



FOUNDATION INVESTIGATION REPORT

Highway 66, Station 12+290, Township of Lebel Culvert Replacement Ministry of Transportation, Ontario GWP 5210-14-00

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1896349-R17

February 27, 2020

GEOCRES NO: 32D-31

LAT: 48.163524

LONG: -79.993886



Distribution List

3 Copies + 1 PDF Copy: Ministry of Transportation, Ontario (NE Region)

1 Copy + 1 PDF Copy: Ministry of Transportation, Ontario (Foundations)

1 Copy + 1 PDF Copy: AECOM Canada Ltd.

1 PDF Copy: Golder Associates Ltd.

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 66, STA 12+290, TOWNSHIP OF LEBEL
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5210-14-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services related to the replacement of the culvert on Highway 66 at Station 12+290, in the Township of Lebel, Ontario. The culvert site is located along the north shore of Gull Lake, approximately 2 km east of the intersection with Toburn Road. The Key Plan of the general location of this section of Highway 66 and the location of the investigated area are shown on Drawing 1.

The purpose of this foundation investigation is to establish the subsurface conditions at the culvert replacement 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 February 2018, and the subsequent clarifications/addenda, which forms part of the Consultant's Assignment Number 5017-E-0039 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 November 2018.

2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on the Drawing 1. For the purpose of this report, Highway 66 is oriented in a west-east direction with the culvert positioned perpendicular to the highway generally in a north-south orientation. At the culvert location, the ditch/creek water flows in a north to south direction, into Gull Lake.

The existing culvert consists of an 800 mm diameter, 21 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are at approximately Elevations 320.0 m and 320.1 m, respectively. In general, the topography to the north, east, and west of the culvert site consist of relatively flat terrain and forested hills; and Gull Lake extends along the south side of the highway. The highway grade at the culvert centreline is approximately Elevation 322 m.

The embankment is approximately 2 m high relative to the culvert invert and the thickness of the soil cover over the culvert is about 1.2 m. The embankment/side slopes at the culvert inclined at about 1 Horizontal to 1 Vertical (1H:1V), are grass covered on the north side and grass/gravel with cobbles and boulders covered on the south side and appear to be performing well, with no visible signs of slope instability or roadway settlement issues. At the time of the subsurface exploration field program the culvert north end was exposed and is in poor condition (bent/corroded and rusted); whereas the south end (outlet) was submerged by Gull Lake, but reportedly is also bent/corroded and rusted through. The ground surface conditions at select locations near the culvert are shown on Photographs 1 to 4.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on December 13, 2018, and May 6 and 7, 2019, during which time three boreholes (Boreholes C207-1 to C207-3) were advanced at the approximate locations shown on Drawing 1. Boreholes C207-1 and C207-2 were advanced through the roadway embankment and Borehole C207-3 was advanced near the culvert inlet. All boreholes (C207-1 to C207-3) were drilled using a CME 550 Rubber Tire All Terrain drilling rig supplied and operated by Landcore Drilling (Landcore) of Chelmsford, Ontario.

Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes C207-1 and C207-2 were advanced using NW casing with wash boring techniques, and NQ coring. Borehole C207-3 was advanced using 108 mm I.D. hollow stem augers. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by a full weight automatic or cathead hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). In-situ vane shear test were carried out in cohesive soils for determination of undrained shear strengths in accordance with Standard Test Method for Field Vane Shear Test procedures (ASTM 2573), using an MTO standard "N"-size vane. The groundwater level inside the augers/casing was observed and recorded after the completion of drilling. The cored section of the boreholes was backfilled with bentonite to the bedrock surface and the boreholes were backfilled in accordance with Ontario Regulation 903 (wells), as amended. The roadway surface at the boreholes drilled through Highway 66 were 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 samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions, and Atterberg Limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. One soil sample was submitted to Bureau Vertas Laboratories (formerly Maxxam) of Sudbury, an accredited analytical laboratory, for testing of a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to highway chainages/station marked on the pavement or offsets from the culvert by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevation at the borehole locations was surveyed by Golder: Borehole C207-1 was surveyed relative to Horizontal Control Point 109 (HCP109); and Boreholes C207-2 and C207-3 were surveyed relative to the highway and culvert centreline provided by AECOM. The MTM NAD 83-CSRS CBN v6-2010.0 (Zone 12) 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)
C207-1	5336569.8 (48.163566)	379639.5 (-79.993844)	322.2	17.1*
C207-2	5336561.5 (48.163492)	379633.7 (-79.993923)	321.9	16.5*
C207-3	5336578.0 (48.163641)	379640.0 (-79.993835)	320.8	9.3

