



FOUNDATION INVESTIGATION REPORT

Culvert Extension for Highway 69 Station 22+350
Township of Dill
Ministry of Transportation, Ontario
GWP 5219-14-00

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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.....	3
4.1 Regional Geology.....	3
4.2 Subsurface Conditions	3
4.2.1 Asphalt/Fill.....	3
4.2.2 Ice/Water.....	4
4.2.3 Peat.....	4
4.2.4 Gravel.....	4
4.2.5 Silt	4
4.2.6 Clayey Silt	5
4.2.7 Lower Silt	5
4.2.8 Bedrock/Refusal.....	5
4.3 Groundwater Conditions	6
4.4 Analytical Laboratory Testing Results.....	6
5.0 CLOSURE	7

DRAWINGS

Drawing 1 Borehole Locations and Soil Strata

PHOTOGRAPHS

Photographs 1 and 2

APPENDICES

APPENDIX A Record of Boreholes

Lists of Symbols and Abbreviations

Record of Boreholes RL-1 to RL-3

Record of Drillhole RL-3

APPENDIX B	Laboratory Test Results
Figure B-1	Grain Size Distribution - Clayey Gravel (FILL)
Figure B-2	Plasticity Chart – Clayey Gravel (FILL)
Figure B-3	Grain Size Distribution – Sand (FILL)
Figure B-4	Grain Size Distribution – Silt
Figure B-5	Plasticity Chart – Silt
Figure B-6	Grain Size Distribution – Clayey Silt
Figure B-7	Plasticity Chart - Clayey Silt
Maxxam Analytical Laboratory Test Report	

PART A

FOUNDATION INVESTIGATION REPORT
CULVERT EXTENSION AT HIGHWAY 69 STA 22+350
TOWNSHIP OF DILL
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5219-14-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by D.M. Wills Associates Ltd. (D.M. Wills) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services related to the extension of the existing culvert at Station 22+350 on Highway 69 in the Township of Dill, Ontario. The culvert is located approximately 300 m east of Richard Lake Drive. The Key Plan of the general location of this section of Highway 69 and the location of the investigated area are shown on Drawing 1.

The purpose of this exploration is to establish the subsurface conditions at the culvert site by borehole drilling, with laboratory testing carried out on selected soil samples.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated August 2017, and the subsequent clarifications/addenda and change order No. 001, which forms part of the Consultant's Assignment Number 5017-E-0029 for this project. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project dated April 2018.

2.0 SITE DESCRIPTION

Based on the preliminary GA drawing provided by D.M. Wills, the existing culvert consists of an 800 mm diameter, 48 m long Corrugated Steel Pipe (CSP). The culvert inlet (south end) and outlet (north end) inverts are approximately Elevations 233.9 m and 233.7 m, respectively. In general, the site conditions near the culvert ends consist of a swampy ravine directly at the culvert and to the west and bedrock outcrops to the east. At the location of the culvert along the highway centreline, the highway grade is at approximately Elevation 241.6 m and the embankment is approximately 7.7 m high relative to the invert of the culvert inlet. The embankment side-slopes appear to be constructed predominantly of blasted rock fill which appear to be performing adequately; however, both ends of the culvert could not be located and appeared to be buried by the embankment fill. Surficial erosion of the granular soils adjacent to the paved shoulder in the upper portion of the embankment slope was observed. The site conditions at select locations in the area of the culvert are shown on Photographs 1 and 2.

3.0 INVESTIGATION PROCEDURES

Field work for the subsurface exploration was carried out on March 11, 12, 18, and 19, 2019, during which time three boreholes (Boreholes RL-1 to RL-3) were advanced at approximately the locations shown on Drawing 1. Borehole RL-3 was advanced through the highway embankment using a track mounted CME 850 drilling rig supplied and operated by Landcore Drilling (Landcore) of Chelmsford, Ontario. Boreholes RL-1 and RL-2 were advanced near the toe of the highway embankment slope adjacent to the culvert inlet using portable tripod equipment supplied and operated by Landcore. A total of four (4) Dynamic Cone Penetration Tests (DCPTs) were advanced in the vicinity of the culvert inlet due to the shallow refusal encountered within the two boreholes advanced with portable tripod equipment. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes RL-1 and RL-2 were advanced using NW casing with wash boring techniques and Borehole RL-3 was advanced through the roadway using 76 mm I.D. Hollow Stem Augers and NW casing with wash boring techniques. The coring in Borehole RL-3 was advanced using an NQ-size core barrel. Soil samples were

generally obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic or manual (i.e., cathead) hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The portable tripod used a standard weight (63.6 kg) hammer. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strength (ASTM D2573) using an MTO Standard “N” size vane. The groundwater level inside the augers/casing was observed during and upon completion of drilling operations. The boreholes were backfilled in accordance with Ontario Regulation 903. The roadway surface at the borehole drilled through the highway was capped at ground surface using cold patch asphalt.

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

The as-drilled borehole locations were measured relative to highway chainages/station marked on the pavement by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevations at the borehole locations were surveyed by Golder relative to the highway/culvert centreline. D.M. Wills provided the site survey with highway centerline elevation (referenced to Geodetic datum) on February 27, 2019. The MTM NAD 83-CSRS CBN v6-2010.0 northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

Borehole Number	MTM NAD 83 Northing (m) [Latitude]	MTM NAD 83 Easting (m) [Longitude]	Ground Surface Elevation (m)	Borehole Depth (m)
RL-1	5143569.0 46.431781	311521.2 -80.912546	235.9	2.5
RL-2	5143566.5 46.431758	311521.7 -80.912540	235.9	2.1
RL-3	5143584.6 46.431921	311519.9 -80.912563	241.5	20.2

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS) ¹ mapping, the culvert site is reportedly located within a glaciolacustrine plain, and the soils in the area primarily consist of silt and sand.

Based on geological mapping (MNDM) ², the site is reportedly underlain by Quartz-felspar sandstone, argillite and conglomerate.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N' values and Field Vanes) as presented on the Record of Borehole sheets and discussed in Section 4.2 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change.

The subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented on the Record of Borehole sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

The depth to effective refusal of four dynamic cone penetration tests advanced in close proximity to Boreholes RL-1 and RL-2 are included in the notes on Record of Borehole RL-1 in Appendix A.

A description of the major soil strata and bedrock encountered during the exploration at the site are described below.

4.2.1 Asphalt/Fill

An approximately 350 mm thick layer of asphalt pavement was encountered in Borehole RL-3 at ground surface (i.e., Elevation 241.5 m). Below the asphalt, a 5.4 m thick layer of variable fill was encountered as follows. It is noted that when fill soils were not able to be sampled using the SPT procedure (i.e., when wash boring with casing was used to advance borehole due to presence of cobble to boulder-sized rock fragments), observations of drilling progress and flush water exiting the casing was used to infer the fill type. Directly below the asphalt, a 0.4 m thick layer of sand and gravel was encountered. An approximately 1.3 m thick layer of blast rock fill was encountered below the sand and gravel fill at Elevation 240.7 m, underlain by an approximately 0.9 m thick layer of silty sand fill at Elevation 239.4 m. Below the silty sand fill layer, an inferred cobble was encountered at

¹ Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE

² Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543

Elevation 238.6 m (based on grinding of casing) followed by an approximately 0.7 m thick layer of clayey gravel fill at Elevation 238.5 m. An approximately 1.4 m thick layer of blast rock fill was encountered below the clayey gravel fill at Elevation 237.7 m. At the bottom of the fill, an approximately 0.5 m thick layer of sand fill was encountered below the blast rock fill layer at Elevation 236.3 m.

