



November 27, 2014

FOUNDATION INVESTIGATION REPORT

**CENTRELINE CULVERT AT STA 11+600, CALDWELL TOWNSHIP
HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER
FROM HIGHWAY 539 EASTERLY TO 0.2 KM EAST
OF WEST JUNCTION OF HIGHWAY 64
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 300-98-00**

Submitted to:

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REPORT





Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	2
4.1 Regional Geology	2
4.2 Subsurface Conditions.....	2
4.2.1 Fill	3
4.2.2 Silt.....	3
4.2.3 Clayey Silt.....	4
4.2.4 Gravelly Silty Sand to Sand	4
4.2.5 Refusal.....	5
4.2.6 Groundwater Conditions	5
5.0 CLOSURE.....	5

DRAWINGS

Drawing 1 Borehole Locations and Soil Strata

APPENDICES

Appendix A Record of Boreholes

List of Symbols and Abbreviations

Record of Boreholes CE-1 to CE-4

Appendix B Laboratory Test Results

Table B1	Summary of Analytical Testing of Creek Water Sample
Figure B1	Grain Size Distribution – Silty Sand (fill) and Silty Clay (Fill)
Figure B2	Plasticity Chart – Silty Clay (Fill)
Figure B3	Grain Size Distribution – Silt
Figure B4	Grain Size Distribution – Clayey Silt
Figure B5	Plasticity Chart – Clayey Silt
Figure B6	Grain Size Distribution – Silt and Sand (Interlayer)
Figure B7	Grain Size Distribution – Silty Sand to Gravelly Sand
Figure B8	Grain Size Distribution – Silt to Clayey Silt (Interlayer)



PART A

**FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH), on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services for the rehabilitation of the Highway 17 Centreline Culvert at STA 11+600 in Caldwell Township in the Municipality of West Nipissing, Ontario. The Key Plan showing the general location of this section of Highway 17 and the location of the investigated area are shown on Drawing 1. The purpose of this investigation is to establish the subsurface conditions at the location of the culvert by borehole drilling, in situ testing and laboratory testing on selected soil samples.

2.0 SITE DESCRIPTION

The centreline culvert is located across Highway 17 east of the Town of Warren approximately 1.0 km west of the junction with Highway 575. In general, the topography in the area of the overall project limits consists of flat terrain primarily utilized as farmland. The existing highway grade is at about Elevation 217 m and the creek bed is about 8 m below the existing highway grade. The side slopes of the existing embankment are inclined at about 1.2 Horizontal to 1 Vertical (1.2H:1V) on the south side of the embankment and 1.6H: 1V on the north side of the embankment. The existing culvert is 35 m long, 2.3 m wide and 1.7 m high Corrugated Steel Pipe Arch (CSPA).

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between December 3 and 6, 2013 and between March 18 and 24, 2014, during which time a total of four boreholes (CE-1 to CE-4) were advanced at the approximate locations shown on Drawing 1.

Boreholes CE-1 and CE-2, 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, supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. Boreholes CE-3 and CE-4, located near the culvert ends, were advanced by wash boring methods with portable equipment using NQ casing provided by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec. A Dynamic Cone Penetration Test (DCPT) was advanced adjacent to Boreholes CE-1, CE-3 and CE-4.

Soil samples were obtained at intervals of depths of about 0.75 m and 1.5 m, using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer at Boreholes CE-1 and CE-2 and a manual hammer at Boreholes CE-3 and CE-4, and performed in accordance with Standard Penetration Test (SPT) procedure (ASTM D1586). A field vane shear test was conducted in the cohesive stratum in Borehole CE-2 to determine undrained shear strength (ASTM D2573, Standard Test Method for Field Vane Strength Shear Test) of this stratum 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. All boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Reg. 903 (as amended).



FOUNDATION REPORT HIGHWAY 17 CENTRELINE CULVERT AT 11+600

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

A sample of the creek water was obtained on March 21, 2014, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B, together with the detailed analytical laboratory test results.

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

Borehole	Borehole Location		Ground Surface Elevation (m)	Borehole/DCPT Depth Below Ground Surface (m)
	Northing	Easting		
CE-1	5142115.8	255218.8	216.8	17.0 / 15.2
CE-2	5142105.5	255233.6	216.7	12.8
CE-3	5142128.2	255231.4	210.0	3.9 / 3.7
CE-4	5142097.7	255209.4	209.5	8.2 / 11.4

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on NOEGTS¹ mapping, the topography in the vicinity of the centreline culvert is generally characterized as a glaciolacustrine plain comprised of mainly silty and sandy soils with undulating and rolling bedrock knobs within approximately 200 m north of the site.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions, as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil core samples, are given on the Record of Borehole sheets in Appendix A. The results of the in situ tests (i.e., SPT “N”-values and

¹ Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey Digital Map 41ISE.



FOUNDATION REPORT HIGHWAY 17 CENTRELINE CULVERT AT 11+600

undrained shear strength from the field vane) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. Detailed results of the laboratory testing of the soil samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile and cross-section shown on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

4.2.1 Fill

Boreholes CE-1 and CE-2 penetrated a layer of asphalt 250 mm thick at Elevation 216.8 m and 216.7 m, respectively, underlain by fill comprised of sand, some gravel transitioning to silty sand, some gravel in Borehole CE-1 and silty clay to silt in Borehole CE-2. The thickness of the overall fill deposit is about 8.7 m and 3.7 m at the respective boreholes. From ground surface in Boreholes CE-3 and CE-4, an approximately 0.8 m thick deposit of fill consisting of sand, some silt, trace gravel, trace organic was encountered.

The SPT 'N'-values measured within the fill range between 2 blows and 45 blows per 0.3 m of penetration indicating a very loose to dense relative density. The SPT 'N'-values measured within the silty clay to silt portion of the fill range from 9 blows to 18 blows per 0.3 m of penetration suggesting a stiff to very stiff consistency.

Grain size analyses were carried out on three samples of the fill deposit (two of the silty sand portion and one of the silty clay portion) and the results are represented on Figure B1 in Appendix B.

An Atterberg limits test carried out on a sample of the cohesive fill measured a liquid limit of about 36 per cent, a plastic limit of about 21 per cent and a plasticity index of about 14 per cent. The result, which is plotted on a plasticity chart on Figure B2 in Appendix B, indicates that the tested sample consist of silty clay of intermediate plasticity.

The natural moisture content measured on selected samples of the sand to silty sand portion of the fill range from about 3 per cent to 30 per cent. The natural moisture content measured on two samples of the silty clay to silt fill are about 20 per cent to 23 per cent.

4.2.2 Silt

Underlying the fill in Borehole CE-2, a 1.9 m thick deposit of silt, trace to some clay was encountered at Elevation 213.0 m.

The SPT 'N'-values measured within this deposit are 13 blows and 15 blows per 0.3 m of penetration, indicating a compact relative density.

A grain size analyses was carried out on a sample of this deposit and the result is represented on Figure B3 in Appendix B.

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

The natural moisture content measured on selected samples of the silt are about 22 per cent and 23 per cent.



4.2.3 Clayey Silt

A deposit of clayey silt was encountered below the silt in Borehole CE-2 at a depth of 5.6 m (Elevation 211.1 m) and below the fill in Borehole CE-4 at a depth of 0.8 m (Elevation 208.7 m), with a thickness of 4.8 m and 3.7 m, respectively. A 0.1 m thick organic layer was noted in Borehole CE-4 at a depth of 2.0 m (Elevation 207.5 m). Sand and/or silt laminations/layers were generally observed in the lower portion of the deposit.