*Including coring for lengths of 3.3 m and 3.1 m in the respective boreholes.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)¹ mapping, the subsoil in the vicinity of the culvert site is comprised of ground moraine (sands) / till.

Based on geological mapping (MNDM)², the site is underlain by metasedimentary rocks.

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 plotted results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N'-values), as presented on the Record of Borehole sheets and 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 results of the analytical laboratory testing (by Bureau Veritas Laboratories) are summarized in Section 4.4 and the detailed laboratory testing report is included in Appendix B.

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.

4.2.1 Asphalt/Fill

An approximately 110 mm and 100 mm thick layer of asphalt pavement was encountered in the roadway in Boreholes C207-1 and C207-2, at Elevations 322.2 m and 321.9 m, respectively. A 2.1 m and 2.9 m thick layer of embankment fill, consisting of an upper 0.5 m to 0.6 m thick layer of sand and gravel, and underlain by a 1.1 m to 2.4 m thick layer of sand and sandy silt was encountered below the asphalt in Boreholes C207-1 and C207-2. A 0.6 m thick zone of cobbles and boulders was encountered interlayered within the sand/sandy silt fill in Borehole C207-2 at a depth of 1.7 m below ground surface. Trace organics, rootlets, wood was encountered in the sandy silt fill near the bottom of Borehole C207-2. In Borehole C207-3, a 0.7 m thick layer of gravelly sandy silt fill was encountered from ground surface at Elevation 320.8.

The SPT "N"-values measured within the sand/gravelly sandy silt/sandy silt fill layers range between 1 blow and 76 blows per 0.3 m of penetration, indicating a very loose to very dense compactness condition; with one "N"-value of 50 blows for 0.05 m of penetration measured at the top of the cobbles and boulders zone.

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

4.2.2 Sand (Upper Deposit)

A 1.5 m and 0.8 m thick deposit of sand some silt was encountered in Boreholes C207-1 and C207-3, respectively, at Elevations 320.0 m and 320.1 m.

The SPT “N”-values measured within the sand deposit range between 5 blows and 23 blows per 0.3 m of penetration, indicating that the deposit has a loose to compact compactness condition.

Grain size distribution was carried out on two samples of the sand deposit and the results are presented on Figure B-1 of Appendix B. The natural moisture content measured on the samples of the deposit are 15 per cent to 26 per cent.

4.2.3 Silt (Upper Deposit)

A 0.8 m and 0.7 m thick deposit of silt, trace to some sand and trace to some clay at one borehole was encountered in Boreholes C207-1 and C207-3, respectively, underlying the sand deposit at Elevations 318.5 m and 319.4 m.

The SPT “N”-values measured within the silt deposit are 1 blow and 13 blows per 0.3 m of penetration, indicating that the deposit has a very loose to compact compactness condition.

Grain size distribution was carried out on one sample of the silt deposit and the result is presented on Figure B-2 of Appendix B. Atterberg limits testing carried out on a sample of the silt and indicates that the material is non-plastic. The natural moisture content measured on the sample of the deposit is 24 per cent.

4.2.4 Clayey Silt

A clayey silt deposit was encountered in the three boreholes underlying the silt deposit in Boreholes C207-1 and C207-3 and underlying the fill in Borehole C207-2. The deposit ranges in thickness from 4.2 m to 4.5 m and was encountered at between Elevations 318.9 to 317.7 m. The upper 1.5 m thick zone of the deposit in Borehole C207-2 is classified as clayey silt with sand, and the overall deposit contains silt laminations throughout.

The SPT “N”-values measured within the clayey silt deposit range from 0 blows (weight of hammer) to 10 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 24 kPa to 48 kPa and sensitivity ranging from about 2 to 3. The SPT “N”-values, together with the field vane test results, suggest that the clayey silt deposit is soft to stiff in consistency.

