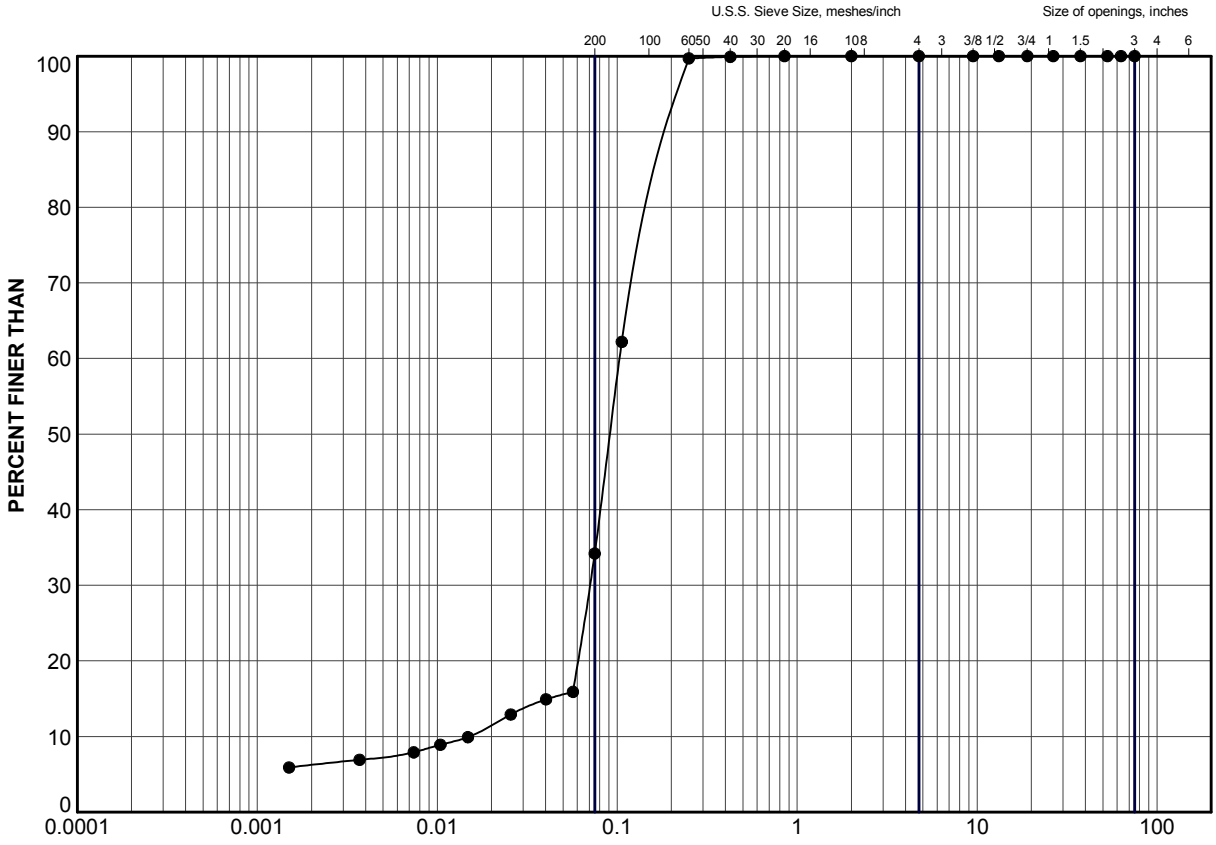
GRAIN SIZE DISTRIBUTION

SILT TO CLAYEY SILT LAMINAE

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Jan 2013	SCALE	N/A
CHECK	AB	Jan 2013	REV.	
APPR	JMAC	Jan 2013	**FIGURE B3**	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-2	14	191.5

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

SILTY SAND SEAM

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Jan 2013	SCALE N/A	REV.
CHECK	AB	Jan 2013		
APPR	JMAC	Jan 2013	**FIGURE B4**	

SUD-MTO GSD (NEW) GLDR_LDN.GDT

CONSOLIDATION TEST SUMMARY

FIGURE B5

SAMPLE IDENTIFICATION

Project Number:	11-1191-0010	Sample Number:	6
Borehole Number:	CC-6	Sample Depth, m:	4.6