The SPT 'N'-values measured within the clayey silt deposit range between 4 blows (weight of hammer) and 8 blows per 0.3 m of penetration and two 'N'-values in the sand and/or silt laminations/layers are 22 blows and 33 blows per 0.3 m of penetration. One in situ field vane test measured an undrained shear strength of about 72 kPa, with a sensitivity of 2. The in situ vane test result indicates that the deposit generally has a stiff consistency.

Grain size analyses were carried out on two samples of this deposit and the results are represented on Figure B4 in Appendix B.

Atterberg limits testing were carried out on four samples of the cohesive deposit and measured liquid limits ranging from about 27 per cent to 33 per cent, plastic limits ranging from about 16 per cent to 20 per cent, and plasticity indices ranging from about 11 per cent to 16 per cent. The results, which are plotted on a plasticity chart on Figure B5 in Appendix B, indicate that the tested samples of the overall deposit consist of clayey silt of low plasticity.

A grain size analysis was carried out on a sample of the silt and sand lamination/layer in Borehole CE-2 and the result is presented on Figure B6 in Appendix B.

The natural moisture content measured on selected samples of the clayey silt deposit ranges between about 26 per cent and 48 per cent; whereas, the natural moisture content measured on the sample of the sand and/or silt interlayer is about 26 per cent.

4.2.4 Gravelly Silty Sand to Sand

A deposit of sand or gravelly silty sand was encountered below the fill in Boreholes CE-1 and CE-3 and a deposit of silty sand to sand was encountered beneath the clayey silt in Boreholes CE-2 and CE-4. The surface of the deposit was encountered between Elevations 209.2 m and 205.0 m. The deposit was explored for a depth of about 2.4 m in Borehole CE-2 and the thickness of the deposit in Boreholes CE-1, CE-3 and CE-4 is between about 3.1 m and 8.3 m as inferred from split-spoon, auger, casing and/or DCPT refusal. A silt to clayey silt layer was encountered in Borehole CE-1 at a depth of 15.5 m below ground surface (Elevation 201.3 m). Heaving of sands into the casing occurred in Boreholes CE-1 and CE-2 as the boreholes were advanced below a depth of 10.7 m.

The SPT 'N'-values measured within this deposit range between 4 blows and 40 blows per 0.3 m of penetration, indicating a loose to dense relative density, however the majority of the 'N'-values are in the compact range. Two SPT 'N' values near/at the bottom of Borehole CE-1 are 79 blows per 0.2 m of penetration indicating a very dense relative density and 97 blows per 0.5 m of penetration on inferred refusal.



FOUNDATION REPORT HIGHWAY 17 CENTRELINE CULVERT AT 11+600

Grain size analyses were carried out on four samples of this deposit and the results are represented on Figure B7 in Appendix B. A grain size analysis was carried out on a sample of the silt to clayey silt layer in Borehole CE-1 and the result is presented on Figure B8 in Appendix B.

The natural moisture content measured on selected samples of this deposit ranges between about 11 per cent and 23 per cent. The natural moisture content measured on the layer of silt to clayey silt in Borehole CE-2 is about 17 per cent.

4.2.5 Refusal

Refusal to further split-spoon, casing and/or auger advancement was encountered in the following boreholes and corresponding DCPTs.

Borehole	Borehole Refusal Depth/Elevation (m)	DCPT Refusal Depth/Elevation (m)
CE-1	17.0/199.8	15.2/201.6
CE-3	3.9/206.1	3.7/206.3
CE-4	8.2/201.3	11.4/198.1

4.2.6 Groundwater Conditions

The unstabilized water levels in Boreholes CE-1 to CE-4 upon completion of drilling range between ground surface to 7.8 m below ground surface, between Elevations 210.1 m and 209.0 m. The creek water level surface was surveyed by MH at Elevation 209.4 m in December 2013.

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

5.0 CLOSURE

The drilling program was supervised by Mr. Mat Riopelle and Mr. Shane Albert. This report was prepared by Mr. Adam Core, E.I.T. and reviewed by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report