Atterberg limits testing was carried out on five samples of the clayey silt deposit and measured liquid limits ranging between about 20 per cent and 32 per cent, plastic limits ranging between about 13 per cent and 20 per cent and plasticity indices ranging from about 6 per cent to 13 per cent. The Atterberg limits results are presented in Figure B-3 in Appendix B and indicate that the deposit is generally comprised of clayey silt of low plasticity. Grain size distribution analysis was carried out on four samples of the clayey silt deposit and the results are presented on Figure B-4 in Appendix B. The natural moisture content measured on the samples of the clayey silt deposit range from about 24 per cent to 39 per cent.

4.2.5 Silt (Lower Deposit)

A 1.2 m and 1.1 m thick deposit of silt was encountered in Boreholes C207-2 and C207-3, respectively, underlying the clayey silt deposit at Elevation 314.4 m.

The SPT “N”-values measured within the silt deposit are 10 blows and 31 blows per 0.3 m of penetration, indicating that the deposit has a compact to dense compactness condition.

Grain size distribution was carried out on one sample of the silt deposit and the result is presented on Figure B-5 of Appendix B. The natural moisture content measured on the sample of the deposit is 19 per cent.

4.2.6 Silty Sand to Sand (Lower Deposit)

A 1.8 m to 5.2 m thick deposit of silty sand to sand was encountered in Boreholes C207-1 to C207-3, at between Elevations 313.5 m to 313.2 m. In Borehole C207-1, cobbles were encountered within the deposit from 12.7 m to 13.0 m depths, and in Borehole C207-3, auger grinding was noted from 8.5 m to 9.1 m depth, which could infer the presence of cobbles.

The SPT “N”-values measured within the silty sand to sand deposit range from 3 blows to 60 blows per 0.3 m of penetration with an “N”-value of 100 blows for 0.13 m of penetration on inferred cobbles and an “N”-value of 21 blows for 0.15 m of penetration on bedrock (refer to Section 4.2.7), indicating that the deposit has a very loose to very dense compactness condition.

Grain size distribution was carried out on one sample of the sand zone of the deposit and the result is presented on Figure B-6 of Appendix B. The natural moisture content measured of one sample of the silty sand to sand zone of the deposit is 14 per cent.

4.2.7 Bedrock

Bedrock was encountered and cored in Boreholes C207-1 and C207-2 at depths of 13.9 m and 13.4 m below ground surface, at Elevations 308.3 m and 308.5 m, respectively. The retrieved 3.3 m and 3.1 m lengths of bedrock core are described as fine grained, fresh to slightly weathered, grey, metasedimentary, as described on the Record of Drillholes presented in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B-7 in Appendix B. The Total Core Recovery (TCR) of the bedrock samples is 100 per cent and the Solid Core Recovery (SCR) ranges from about 60 per cent to 95 per cent. The Rock Quality Designation (RQD) of the bedrock core samples ranges between 89 per cent and 100 per cent and based on the Classification in Table 3.10 of CFEM (2006)³, the bedrock is considered of good to excellent quality.

4.3 Groundwater Conditions

The unstabilized groundwater levels, relative to the ground surface measured inside the casing or augers upon completion of drilling are summarized below. The water level of Gull Lake surveyed by Callon Dietz in June 2019

³ Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual (CFEM), 4th Edition.

was approximately Elevation 320.4 m. Groundwater and lake water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C207-1	1.6	320.6
C207-2	1.0	320.9
C207-3	Ground Surface	320.8

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of sand fill recovered from Borehole C207-1. The soil sample was submitted to Bureau Veritas Laboratories 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)	Chloride (Cl) Content (µg/g)	Sulphide (µg/g)	pH
C207-1	1	0.8 – 1.4	5,000	201	<20 ¹	39	<0.50 ¹	7.19

Note:

1. The sulphate and sulphide concentrations are below the reportable detection limit of 20 µg/g and 0.50 µg/g, respectively.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle, under the overall direction of Mr. André Bom, P.Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Mr. Trevor Romanyszyn, and Mr. André Bom, P.Eng., an Associate of Golder, provided a technical review of the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

Signature Page

Golder Associates Ltd.