Two SPT “N”-values measured within the clayey gravel fill and sand fill layers encountered in Borehole RL-3 at Elevations 238.5 m and 236.3 m, respectively, are 9 blows and 13 blows per 0.3 m of penetration, indicating a loose to compact compactness condition.

A grain size distribution analysis was carried out on one sample of the clayey gravel fill and the result is presented on Figure B-1 in Appendix B. An Atterberg limit test was carried out on the fine portion of the same clayey gravel fill and measured a liquid limit of 18 per cent, a plastic limit of 12 per cent, and a plastic index of 6 per cent. The results, which are presented on Figure B-2 in Appendix B, indicate that the fines portion of the sample is classified as a silt /clayey silt of low plasticity. The natural moisture content measured on the clayey gravel fill sample is 11 per cent. A grain size distribution analysis was carried out on one sample of the sand fill and the result is presented on Figure B-3 in Appendix B. The natural moisture content measured on the sand fill sample is 15 per cent.

4.2.2 Ice/Water

Boreholes RL-1 and RL-2 (located near the toe of the embankment) encountered an 80 mm thick layer of ice at Elevation 235.9 m over about 1.4 m of water at the time of investigation.

4.2.3 Peat

At the bottom of the water in Boreholes RL-1 and RL-2, a 0.6 m to 0.8 m thick layer of fibrous peat was encountered at Elevation 234.4 m. Borehole RL-2 was terminated at the bottom of this fibrous peat layer upon split-spoon refusal during the SPT at Elevation 233.8 m.

The SPT “N”-value measured within the fibrous peat layer encountered in Borehole RL-1 is 1 blow per 0.3 m of penetration suggesting a very soft consistency.

4.2.4 Gravel

Below the peat in Borehole RL-1, an approximately 0.2 m thick layer of coarse gravel was encountered at Elevation 233.6 m. Borehole RL-1 was terminated at the bottom of this coarse gravel layer due to split-spoon refusal during the SPT at Elevation 233.4 m.

4.2.5 Silt

A 7.0 m thick deposit of silt was encountered underlying the fill in Borehole RL-3 at Elevation 235.8 m. The silt typically contained some clay, with trace organics encountered near the interface with the fill.

The SPT “N”-value measured within this silt ranges from 5 blows to 41 blows per 0.3 m of penetration, indicating a loose to dense compactness condition. One in situ field vane test performed within this layer measured a shear strength value greater than 100 kPa.

Three grain size distribution analyses were carried out on samples of the silt layer and the results are presented on Figure B-4 in Appendix B. Three Atterberg limit tests were carried out on samples of the deposit with one test yielding a non-plastic result and the other two tests yielding a liquid limit of 20 per cent and 24 four percent, a plastic limit of 15 per cent and 19 per cent, and a plastic index of 5 per cent. The results are shown on Figure B-5 and confirm that portions of the silt have slight plasticity and are near the transition to being classified as clayey silt with low plasticity. The natural moisture content measured on samples of the deposit ranges between 16 per cent and 26 per cent.

4.2.6 Clayey Silt

An approximately 3.9 m thick layer of clayey silt was encountered underlying the silt layer within Borehole RL-3 at about Elevation 228.9 m.

The STP “N”-values measured within the clayey silt layer range between weight of hammer (WH) per 0.3 m of penetration to 6 blows per 0.3 m of penetration. Two in situ field vane tests performed within the layer measured shear strengths of about 38 kPa, indicating a firm consistency.

One grain size distribution analysis was carried out on a sample within the clayey silt layer and the results are presented on Figure B-6 in Appendix B. One Atterberg limits test was carried out on a sample of the deposit yielding a liquid limit of 21 per cent, a plastic limit of 16 per cent and a plastic index of 5 per cent. The results, which are presented on Figure B-7 in Appendix B, indicate the layer is a clayey silt-silt of low plasticity. The natural moisture content measured on one sample of the deposit is 23 per cent.

4.2.7 Lower Silt

An approximately 0.4 m thick layer of silt was encountered below the clayey silt layer in Borehole RL-3 at approximately Elevation 224.9 m.

An SPT was attempted within this layer and measured 5 blows per 0.13 m of penetration, after which depth the split-spoon achieved effective refusal on bedrock.

4.2.8 Bedrock/Refusal

Bedrock was inferred to be encountered upon refusal of the split-spoon sampler in Boreholes RL-1 and RL-2, and confirmed by coring in Borehole RL-3. Also, bedrock outcrops were confirmed east of the culvert inlet by visual observation and as shown on Drawing 1.

In Boreholes RL-1 and RL-2 (and the four accompanying DCPTs advanced near the culvert inlet), refusal to further penetration was encountered between 1.7 m and 2.9 m below ice surface, corresponding to inferred top of bedrock between Elevations 234.2 m and 233.0 m.

In Borehole RL-3, bedrock was cored from Elevation 224.5 m to 221.3 m (length of 3.2 m). The total core recovery (TCR) of the bedrock core is 100 per cent, solid core recovery (SCR) ranges from 27 percent to 90 per cent and the Rock Quality Designation (RQD) ranges from 27 per cent to 98 per cent. The rock core is described as fine to medium grained, slightly weathered to fresh, grey granitic gneiss. The record of drillhole is displayed in Appendix A.

4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface measured inside the casing or augers upon completion of drilling are summarized below. The ice level of the watercourse near the culvert inlet, as surveyed by Golder on March 19, 2019, was Elevation 235.9 m. Groundwater and watercourse levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Ground/Ice Surface Elevation (m)	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
RL-1	235.9	0.0	*235.9
RL-2	235.9	0.0	*235.9
RL-3	241.5	5.3	236.3

Note: *Ice surface elevation of watercourse near culvert inlet/swamp

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of the silt deposit near the invert level recovered from Borehole RL-3. The soil sample was submitted to Maxxam Analytics of Sudbury, Ontario for corrosivity testing. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

Borehole No.	Sample No.	Depth (m)	Parameters					
			Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO ₄) Content (µg/g)	Sulphide (S ⁻) (µg/g)	Soluble Chloride (Cl) Content (µg/g)	pH
RL-3	2b	5.7-5.8	2,000	506	<20 ¹	<0.50 ¹	240	7.69

Note:


1. Below the reportable detection limit.

5.0 CLOSURE

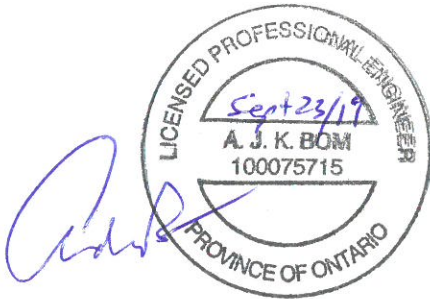
The field exploration program was carried out under the supervision of Mr. Mathew Riopelle, under the overall direction of Mr. André Bom, P.Eng. This Foundation Investigation Report was prepared by Mr. Gavin Mundry, and Mr. André Bom, P.Eng. provided a technical review of the report. Mr. Kevin Bentley, P.Eng., an MTO Foundations Designated Contact and Associate for Golder, conducted an independent quality control review of this report.