FOUNDATION REPORT HIGHWAY 17 CENTRELINE CULVERT AT 11+600

Report Signature Page

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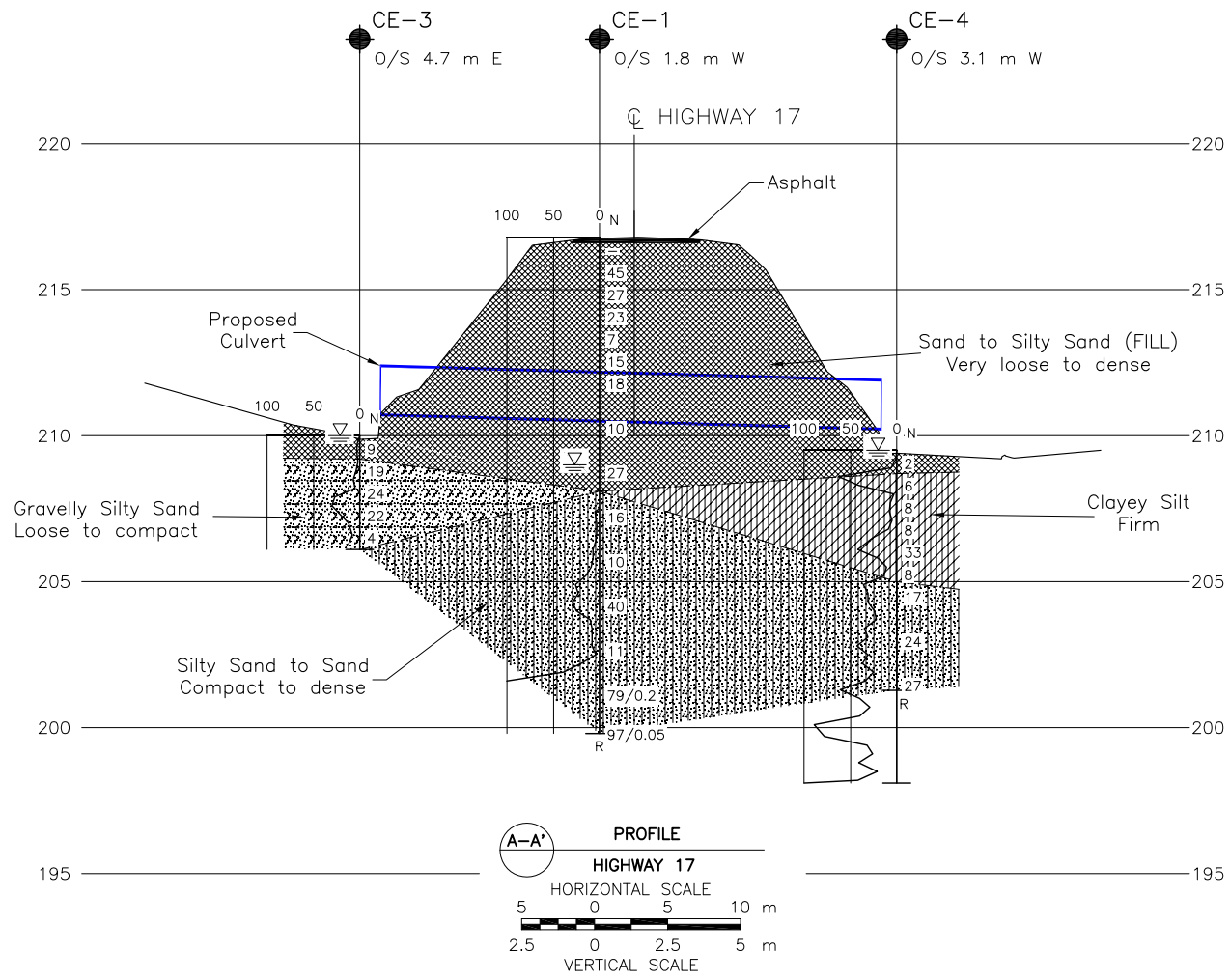
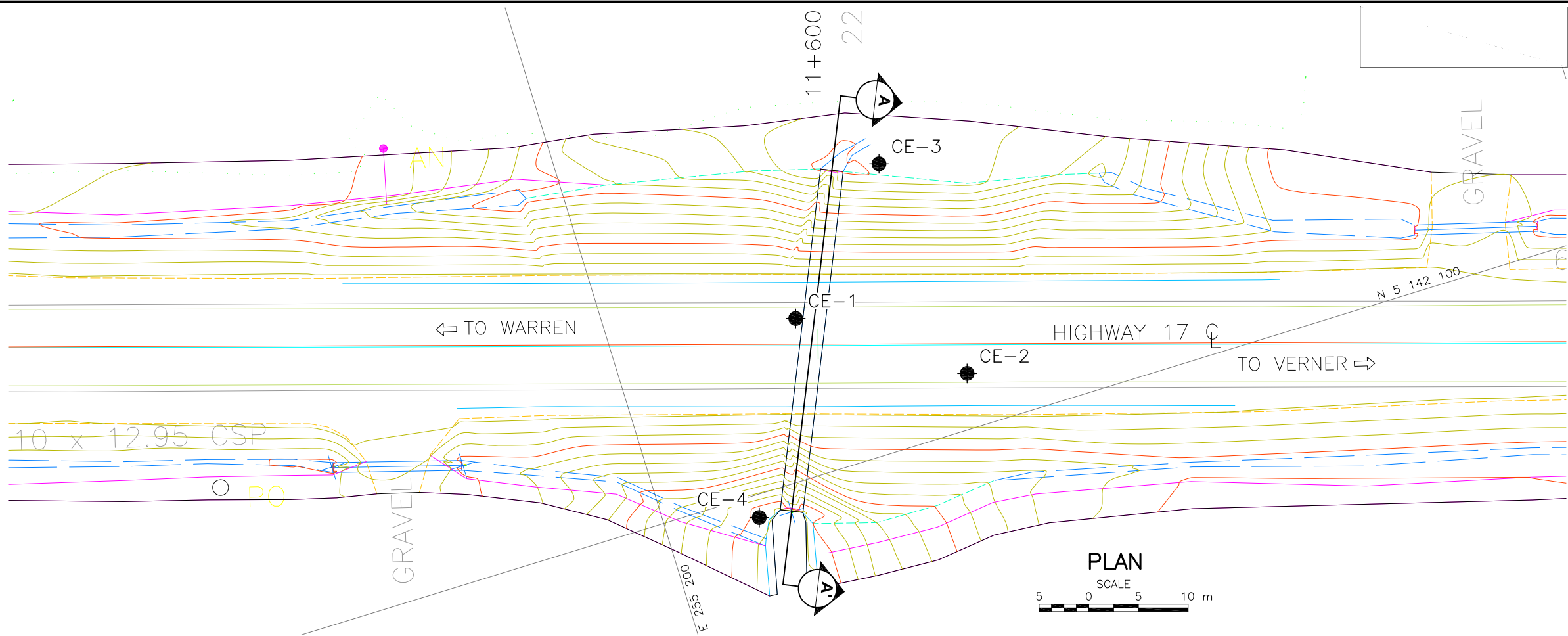


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CONT No.
GWP No. 300-98-00

HIGHWAY 17
CENTRELINE CULVERT - STA 11+600
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



LEGEND

Borehole - Current Investigation

N Standard Penetration Test Value

16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)

R Refusal

WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
CE-1	216.8	5142115.8	255218.8
CE-2	216.7	5142105.5	255233.6
CE-3	210.0	5142128.2	255231.4
CE-4	209.5	5142097.7	255209.4

NOTES

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

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

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

REFERENCE

Base plans provided in digital format by Morrison Hershfield, drawing file no. 43-165C-01.dwg, received on APR 7, 2014. Proposed grade profile drawing file no. Biquette Creek Culvert and 11+600 culvert.dwg, received on NOV 05, 2014.

NO.	DATE	BY	REVISION
Geocres No. 411-320			
HWY. 17	PROJECT No. 13-1184-0074		DIST.
SUBM'D. MT	CHKD.	DATE: NOV 2014	SITE:
DRAWN: TB	CHKD. AB	APPD. JMAC	DWG. 1



**FOUNDATION REPORT
HIGHWAY 17 CENTRELINE CULVERT AT 11+600**

APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS


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

PROJECT 13-1184-0074			RECORD OF BOREHOLE No CE-1			1 OF 2 METRIC						
G.W.P. 300-98-00			LOCATION N 5142115.8; E 255218.8			ORIGINATED BY SA						
DIST _____ HWY 17			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers			COMPILED BY MT						
DATUM GEODETIC			DATE December 3 and 5, 2013			CHECKED BY DAM						
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	"N" VALUES					
216.8	GROUND SURFACE											
0.0	ASPHALT (250 mm)											
0.2	Sand, some gravel, trace to some silt (FILL) Compact to dense Brown Moist		1	AS	-							
			2	SS	45	216						
			3	SS	27	215						
			4	SS	23	214						
213.8	Silty sand, some gravel, some clay (FILL) Loose to compact Brown Moist		5	SS	7	213						16 43 29 12
3.0			6	SS	15	212						
			7	SS	18	211						
			8	SS	10	210						25 41 25 9
			9	SS	27	209						
208.1	SAND, trace to some gravel, trace to some silt, trace clay Compact to dense Brown Wet		10	SS	16	208						
8.7			11	SS	10	207						
	Heaving of sand into casing below 10.7 m depth.		12	SS	40	206						8 82 8 2
			13	SS	11	205						
						204						
						203						10 78 (12)
						202						

Continued Next Page

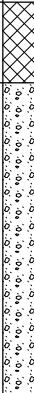
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 29/10/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>				RECORD OF BOREHOLE No CE-1				2 OF 2 METRIC									
G.W.P. <u>300-98-00</u>				LOCATION <u>N 5142115.8; E 255218.8</u>				ORIGINATED BY <u>SA</u>									
DIST <u> </u> HWY <u>17</u>				BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>				COMPILED BY <u>MT</u>									
DATUM <u>GEODETIC</u>				DATE <u>December 3 and 5, 2013</u>				CHECKED BY <u>DAM</u>									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)				
								20	40	60	80	100	20	40	60		
199.8	SAND, trace to some gravel, trace to some silt, trace clay Compact to dense Brown Wet SILT to clayey silt layer at 15.5 m depth.		14	SS	79/0.2		201										1 15 62 22
17.0	END OF BOREHOLE AUGER AND SPLIT-SPOON REFUSAL Note: 1. Water level at a depth of 7.8 m below ground surface (Elev. 209.0 m) upon completion of drilling. 2. DCPT advanced 1 m west of Borehole CE-1. Preaugered to 9.1 m depth and refusal at 15.2 m depth.		15	SS	97/0.05		200										