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

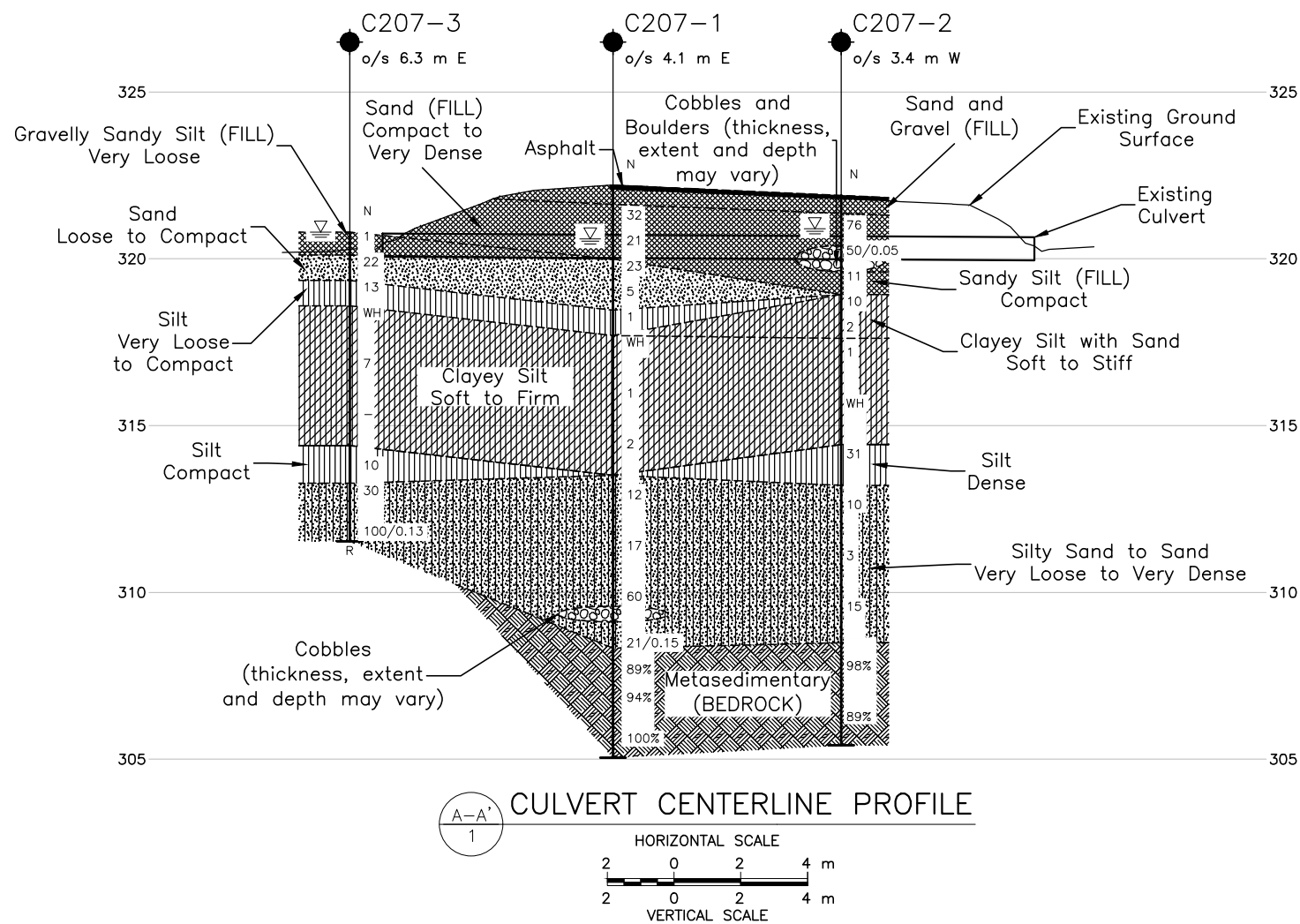


Jorge M. A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

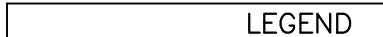
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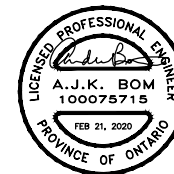


GOLDER



- BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
C207-1	322.2	5336569.8	379639.5
C207-2	321.9	5336561.5	379633.7
C207-3	320.8	5336578.0	379640.0



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.