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	August 14/12		
Date Completed	August 28/12		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.526	Unit Weight, kN/m^3	16.69
Sample Diameter, cm	6.351	Dry Unit Weight, kN/m^3	10.05
Area, cm^2	31.68	Specific Gravity, Assumed	2.70
Volume, cm^3	80.02	Solids Height, cm	0.959
Water Content, %	66.00	Volume of Solids, cm^3	30.39
Wet Mass, g	136.19	Volume of Voids, cm^3	49.64
Dry Mass, g	82.04	Degree of Saturation, %	109.1

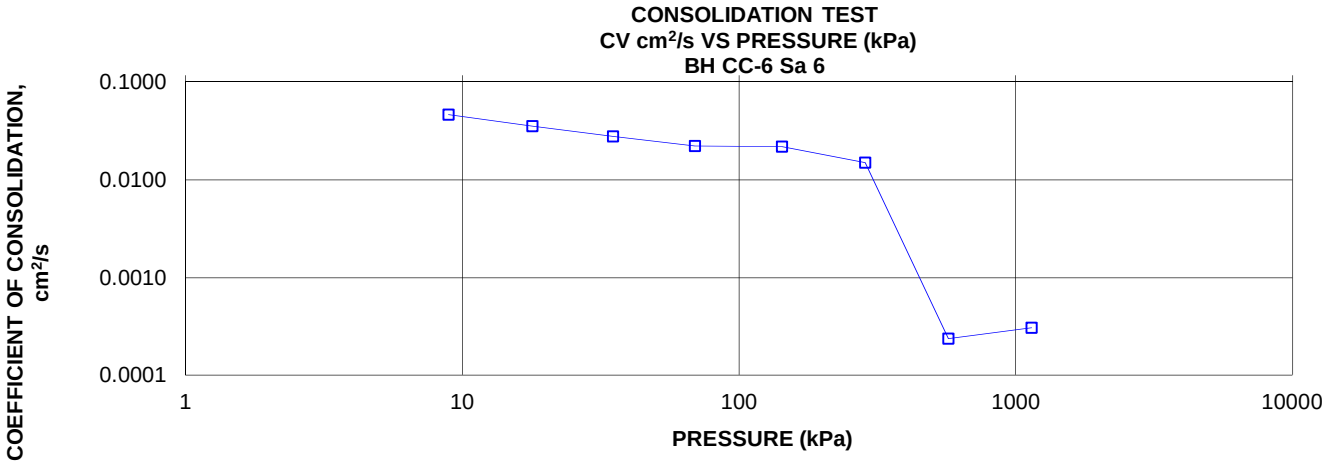
TEST COMPUTATIONS

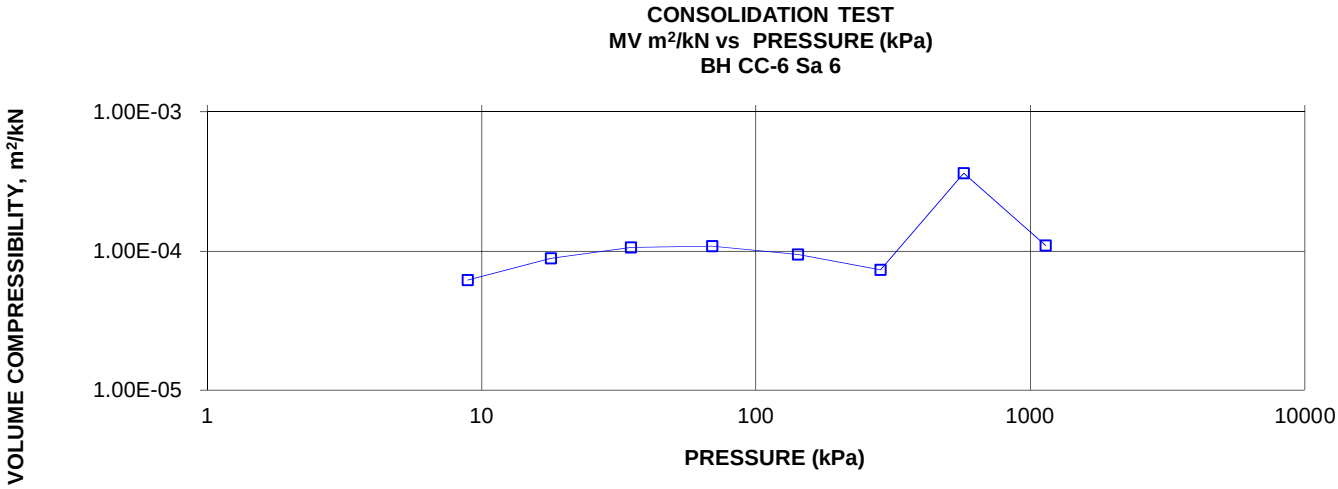
Pressure	Primary	Corr. Height	Void	Average Height	t_{90}	cv.	mv	k	Total Work
kPa	Consolidation	cm	Ratio	cm	sec	cm^2/s	m^2/kN	cm/s	kJ/m3
0	0	2.526	1.634	2.526					
9	0.01	2.525	1.632	2.525	29	0.0466	6.21E-05	2.84E-07	0.002
18	0.02	2.523	1.630	2.524	38	0.0355	8.86E-05	3.08E-07	0.013
35	0.05	2.518	1.625	2.520	49	0.0277	1.06E-04	2.87E-07	0.061