Signature Page

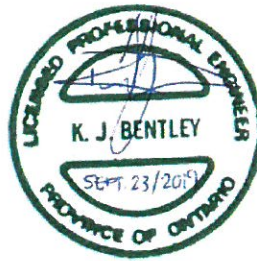
Golder Associates Ltd.



Gavin Mundry, EIT
Geotechnical Engineer-in-Training



André Bom, P.Eng.
Senior Geotechnical Engineer, Associate

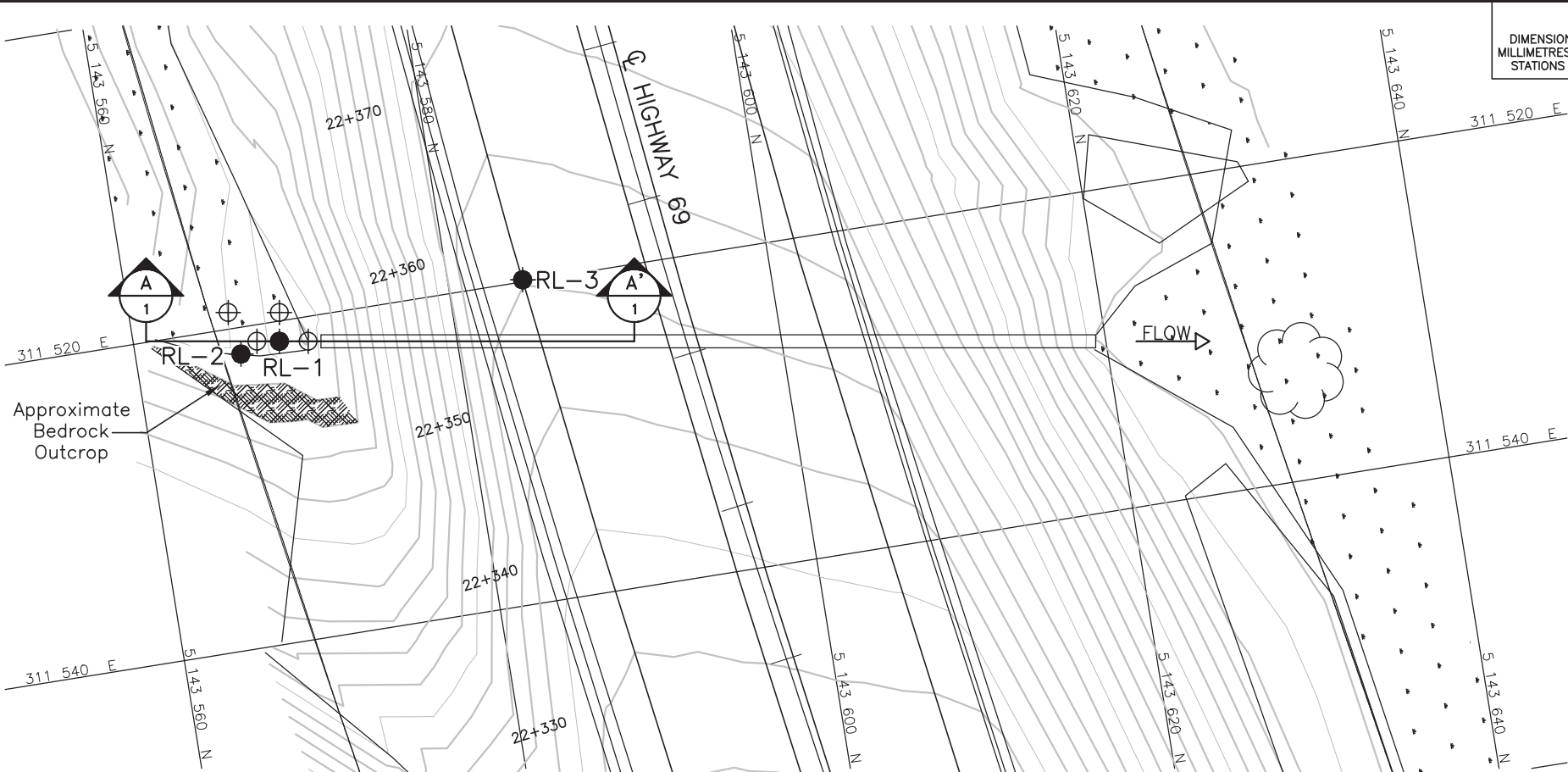


Kevin Bentley, P.Eng.
MTO Foundations Designated Contact, Associate

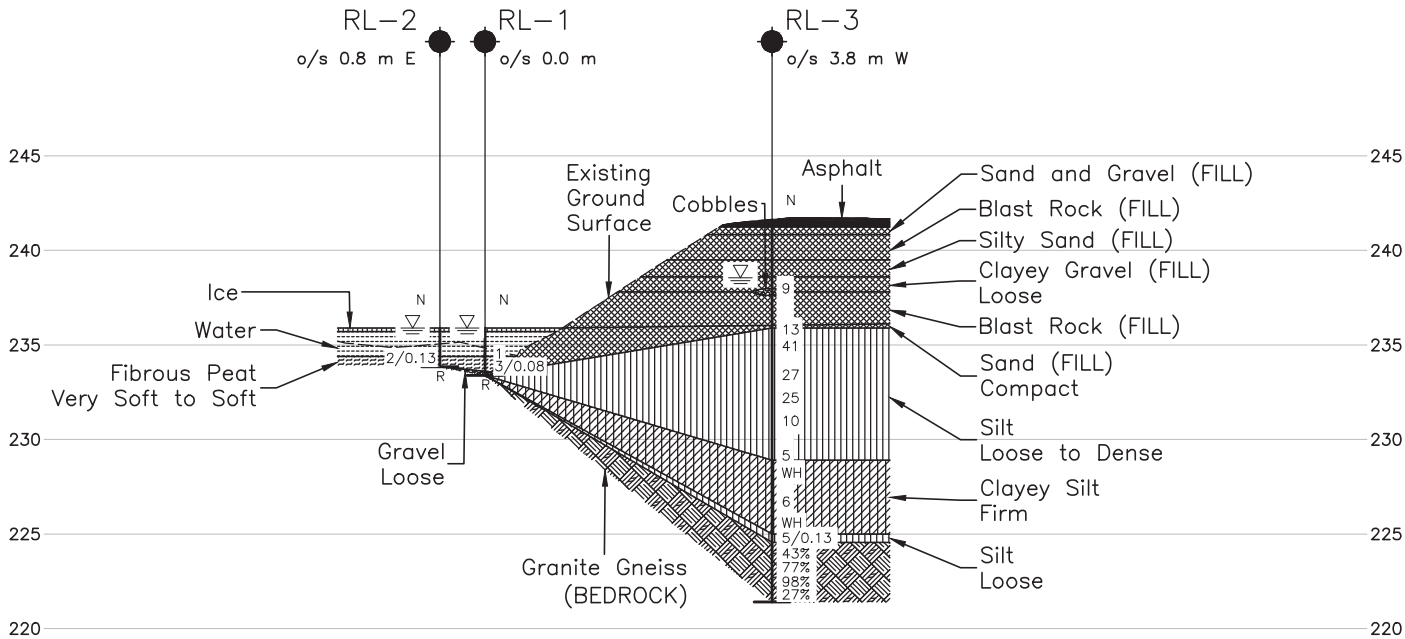
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https://golderassociates.sharepoint.com/sites/22732g/deliverables/foundations/2. reporting/3. final/1790361 r-rev0 mto deep fill culvert hwy 69 fir 23sept_19.docx