Base plans provided in digital format by CALLON DIETZ LTD. drawing file nos. gwp52101400a.dwg, received AUGUST 14, 2019.

NO.		DATE		BY	
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HWY. 66			PROJECT NO. 1896349		DIST. .
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DRAWN: TR		CHKD. AB		APPD. JMAC	
				DWG. 1	



Gull Lake

Photograph 1: Embankment South Slope at Culvert Location, Facing East (June 2019)



Culvert
Inlet

Photograph 2: Embankment North Slope at Culvert Location, Facing East (June 2019)



Photograph 3: Culvert Inlet (North End), Facing West (AECOM, October 2018)



Photograph 4: Culvert Outlet (South End at Gull Lake) (AECOM, October 2018)

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

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes



An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

S:\CLIENTS\MT0\HWY65&66\02 DATA\GINT\1896349.GPJ GAL-MISS.GDT 19-12-16 TR

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

PROJECT <u>1896349</u>			RECORD OF BOREHOLE No C207-1				2 OF 2 METRIC										
G.W.P. <u>5210-14-00</u>			LOCATION <u>N 5336569.8; E 379639.5 NAD83 MTM ZONE 12 (LAT. 48.163566; LONG. -79.993844)</u>				ORIGINATED BY <u>MR</u>										
DIST <u> </u> HWY <u>66</u>			BOREHOLE TYPE <u>NW Casing, Wash Boring and NQ Coring</u>				COMPILED BY <u>GM</u>										
DATUM <u>GEODETIC</u>			DATE <u>December 13, 2018</u>				CHECKED BY <u>AB</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					
308.3	SILTY SAND, trace to some gravel Compact to very dense Grey Wet - Cobbles encountered from 12.7 m to 13.0 m depths		11	SS	60		310										
13.9	Metasedimentary (BEDROCK) For coring details see Record of Drillhole C207-1.		12	SS	21/0.15		309										
			1	RC	REC 100%		308										RQD = 89%
			2	RC	REC 100%		307										RQD = 94%
			3	RC	REC 100%		306										RQD = 100%
305.1	END OF BOREHOLE NOTE: 1. Water level measured inside casing at a depth of 1.6 m below ground surface (Elev. 320.6 m) upon completion of drilling.																
17.1																	

SHEET 1 OF 1

DATUM: GEODETIC

DRILLING CONTRACTOR: Landcore Drilling

- Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
- Fault	FO - Foliation	CU - Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
R- Shear	CO- Contact	UN - Undulating	SM- Smooth	
- Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
- Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

CHECKED: AB

SUD-MTO-RCK S:\CLIENTS\MTO\HWY65&66\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 19-12-16 TR

S:\CLIENTS\MT0\HWY65&66\02 DATA\GINT\1896349.GPJ GAL-MISS.GDT 19-12-16 TR

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

PROJECT 1896349		RECORD OF BOREHOLE No C207-2				2 OF 2 METRIC											
G.W.P. 5210-14-00		LOCATION N 5336561.5; E 379633.7 NAD83 MTM ZONE 12 (LAT. 48.163492; LONG. -79.993923)				ORIGINATED BY YS											
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring				COMPILED BY GM											
DATUM GEODETIC		DATE May 6 to 7, 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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)			γ kN/m³	GR SA SI CL
							20 40 60 80 100	20 40 60 80 100	W _p W W _L	20 40 60							
308.5	SILTY SAND to SAND, trace to some gravel Very Loose to compact Grey Wet		11	SS	15		309										
13.4	Metasedimentary (BEDROCK) For coring details see Record of Drillhole C207-2.		1	RC	REC 100%		308									RQD = 98%	
							307										
			2	RC	REC 100%		306									RQD = 89%	
305.4	END OF BOREHOLE																
16.5	NOTE: 1. Water level measured inside casing at a depth of 1.0 m below ground surface (Elev. 320.9 m) upon completion of drilling.																