PROJECT		13-1184-0074		RECORD OF BOREHOLE		No CE-2		1 OF 1		METRIC				
G.W.P.		300-98-00		LOCATION		N 5142105.5; E 255233.6		ORIGINATED BY		SA				
DIST		HWY 17		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers		COMPILED BY		MT				
DATUM		GEODETIC		DATE		December 6, 2013		CHECKED BY		DAM				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
216.7	GROUND SURFACE													
0.0	ASPHALT (250 mm)													
0.2	Sand, some gravel, trace to some silt (FILL) Compact Brown Moist		1	AS	-									
215.6			2A	SS	10									
1.1	Silty clay to silt, trace sand (FILL) Stiff to very stiff Grey to brown Moist		2B											
			3	SS	12									
			4	SS	18									
			5	SS	9									
213.0														
3.7	SILT, trace to some clay, trace sand Compact Grey to brown Wet		6	SS	13									
			7	SS	15									
211.1														
5.6	CLAYEY SILT, trace sand Stiff Grey to brown Wet		8	SS	7									
	Approximately 0.6 m thick silt and sand layer encountered at 7.6 m depth.		9	SS	22									
			10	SS	4									
206.3														
10.4	Silty SAND, trace gravel, trace clay Compact Grey Wet		11	SS	10									
	Approximately 0.3 m of heave encountered at 10.7 m depth.													
			12	SS	21									
203.9														
12.8	END OF BOREHOLE													
	Note: 1. Water level at a depth of 6.6 m below ground surface (Elev. 210.1 m) upon completion of drilling.													

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 29/10/14 DATA INPUT:

PROJECT		13-1184-0074		RECORD OF BOREHOLE No CE-3		1 OF 1 METRIC								
G.W.P.		300-98-00		LOCATION		N 5142128.2; E 255231.4								
DIST		HWY 17		BOREHOLE TYPE		NW Casing, Wash Boring								
DATUM		GEODETIC		DATE		March 21 and 24, 2014								
ORIGINATED BY		MR		COMPILED BY		MT								
CHECKED BY		DAM												
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L				
210.0	GROUND SURFACE													
0.0	Sand, some silt, trace gravel, trace organics (FILL)		1	SS	9									
209.2	Loose Brown Wet													
0.8	Gravelly Silty SAND to Gravelly SAND, some silt, trace clay		2	SS	19									
	Loose to compact Grey Wet		3	SS	24									
			4	SS	22									
	Coarse gravel (up to 75 mm) recovered in casing barrel below 3.7 m depth.		5	SS	4									
206.1	END OF BOREHOLE REFUSAL TO FURTHER CASING ADVANCEMENT													
3.9	Notes: 1. Water level at ground surface (Elev. 210.0 m) upon completion of drilling. 2. DCPT advanced 0.5 m west of Borehole CE-1 and refusal at 3.7 m depth.													

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 29/10/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No CE-4			1 OF 1 METRIC													
G.W.P. 300-98-00			LOCATION N 5142097.7; E 255209.4			ORIGINATED BY MR													
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT													
DATUM GEODETIC			DATE March 18, 2014			CHECKED BY DAM													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa			WATER CONTENT (%)			γ					
209.5	GROUND SURFACE							20 40 60 80 100	○ UNCONFINED + FIELD VANE	20 40 60	W _p	W	W _L						
0.0	Sand, some silt, trace gravel, trace organics (FILL) Very loose Brown Wet		1	SS	2		209		● QUICK TRIAXIAL × REMOULDED										
208.7	CLAYEY SILT, trace sand Firm Grey Wet		2	SS	6		208												
0.8			3	SS	8		207												
	Approximately 0.1 m thick organic layer at 2.0 m depth.		4	SS	8		206												
	Approximately 0.7 m sand layer encountered at 3.0 m depth.		5	SS	33		205												
	Silt laminations in Sample 6.		6	SS	8		204												
205.0	Silty SAND to SAND, some gravel, trace clay Compact Grey Wet		7	SS	17		203												
4.5			8	SS	24		202												
			9	SS	27		201												
201.3	END OF BOREHOLE REFUSAL TO FURTHER CASING ADVANCEMENT						200												
8.2							199												
198.1	END OF DCPT DCPT REFUSAL																		
11.4	Notes: 1. Water level at ground surface (Elev. 209.5 m) upon completion of drilling. 2. DCPT advanced 0.8 m east of Borehole CE-4.																		

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 29/10/14 DATA INPUT:



APPENDIX B

Laboratory Test Results



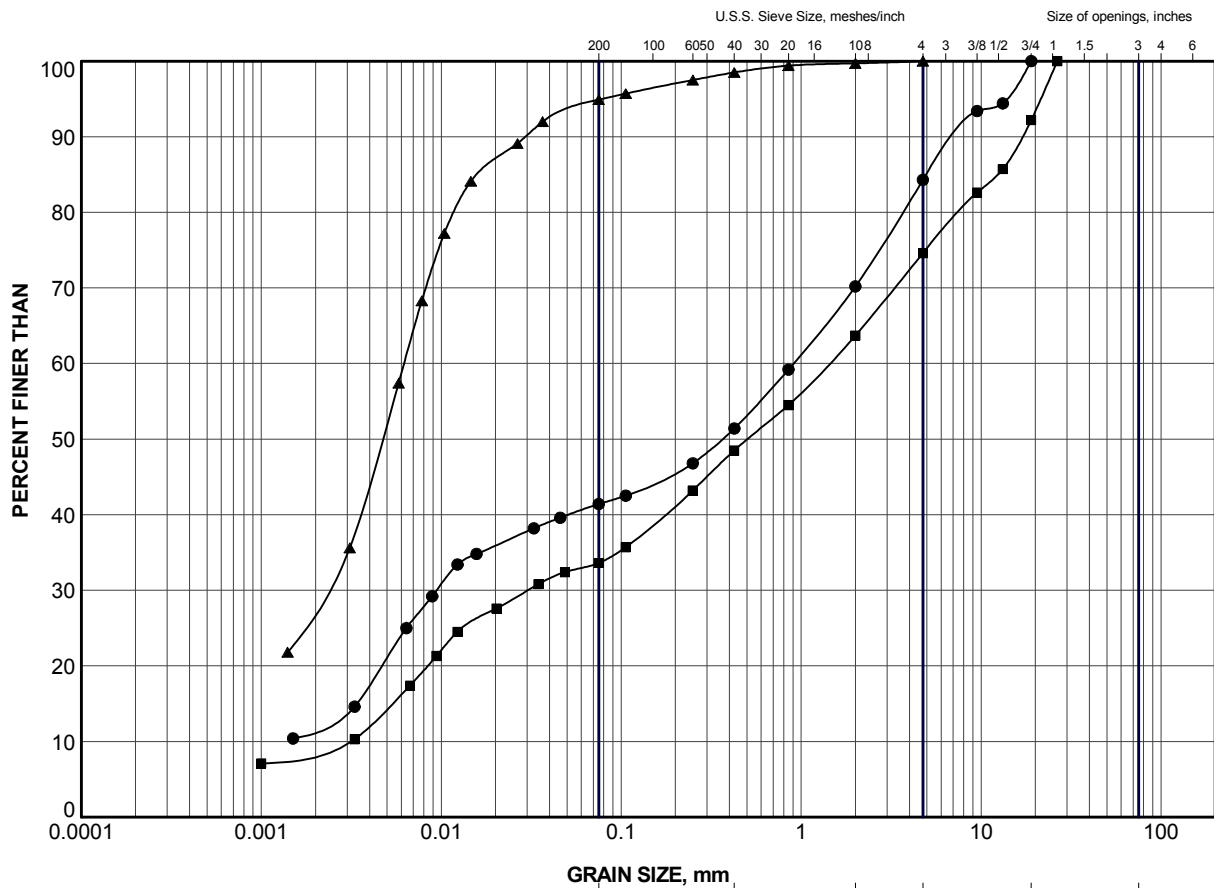
**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 CENTRELINE CULVERT AT 11+600**

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

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	48
Dissolved Sulphate	mg/L	1	2
Conductivity	µohm/cm	1	240
Resistivity	ohm-cm	n/a	4100
pH	n/a	n/a	6.98

Notes: 1. Sample obtained on March 21, 2014.
2. Analytical testing carried out by Maxxam Analytics.