PLAN
SCALE
0 4 8 m



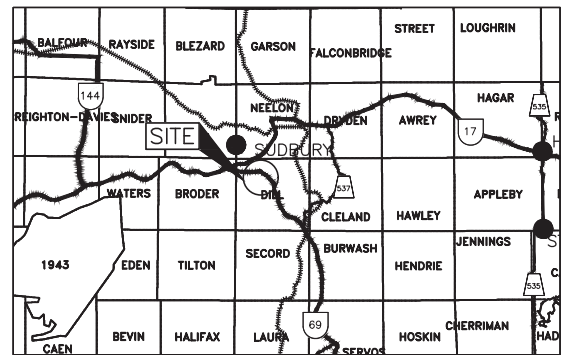
A-A'
1
CROSS-SECTION
SCALE
0 4 8 m

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

CONT No. .
GWP No. 5219-14-00



HIGHWAY 69
DEEP FILL CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA



KEY PLAN

SCALE
0 10 20 km

LEGEND

- Borehole - Current Investigation
- ⊕ Dynamic Cone Penetration Test
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Split-spoon refusal
- 100% Rock Quality Designation (RQD)
- ∇ WL upon completion of drilling

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
RL-1	235.9	5143569.0	311521.2
RL-2	235.9	5143566.5	311521.7
RL-3	241.5	5143584.6	311519.9



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.

REFERENCE

Base plans provided in digital format by CALLON DIETZ INC. drawing file no. gwp52191400b.dwg, received MAY 16, 2019.

NO.	DATE	BY	REVISION
Geocres No. 411-363			
HWY. 69	PROJECT NO. 1790361	DIST. .	
SUBM'D.	CHKD. GM	DATE: 9/23/2019	SITE: .
DRAWN: TR	CHKD. AB	APPD. KB	DWG. 1



Photograph 1: South Embankment (Inlet End), Looking South-West (from D.M. Wills)



Photograph 2: South Embankment (Inlet End), Looking South-East (from D.M. Wills)

APPENDIX A

Record of Boreholes

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

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.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An 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 (*u*) and sleeve friction (*f_s*) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); 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

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, 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
GS	specific gravity
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 (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	≥ 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

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

* 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 $= (w_l - w_p)$
NP	non-plastic
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 $= \sigma'_p / \sigma'_{vo}$

(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

Notes: 1
2

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

PROJECT		1790361		RECORD OF BOREHOLE No RL-1				1 OF 1 METRIC						
G.W.P.		5219-14-00		LOCATION		N 5143569.0; E 311521.2 NAD83 MTM ZONE 12 (LAT. 46.431781; LONG. -80.912546)		ORIGINATED BY MR						
DIST		HWY 69		BOREHOLE TYPE		Portable Equipment, NW Casing and Wash Boring		COMPILED BY GM/TR						
DATUM		GEODETIC		DATE		March 11, 2019		CHECKED BY AB						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
235.9	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	ICE (80 mm)													
0.1	WATER													
234.4	Fibrous PEAT, some silt, trace to some sand, trace gravel Very soft Dark brown Wet		1	SS	1									
233.6														
233.4	Coarse GRAVEL, trace sand, trace wood Grey Wet		2	SS	3/0.08									
2.5	END OF BOREHOLE Split-Spoon Refusal (Hammer Bouncing)													
NOTES: 1. Water level at ice surface (Elev. 235.9 m) upon completion of drilling. 2. Advanced DCPT 1.4 m south of borehole and refusal at a depth of 1.9 m below ice surface. 3. Advanced DCPT 1.8 m north of borehole and refusal at a depth of 2.8 m below ice surface. 4. Advanced DCPT 1.8 m west of borehole and refusal at a depth of 1.7 m below ice surface. 5. Advanced DCPT 3.2 m south and 1.8 m west of borehole and refusal at a depth of 2.9 m below ice surface.														

PROJECT <u>1790361</u>		RECORD OF BOREHOLE No RL-2				1 OF 1 METRIC							
G.W.P. <u>5219-14-00</u>		LOCATION <u>N 5143566.5; E 311521.7 NAD83 MTM ZONE 12 (LAT. 46.431758; LONG. -80.91254)</u>				ORIGINATED BY <u>MR</u>							
DIST <u> </u> HWY <u>69</u>		BOREHOLE TYPE <u>Portable Equipment, NW Casing and Wash Boring</u>				COMPILED BY <u>GM/TR</u>							
DATUM <u>GEODETIC</u>		DATE <u>March 11, 2019</u>				CHECKED BY <u>AB</u>							
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa		WATER CONTENT (%)			
235.9	GROUND SURFACE												
0.0	ICE (80 mm)												
0.1	WATER												
234.4	Fibrous PEAT, trace gravel Soft Dark brown Wet		1	SS	2/0.13								
233.8	END OF BOREHOLE Split-Spoon Refusal (Hammer Bouncing)												
2.1	NOTE: 1. Water level at ice surface (Elev. 235.9 m) upon completion of drilling.												

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

PROJECT 1790361		RECORD OF BOREHOLE No RL-3				2 OF 2 METRIC											
G.W.P. 5219-14-00		LOCATION N 5143584.6; E 311519.9 NAD83 MTM ZONE 12 (LAT. 46.431921; LONG. -80.912563)				ORIGINATED BY MR											
DIST HWY 69		BOREHOLE TYPE 76 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring				COMPILED BY GM/TR											
DATUM GEODETIC		DATE March 18-19, 2019				CHECKED BY AB											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ kN/m³	GR SA SI CL
							20 40 60 80 100	○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED	W _p	W	W _L	20 40 60				
228.9	SILT, some clay, trace sand Loose to compact Brown to grey Wet		7	SS	5		229							H ○			0 1 83 16
12.7	CLAYEY SILT, trace sand Firm Grey Wet		8	SS	WH		228										
							227										
			9	SS	6		226										
							225										
224.9	SILT, trace plastic fines Loose Grey Wet		11	SS	5/0.13		224							H ○			0 1 78 21
16.6							223										
224.5	GRANITIC GNEISS (BEDROCK)		1	RC	REC 100%		222										
17.0	For coring details see Record of Drillhole RL-3.		2	RC	REC 100%												RQD = 43%
			3	RC	REC 100%												RQD = 77%
			4	RC	REC 100%												RQD = 98%
221.3	END OF BOREHOLE																RQD = 27%
20.2	NOTE: 1. Water level at a depth of 5.3 m below ground surface (Elev. 236.3 m) upon completion of drilling. 2. Drilling through fill soils started with hollow stem augers but switched to casing / coring techniques to penetrate rockfill. 3. Fill descriptions (where not sampled) are inferred from observation during drilling / casing advancement and observing flush water returns.																