PROJECT: 1896349

RECORD OF DRILLHOLE: C207-2

SHEET 1 OF 1

LOCATION: N 5336561.5; E 379633.7

DRILLING DATE: May 7, 2019

DATUM: GEODETIC

NAD83 MTM ZONE 12 (LAT. 48.163492; LONG. -79.993923)

DRILL RIG: CME550 Buggy

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Landcore Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY				Diametral Point Load Index (MPa)	RMC -Q' AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
							FLUSH	TOTAL CORE %			SOLID CORE %	B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	k, cm/s																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															

DEPTH SCALE

1 : 60

**GOLDER**

LOGGED: YS

CHECKED: AB

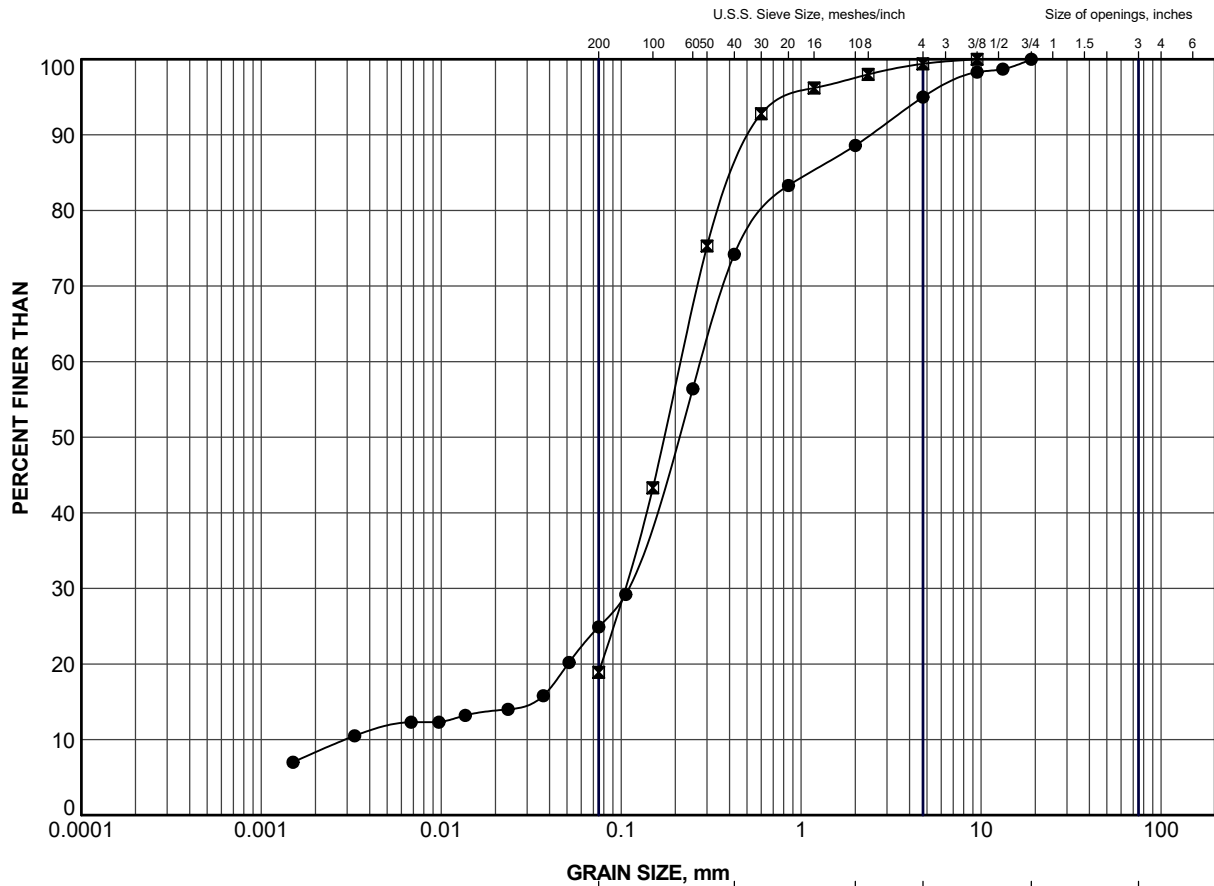
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SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02 DATA\GINT\1896349.GPJ GAL-MISS.GDT 19-12-16 TR