Checked by: AB



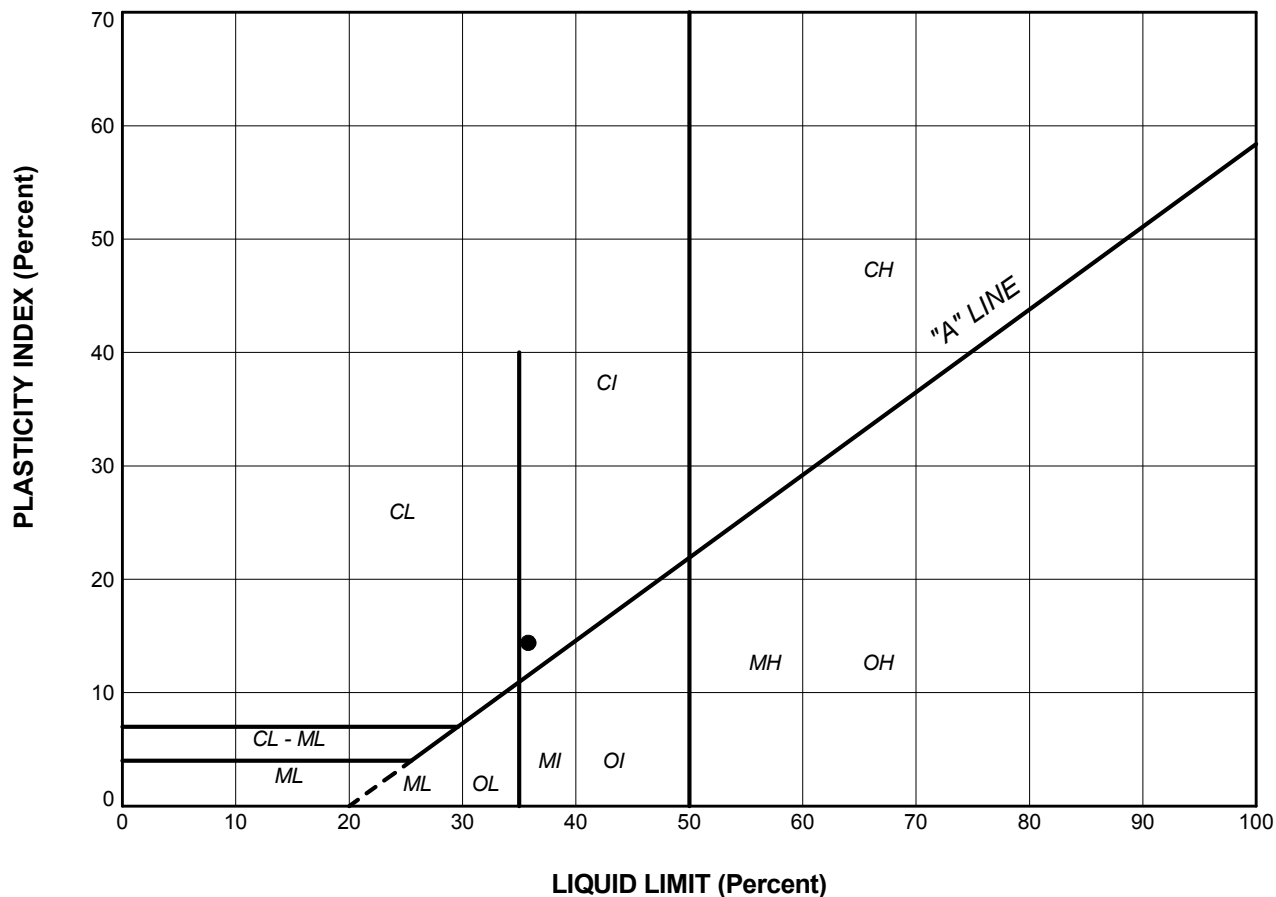
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-1	5	213.5
■	CE-1	8	210.4
▲	CE-2	3	214.9

PROJECT					
HIGHWAY 17 CENTRELINE CULVERT - STA 11+600					
TITLE					
GRAIN SIZE DISTRIBUTION SILTY SAND and SILTY CLAY (FILL)					
PROJECT No.		13-1184-0074		FILE No. 13-1184-0074.GPJ	
DRAWN	TB	Oct 2014	SCALE	N/A	REV.
CHECK	AB	Oct 2014			
APPR	JMAC	Oct 2014			
			FIGURE B1		





SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

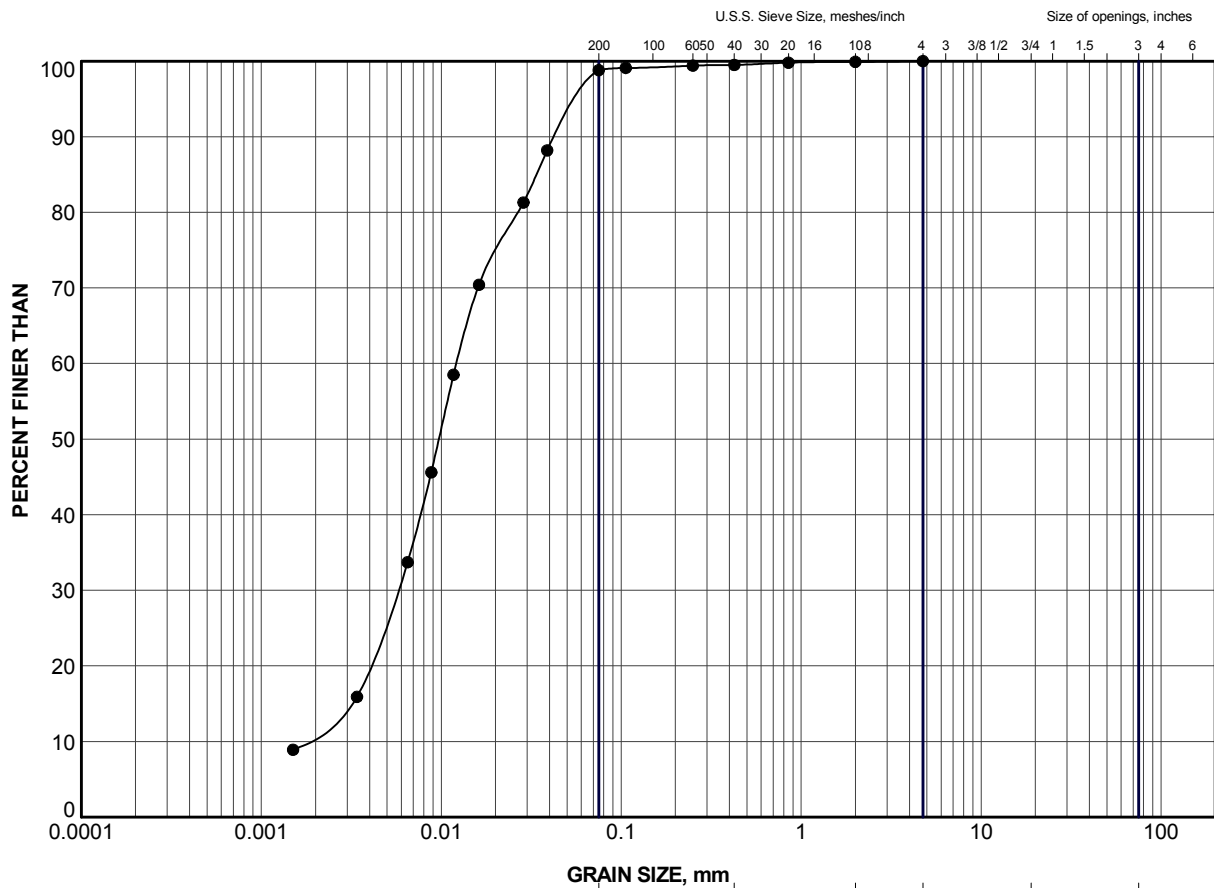
PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CE-2	3	35.8	21.4	14.4