69	0.09	2.509	1.615	2.513	60	0.0223	1.09E-04	2.38E-07	0.255
143	0.18	2.491	1.597	2.500	60	0.0221	9.48E-05	2.05E-07	0.998
285	0.26	2.465	1.570	2.478	86	0.0151	7.35E-05	1.19E-07	3.360
570	2.62	2.203	1.297	2.334	4860	0.0002	3.63E-04	8.45E-09	48.791
1140	1.57	2.046	1.133	2.124	3110	0.0003	1.09E-04	3.30E-09	109.849
570	-0.14	2.060	1.148	2.053					
143	-0.54	2.114	1.204	2.087					
35	-0.61	2.175	1.268	2.145					
9	-0.55	2.231	1.326	2.203					

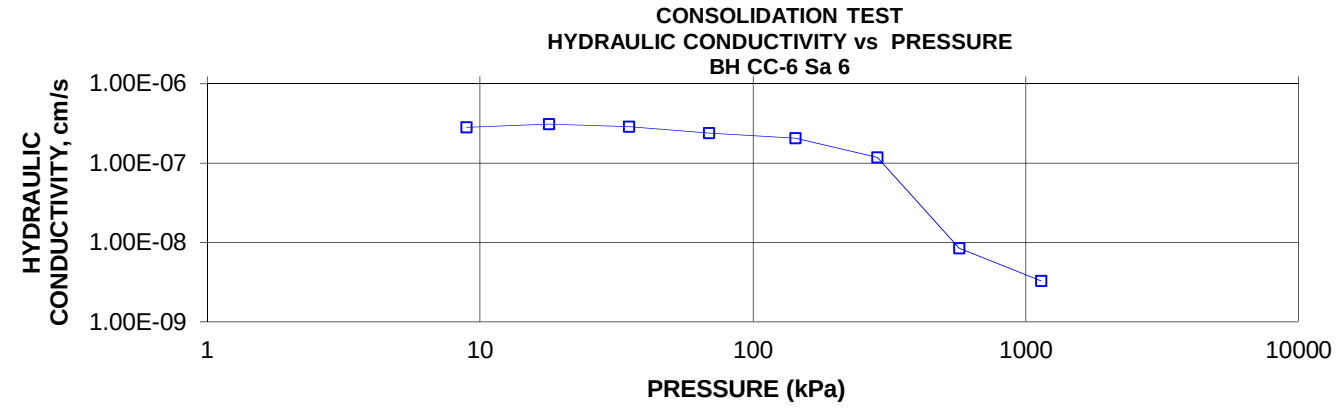
Note:
k calculated using α based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.231	Unit Weight, kN/m^3	16.93
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	11.39
Area, cm^2	31.68	Specific Gravity, Assumed	2.70
Volume, cm^3	70.66	Solids Height, cm	0.959
Water Content, %	48.72	Volume of Solids, cm^3	30.39
Wet Mass, g	122.01	Volume of Voids, cm^3	40.28
Dry Mass, g	82.04		