PROJECT: 1790361

LOCATION: N 5143584.6; E 311519.9

NAD83 MTM ZONE 12 (LAT. 46.431921; LONG. -80.912563)

INCLINATION: -90° AZIMUTH: —

RECORD OF DRILLHOLE: RL-3

SHEET 1 OF 1

DRILLING DATE: March 19, 2019

DATUM: GEODETIC

DRILL RIG: CME 850 Track Mount

DRILLING CONTRACTOR: Landcore Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.										DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY				Diametral Point Load Index (MPa)	RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
							RECOVERY			FRACT. INDEX METRES	TYPE AND SURFACE DESCRIPTION			Jr	Ja	Jn	k, cm/s	10 ⁻⁵	10 ⁻⁴	10 ⁻³																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
							TOTAL CORE %	SOLID CORE %	R.Q.D. %		B Angle	DIP w.r.t. CORE AXIS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
							FLUSH	80	90		95	100	10								20	30	40	50			60	70	80	90	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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DEPTH SCALE

1 : 60

**GOLDER**

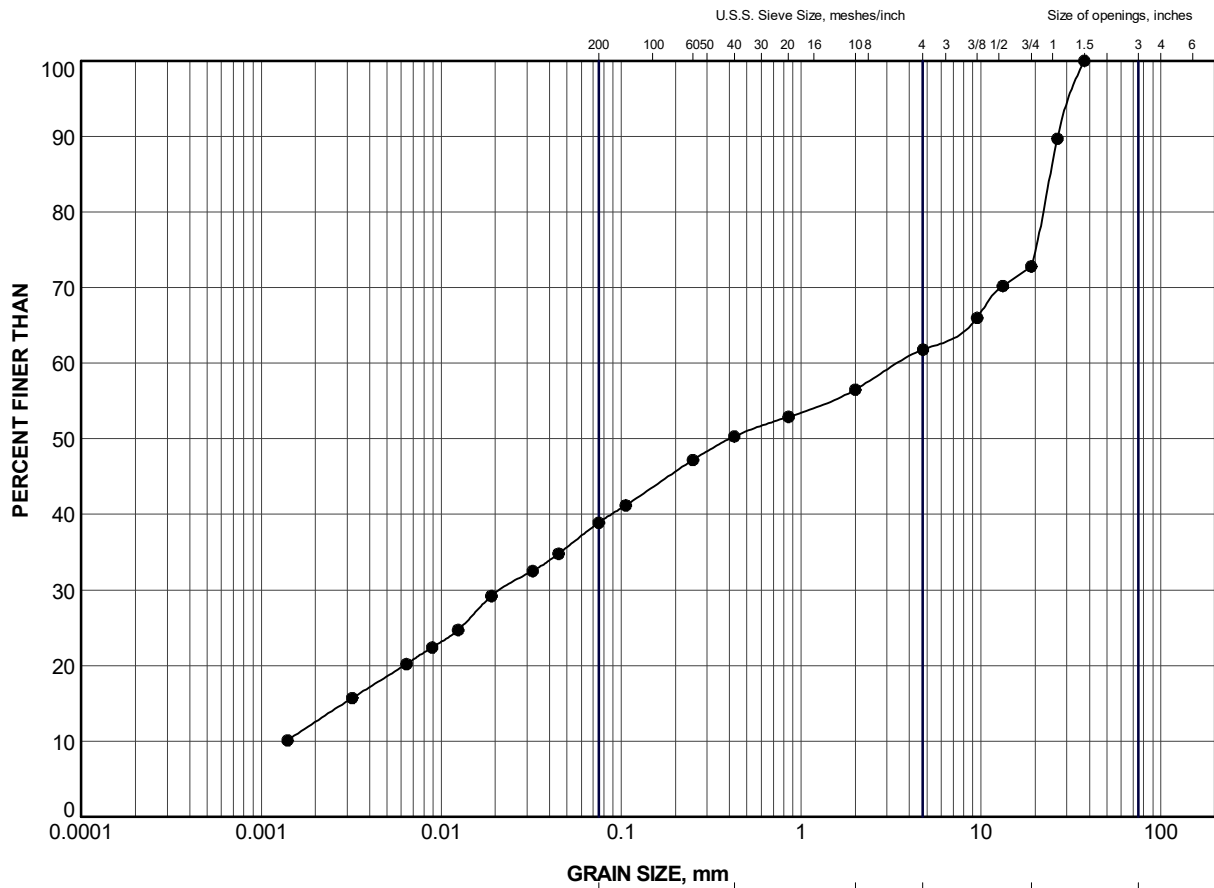
LOGGED: MR

CHECKED: AB

SUD-MTO-RCK S:\CLIENTS\MTOWHY6902 DATA\GINT\HWY69.GPJ GAL-MISS.GDT 6-24-19 TR

APPENDIX B

Laboratory Test Results



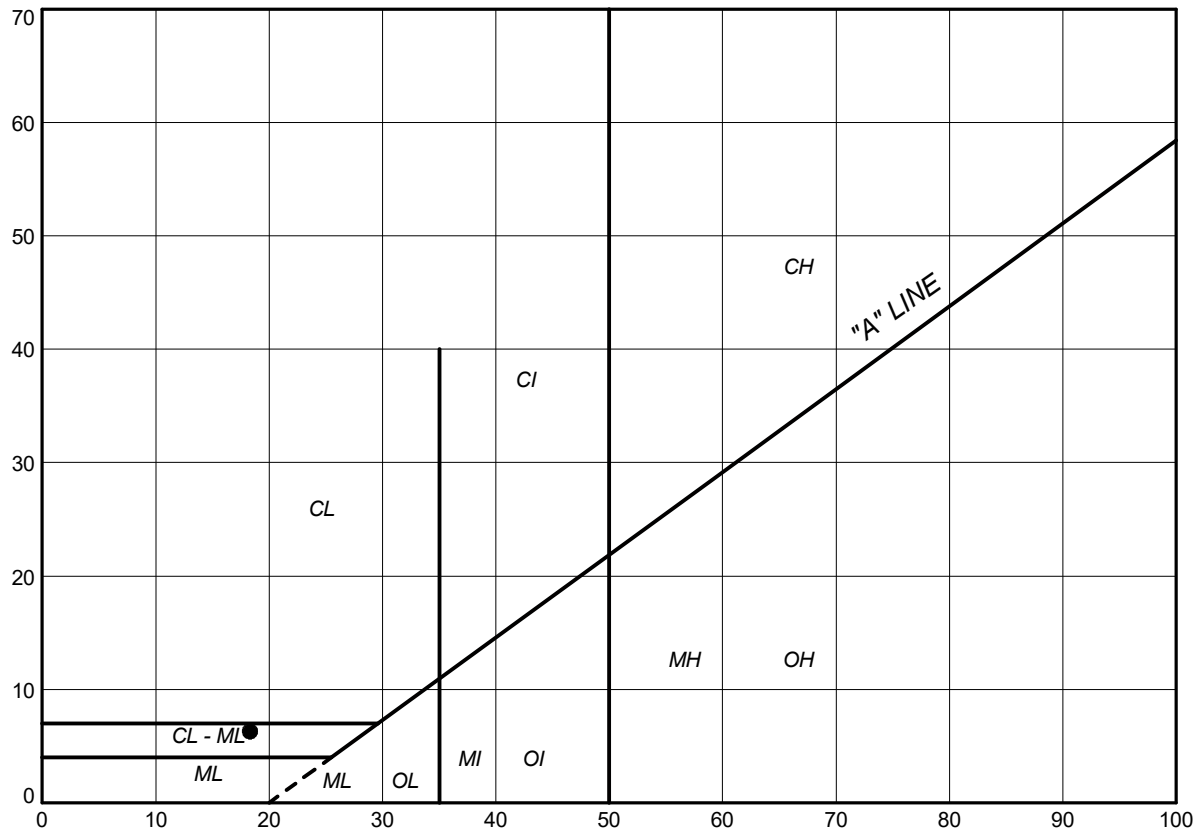
GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	RL-3	1	238.2