PROJECT					
HIGHWAY 17 CENTRELINE CULVERT - STA 11+600					
TITLE					
PLASTICITY CHART SILTY CLAY (FILL)					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		Sep 2014	
CHECK		AB		Sep 2014	
APPR				Sep 2014	
SCALE		N/A		REV.	
FIGURE B2					





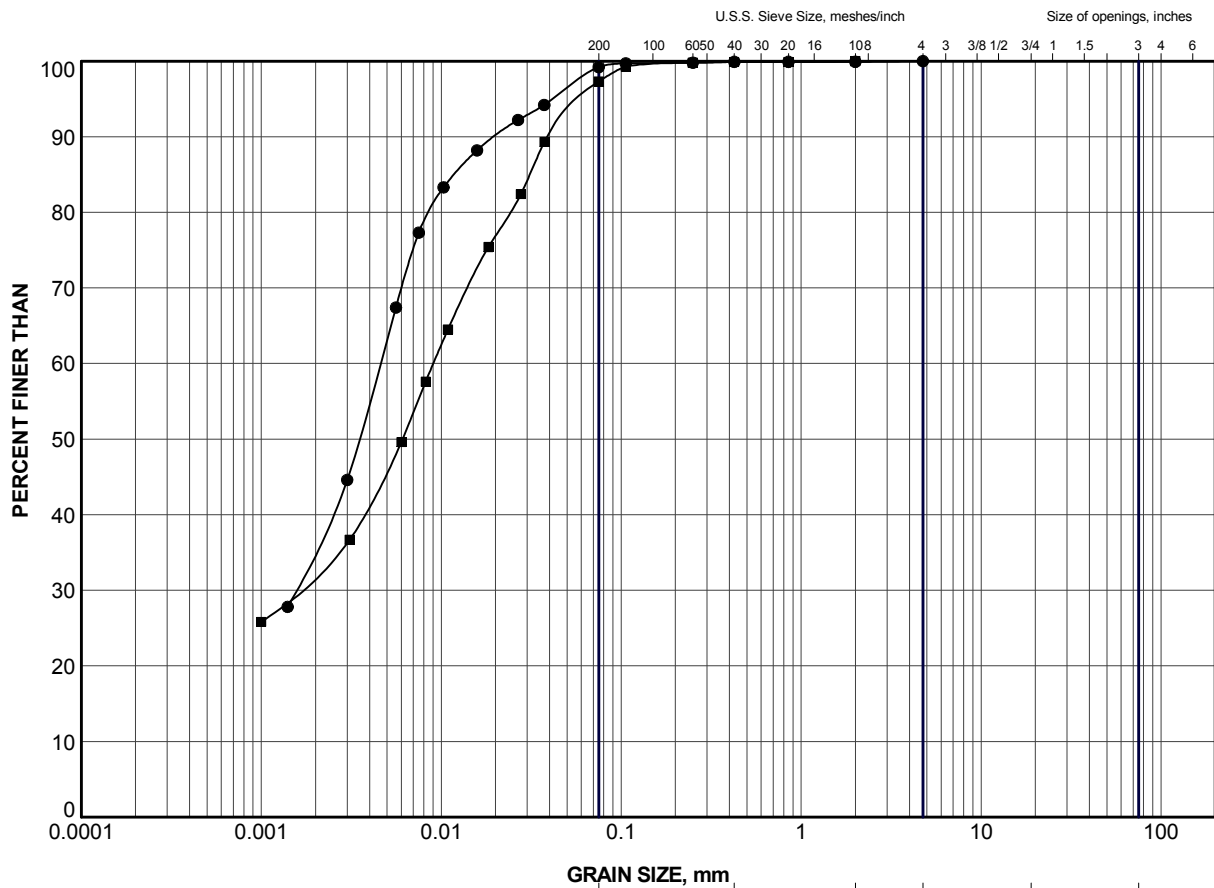
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-2	6	212.6

PROJECT						HIGHWAY 17 CENTRELINE CULVERT - STA 11+600					
TITLE						GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.			13-1184-0074			FILE No.			13-1184-0074.GPJ		
DRAWN	TB	Oct 2014	SCALE	N/A	REV.						
CHECK	AB	Oct 2014									
APPR	JMAC	Oct 2014									
									FIGURE B3		





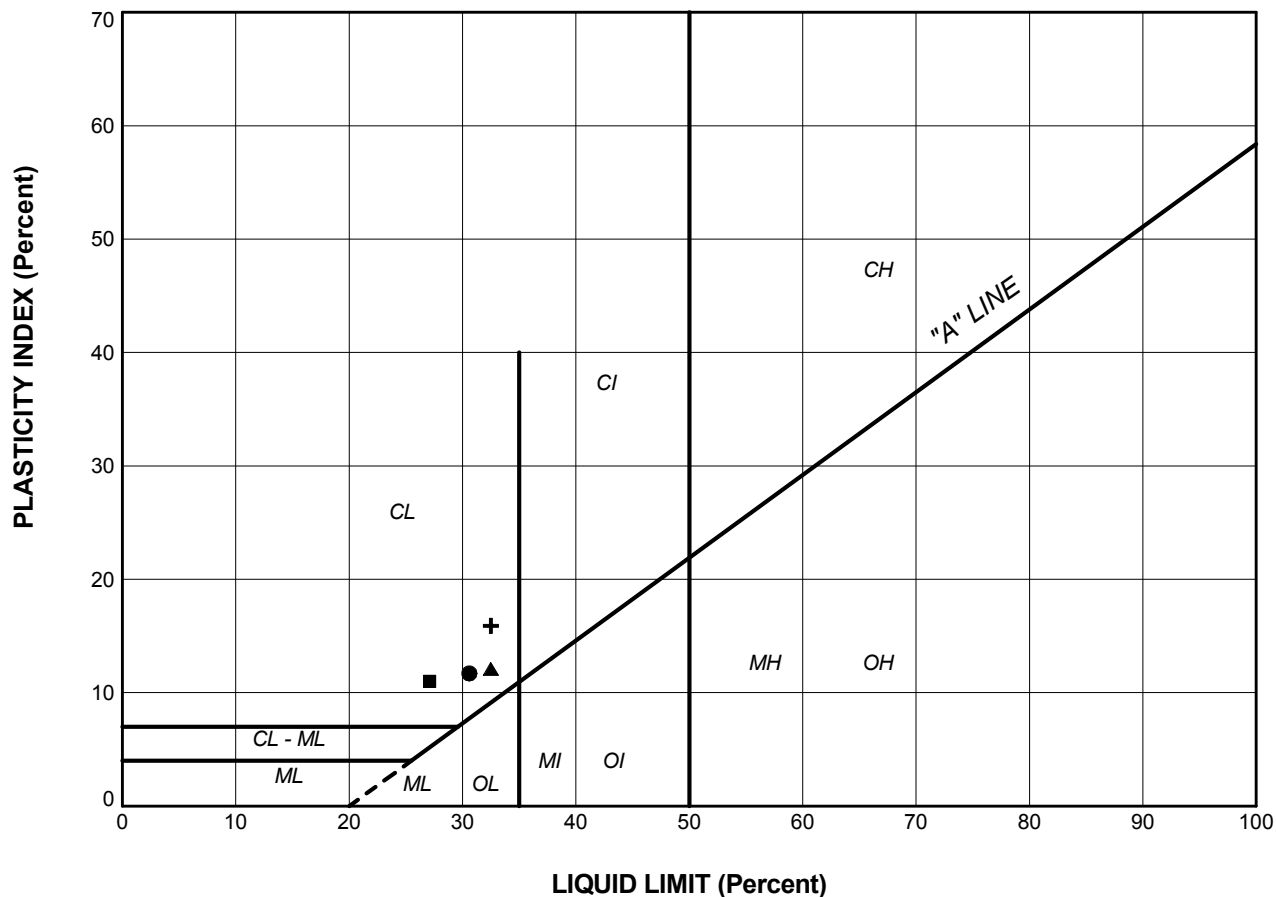
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		