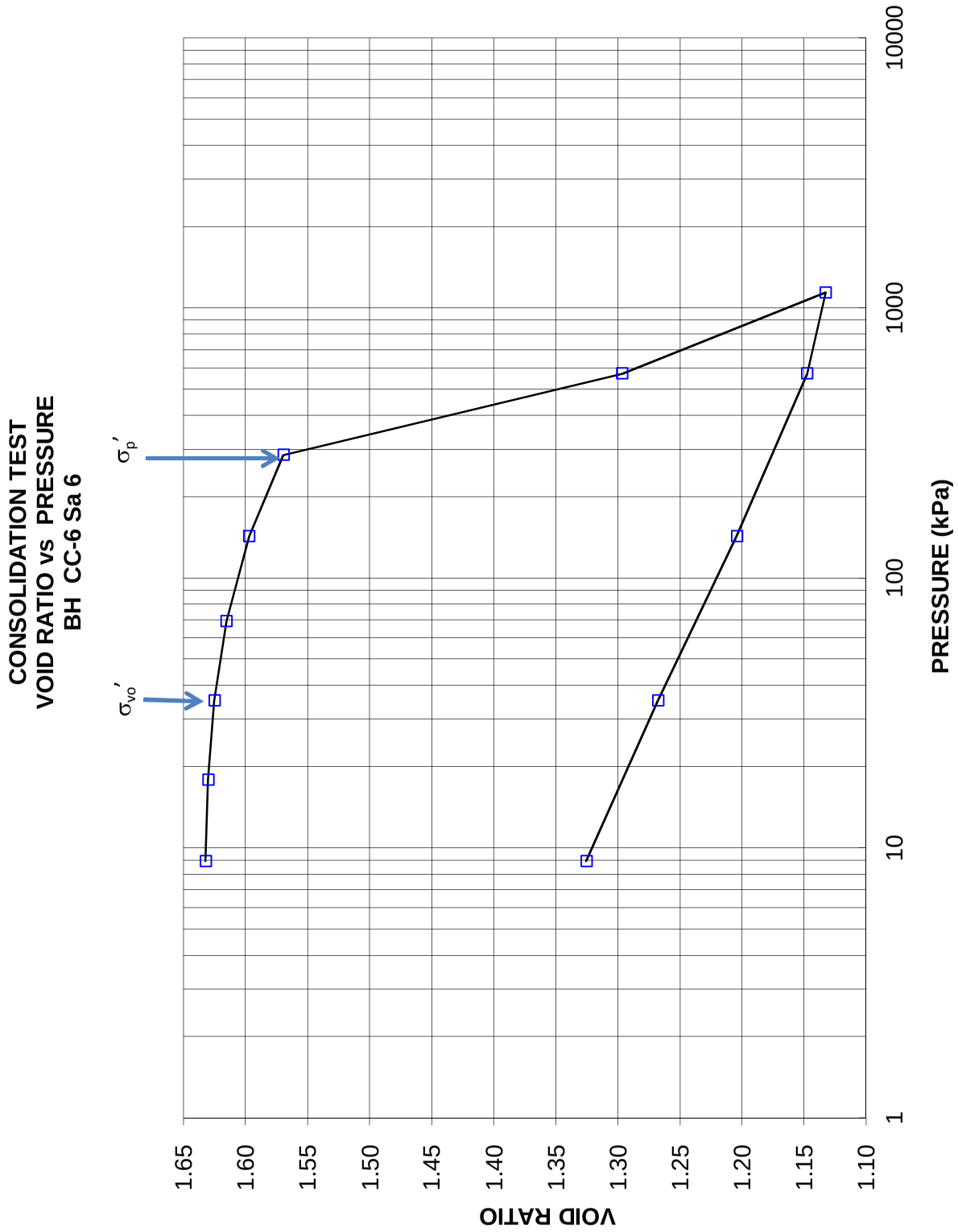
Project No. 11-1191-0010

Prepared By: SL

Golder Associates

Checked By: TG

CONSOLIDATION TEST VOID RATIO VS LOG PRESSURE	FIGURE B5 Pg. 3 of 4



Project No. 11-1191-0010

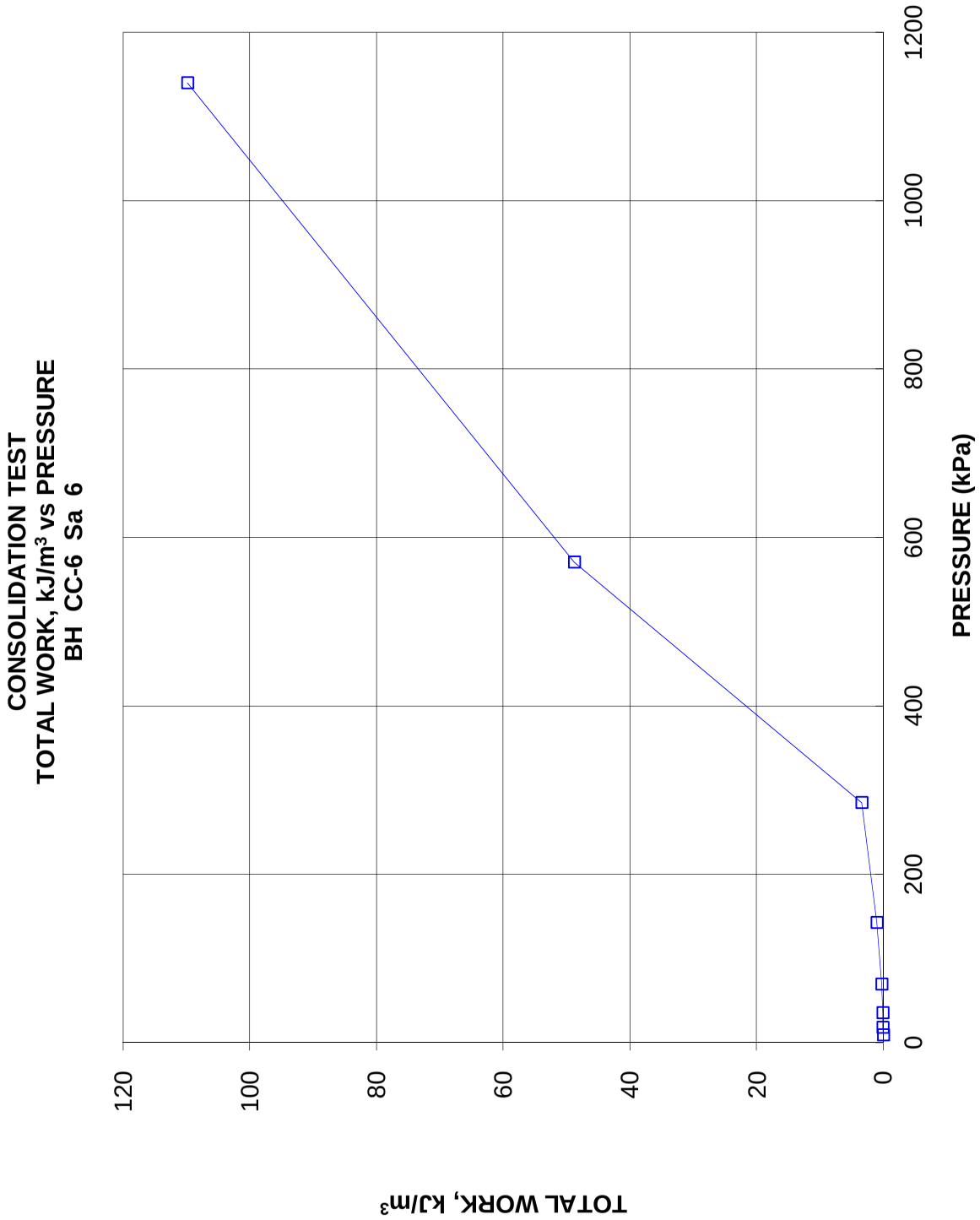
Prepared By: SL

Golder Associates

Checked By: TG

CONSOLIDATION TEST
TOTAL WORK VS PRESSURE