PROJECT					
HIGHWAY 69 DEEP FILL CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Clayey Gravel (FILL)					
PROJECT No. 1790361			FILE No. 1790361.GPJ		
DRAWN	TR	Sep 2019	SCALE	N/A	REV.
CHECK	AB	Sep 2019			
APPR	KB	Sep 2019			
GOLDER SUDBURY, ONTARIO			FIGURE B-1		

PLASTICITY INDEX (Percent)



LIQUID LIMIT (Percent)

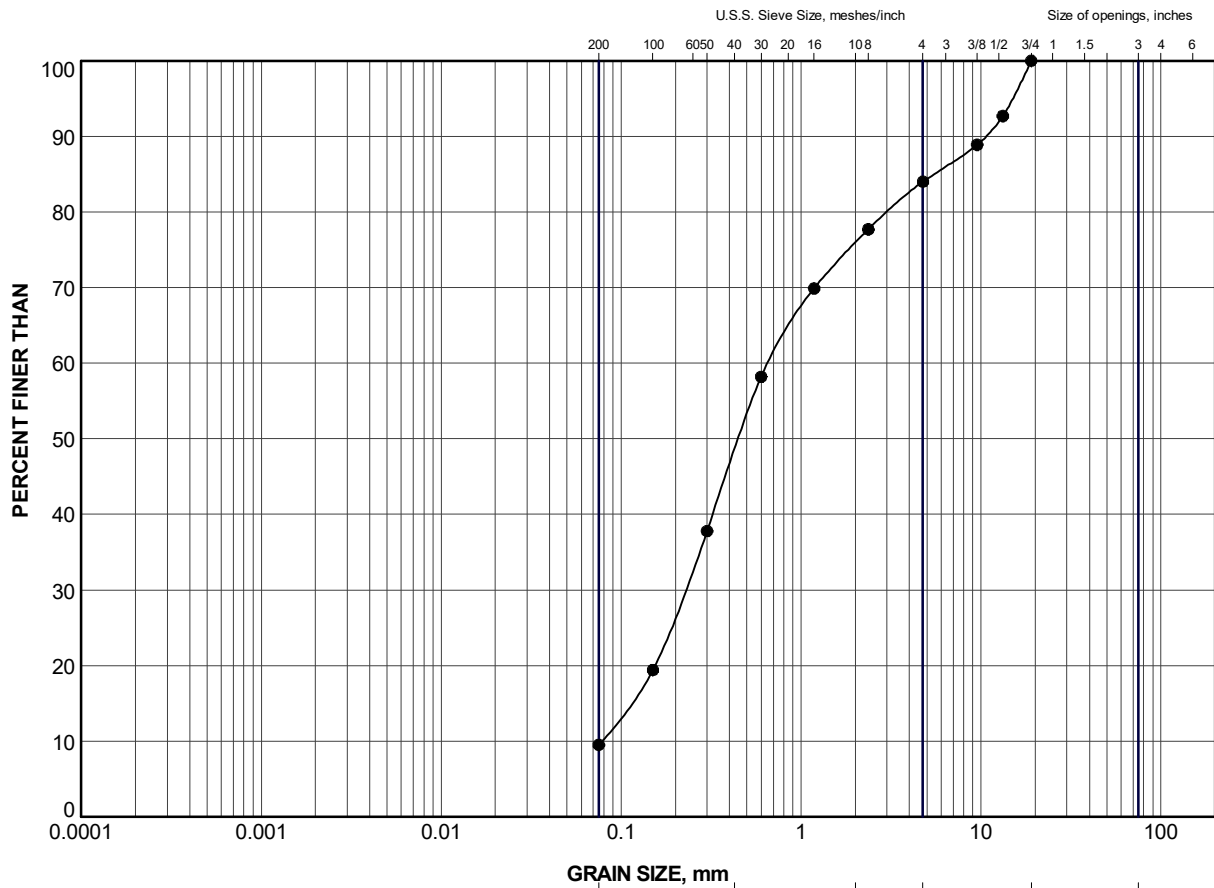
SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	RL-3	1	18.3	12.0	6.3

PROJECT					
HIGHWAY 69 DEEP FILL CULVERT					
TITLE					
PLASTICITY CHART Clayey Gravel (FILL)					
PROJECT No. 1790361			FILE No. 1790361.GPJ		
DRAWN	TR	Sep 2019	SCALE	N/A	REV.
CHECK	AB	Sep 2019	FIGURE B-2		
APPR	KB	Sep 2019			
SUDBURY, ONTARIO					