LEGEND

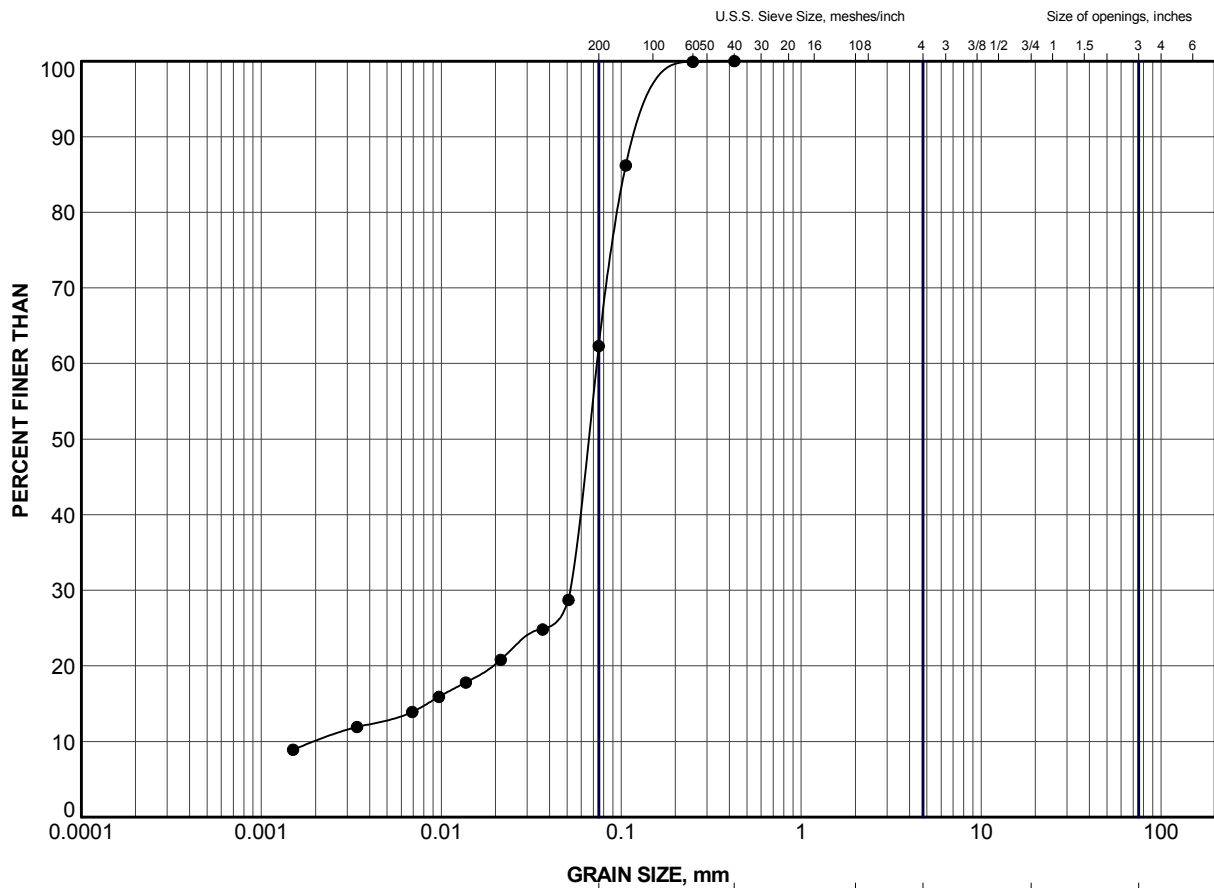
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-2	8	210.3
■	CE-2	10	207.3

PROJECT						HIGHWAY 17 CENTRELINE CULVERT - STA 11+600					
TITLE						GRAIN SIZE DISTRIBUTION CLAYEY SILT					
PROJECT No.			13-1184-0074			FILE No.			13-1184-0074.GPJ		
DRAWN	TB	Oct 2014	SCALE	N/A	REV.						
CHECK	AB	Oct 2014									
APPR	JMAC	Oct 2014									
						FIGURE B4					





PROJECT				
HIGHWAY 17 CENTRELINE CULVERT - STA 11+600				
TITLE				
PLASTICITY CHART CLAYEY SILT				
PROJECT No.		13-1184-0074		FILE No.
DRAWN		TB	May 2014	SCALE
CHECK		DAM	May 2014	N/A
APPR			May 2014	REV.
 Golder Associates SUDBURY, ONTARIO		FIGURE B5		