FIGURE B5
Pg. 4 of 4

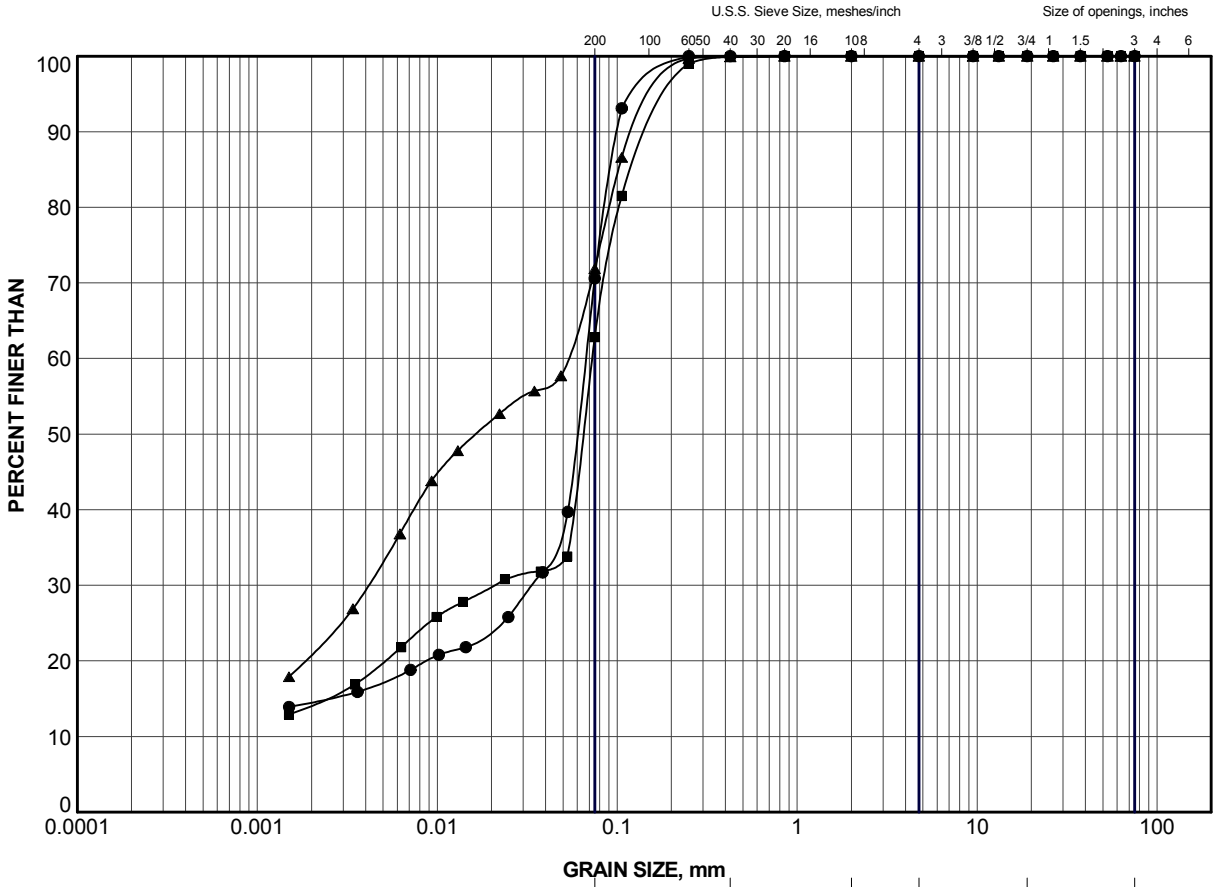


Project No: 11-1191-0010

Prepared By: SL

Golder Associates

Checked By: TG



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-2	17	185.0
■	CC-5	11	185.2
▲	CC-6	11	187.9

PROJECT

HIGHWAY 17
BIG CACHE CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

SANDY SILT TO SAND AND SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0010		FILE No.	11-1191-0010.GPJ
DRAWN	TB	Dec 2012	SCALE N/A	REV.
CHECK	AB	Dec 2012		
APPR		Dec 2012	**FIGURE B6**	

SUD-MTO GSD (NEW) 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.

For more information, visit golder.com

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