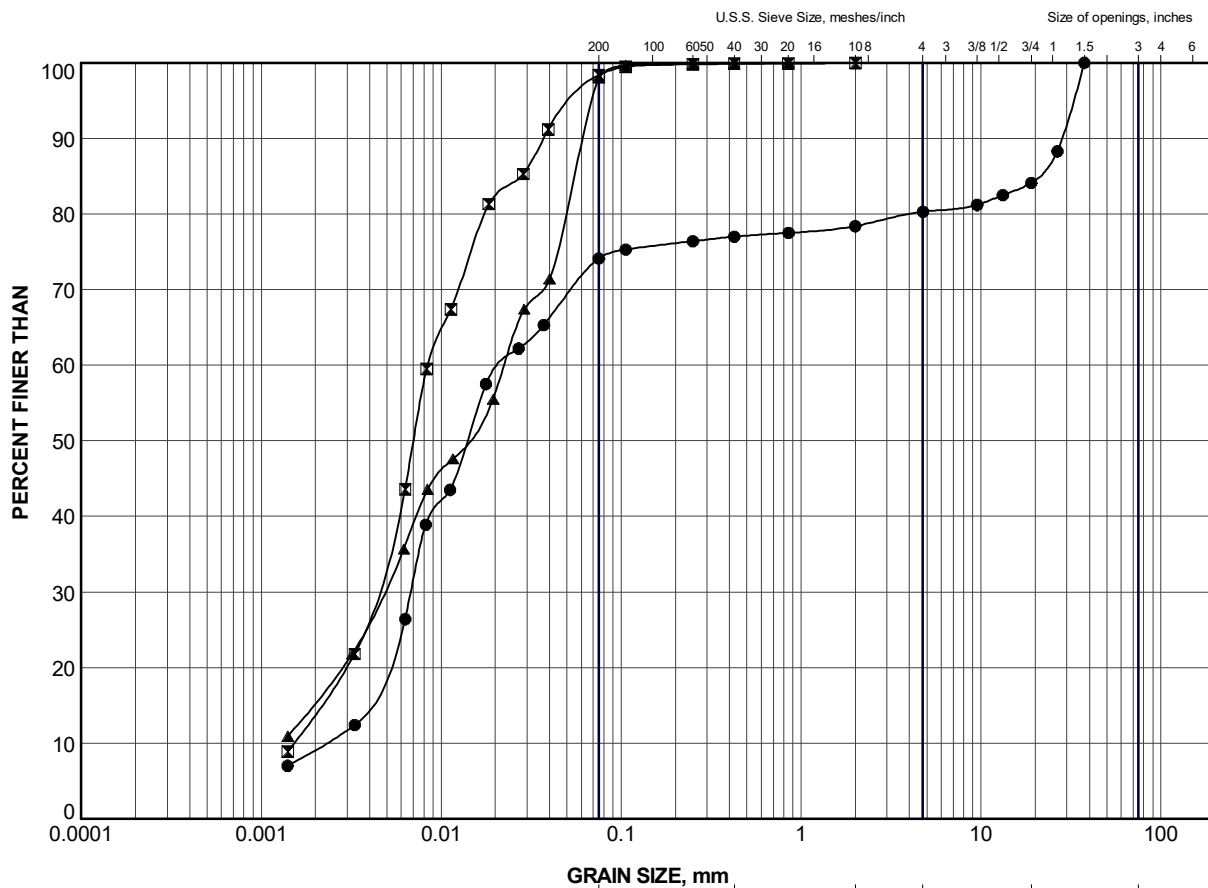


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	RL-3	2A	236.1

PROJECT					
HIGHWAY 69 DEEP FILL CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Sand (FILL)					
PROJECT No. 1790361			FILE No. 1790361.GPJ		
DRAWN	TR	Sep 2019	SCALE	N/A	REV.
CHECK	AB	Sep 2019	FIGURE B-3		
APPR	KB	Sep 2019			
SUD-BURY, ONTARIO					



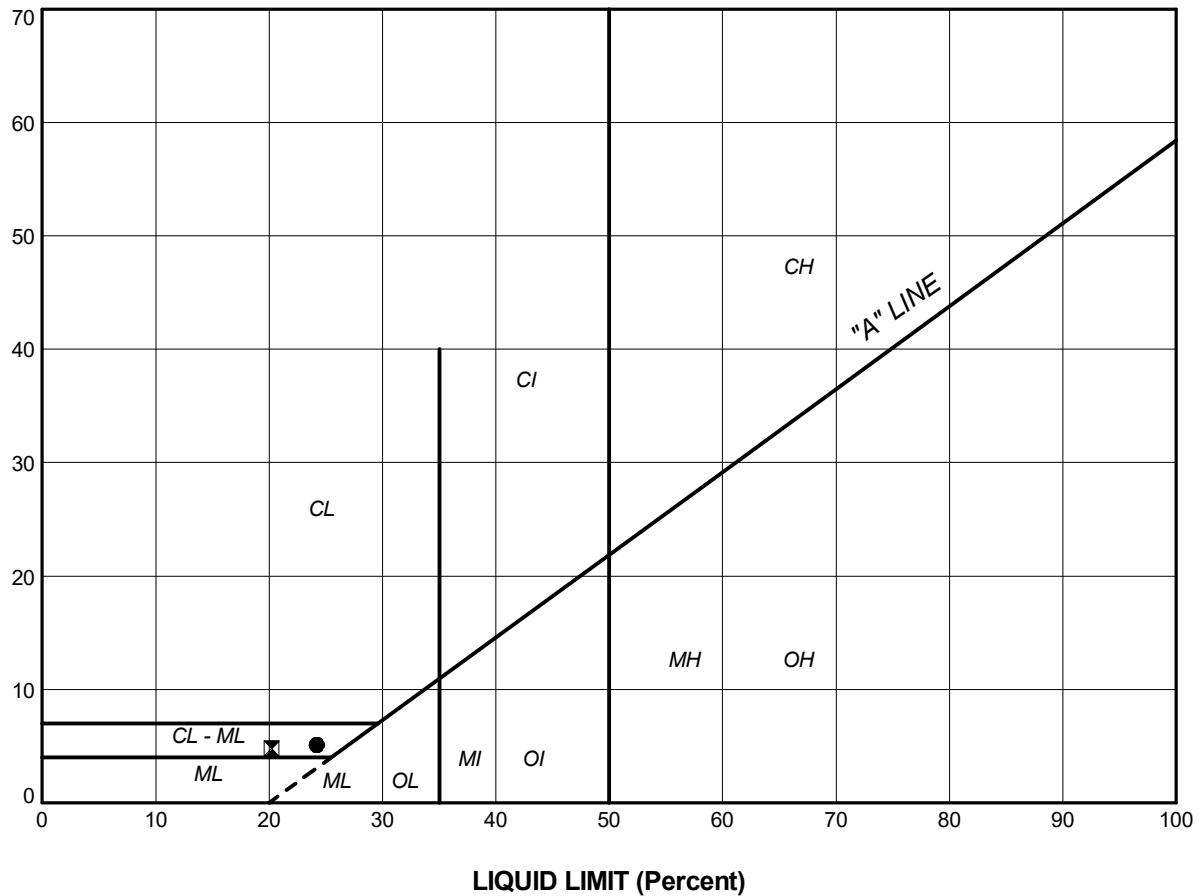
GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	RL-3	3	235.1
⊠	RL-3	5	232.3
▲	RL-3	7	229.2

PROJECT					
HIGHWAY 69 DEEP FILL CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Silt					
PROJECT No.		1790361		FILE No.	
DRAWN		TR		Sep 2019	
CHECK		AB		Sep 2019	
APPR		KB		Sep 2019	
GOLDER		SUDBURY, ONTARIO		SCALE N/A	
REV.		FIGURE		B-4	

PLASTICITY INDEX (Percent)



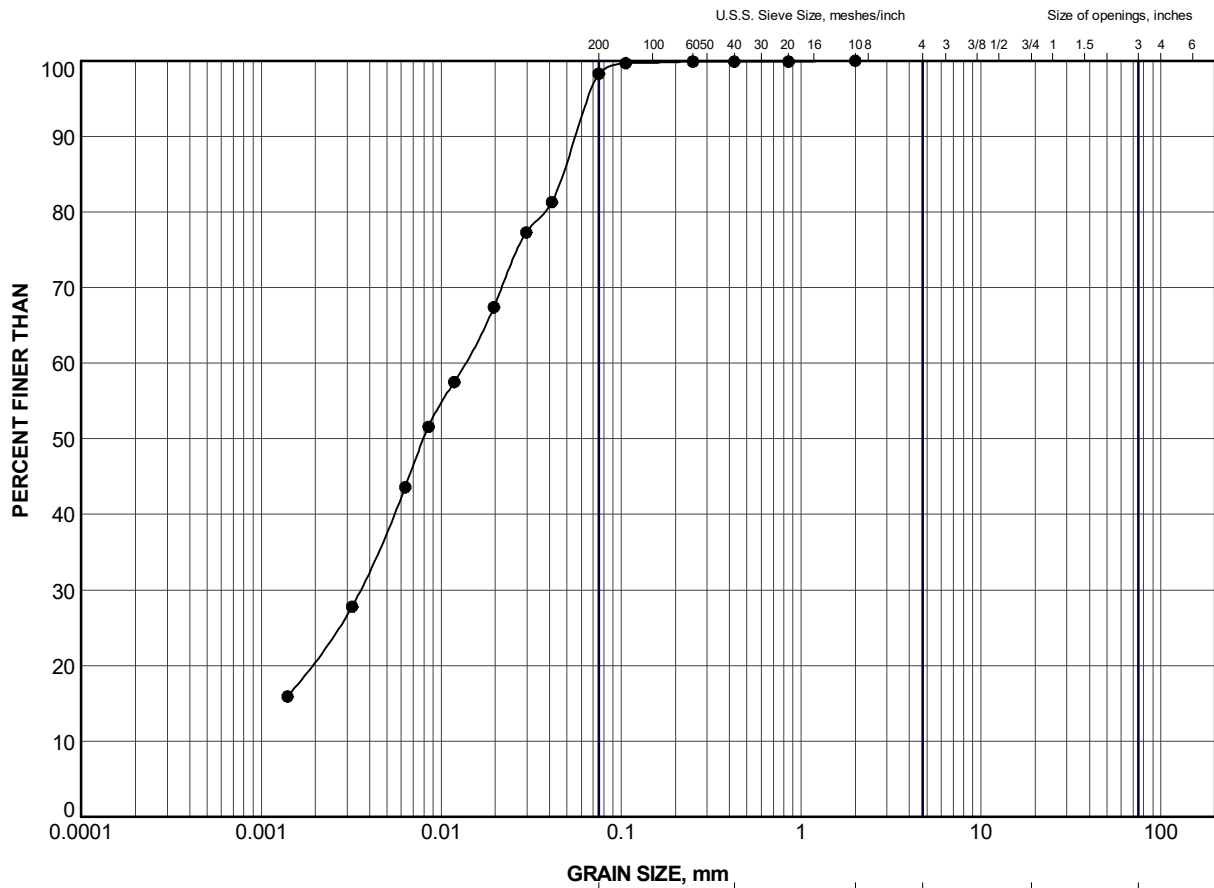
SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	RL-3	5	24.2	19.1	5.1
☒	RL-3	7	20.2	15.4	4.8