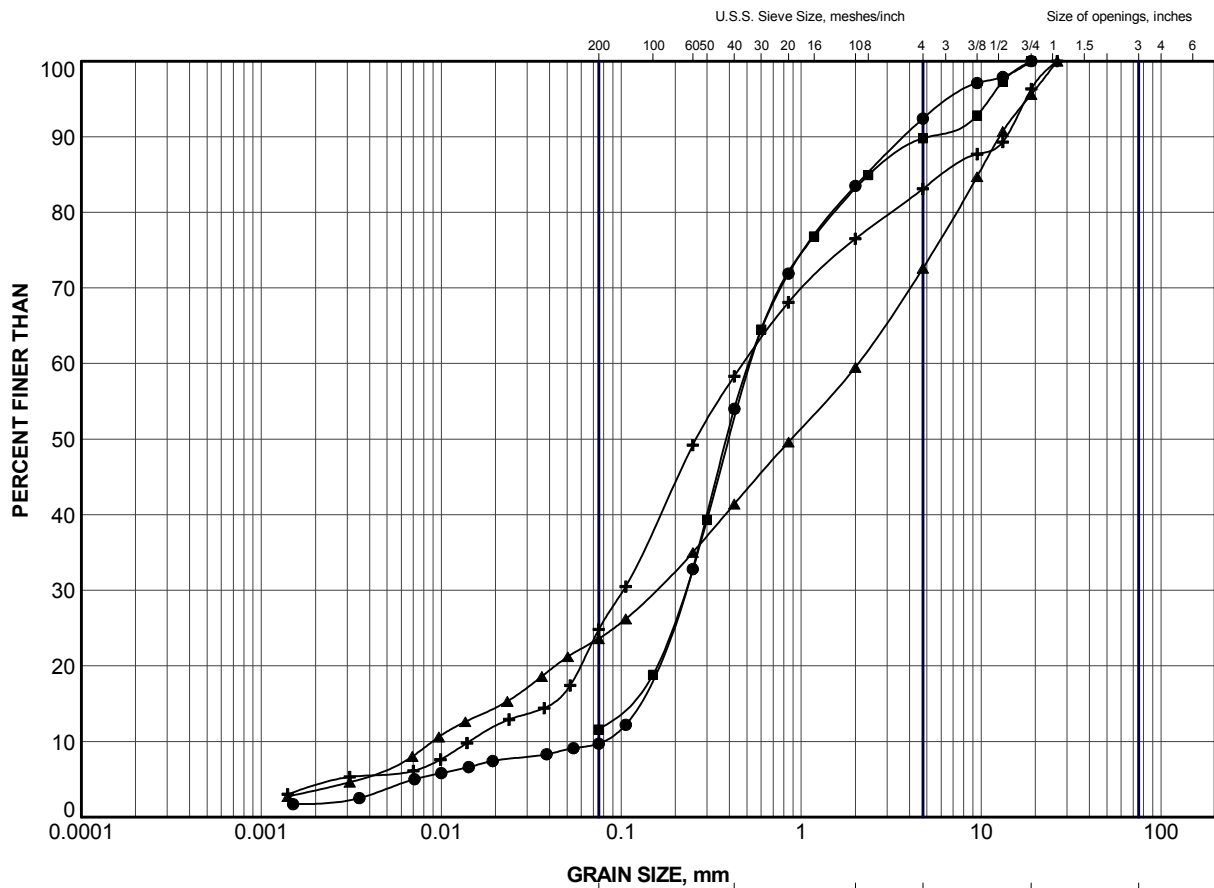
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-2	9	208.8

PROJECT						HIGHWAY 17 CENTRELINE CULVERT - STA 11+600					
TITLE						GRAIN SIZE DISTRIBUTION SILT and SAND (INTERLAYER)					
PROJECT No.			13-1184-0074			FILE No.			13-1184-0074.GPJ		
DRAWN	TB	Oct 2014	SCALE	N/A	REV.						
CHECK	AB	Oct 2014									
APPR	JMAC	Oct 2014									
									FIGURE B6		





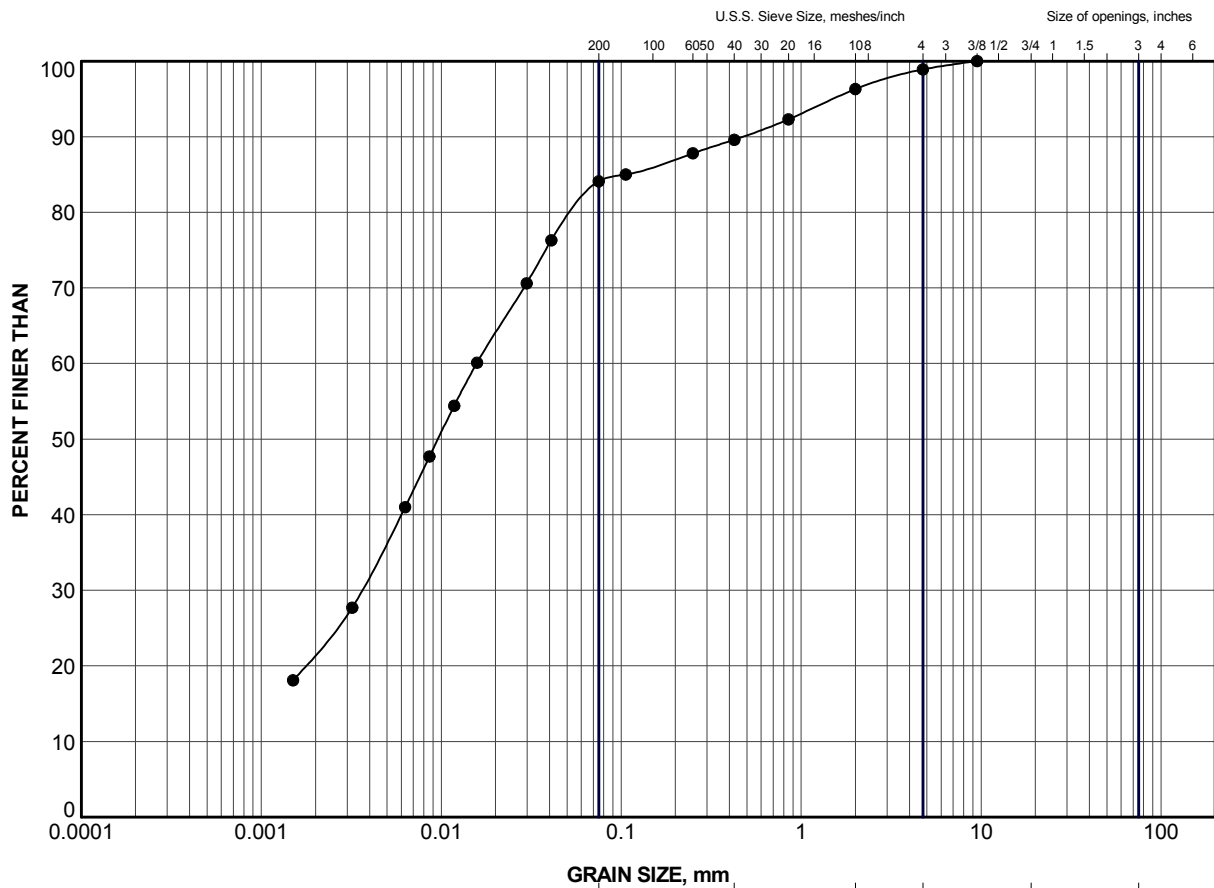
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-1	11	205.8
■	CE-1	13	202.8
▲	CE-3	3	208.2
+	CE-4	8	203.1

PROJECT					
HIGHWAY 17 CENTRELINE CULVERT - STA 11+600					
TITLE					
GRAIN SIZE DISTRIBUTION SILTY SAND to GRAVELLY SAND					
PROJECT No.		13-1184-0074		FILE No. 13-1184-0074.GPJ	
DRAWN	TB	Oct 2014	SCALE	N/A	REV.
CHECK	AB	Oct 2014			
APPR	JMAC	Oct 2014			
			FIGURE B7		





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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-1	14	201.3

PROJECT						HIGHWAY 17 CENTRELINE CULVERT - STA 11+600					
TITLE						GRAIN SIZE DISTRIBUTION SILT to CLAYEY SILT (INTERLAYER)					
PROJECT No.			13-1184-0074			FILE No.			13-1184-0074.GPJ		
DRAWN	TB	Oct 2014	SCALE	N/A	REV.						
CHECK	AB	Oct 2014									
APPR	JMAC	Oct 2014									
			FIGURE B8								



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

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