PROJECT					
HIGHWAY 69 DEEP FILL CULVERT					
TITLE					
PLASTICITY CHART Silt					
PROJECT No. 1790361			FILE No. 1790361.GPJ		
DRAWN	TR	Sep 2019	SCALE	N/A	REV.
CHECK	AB	Sep 2019	FIGURE B-5		
APPR	KB	Sep 2019			
SUDBURY, ONTARIO					



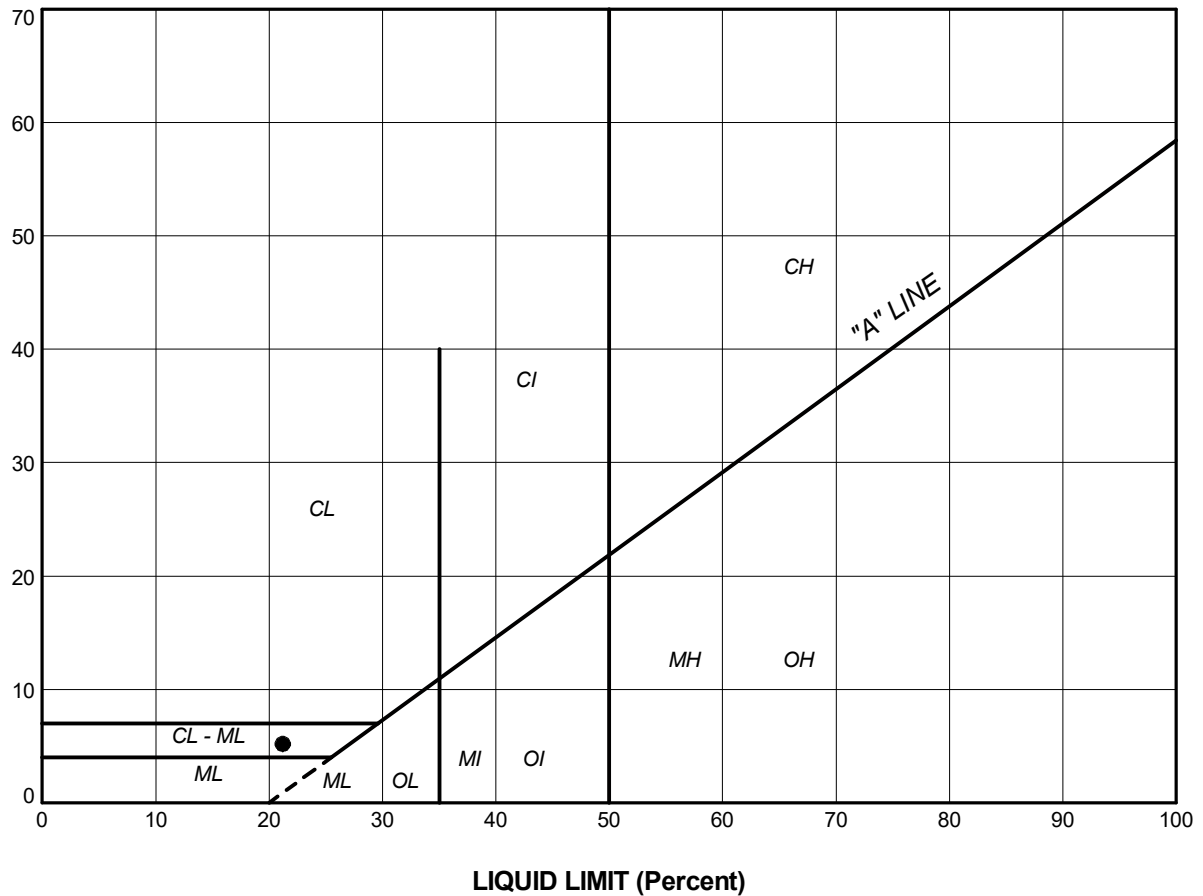
GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	RL-3	10	225.3

PROJECT					
HIGHWAY 69 DEEP FILL CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION Clayey Silt					
PROJECT No. 1790361			FILE No. 1790361.GPJ		
DRAWN	TR	Sep 2019	SCALE	N/A	REV.
CHECK	AB	Sep 2019			
APPR	KB	Sep 2019			
GOLDER			FIGURE B-6		
SUDBURY, ONTARIO					

PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	RL-3	10	21.2	16.0	5.2

PROJECT					
HIGHWAY 69 DEEP FILL CULVERT					
TITLE					
PLASTICITY CHART Clayey Silt					
PROJECT No. 1790361			FILE No. 1790361.GPJ		
DRAWN	TR	Sep 2019	SCALE	N/A	REV.
CHECK	AB	Sep 2019	FIGURE B-7		
APPR	KB	Sep 2019			
SUDBURY, ONTARIO					

RESULTS OF ANALYSES OF SOIL

Maxxam ID		JGE906			JGE906		
Sampling Date		2019/03/18 15:00			2019/03/18 15:00		
COC Number		127608			127608		
	UNITS	RL-3 SA1	RDL	QC Batch	RL-3 SA1 Lab-Dup	RDL	QC Batch
CONVENTIONALS							
Sulphide	ug/g	<0.50	0.50	6062227			
Calculated Parameters							
Resistivity	ohm-cm	2000		6035108			
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	240	20	6036711	230	20	6036711
Conductivity	umho/cm	506	2	6037167	496	2	6037167
Available (CaCl2) pH	pH	7.69		6036826			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	6036712	<20	20	6036712
Physical Testing							
Moisture-Subcontracted	%	20	0.30	6062226			
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate							



golder.com