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

APPENDIX B


Laboratory Test Results

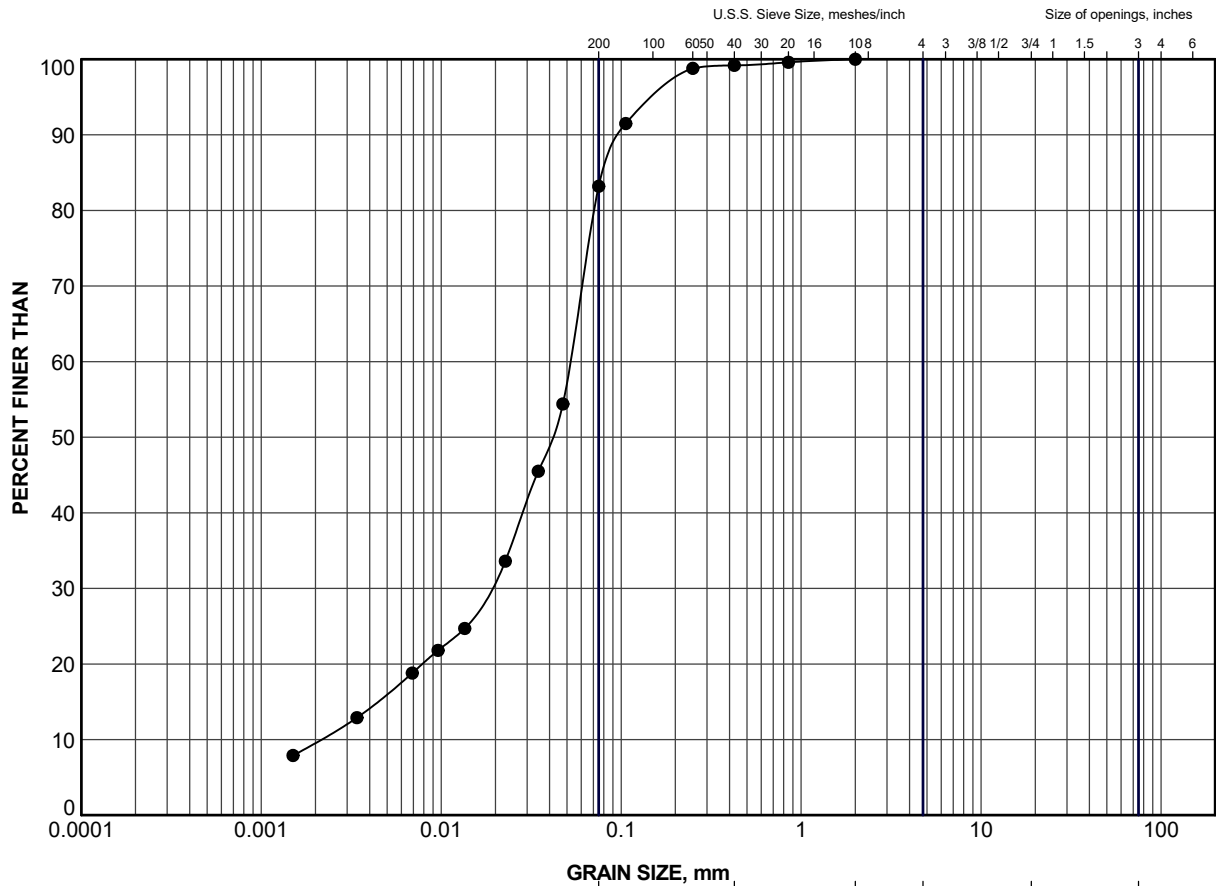


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-1	3	319.6
×	C207-3	2	319.7


PROJECT						HIGHWAY 66 STATION 12+290 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Sand (Upper Deposit)					
PROJECT No. 1896349						FILE No. 1896349.GPJ					
DRAWN		TR		Dec 2019		SCALE		N/A		REV.	
CHECK		AB		Dec 2019							
APPR		JMAC		Dec 2019							
 GOLDER SUDBURY, ONTARIO						FIGURE B-1					

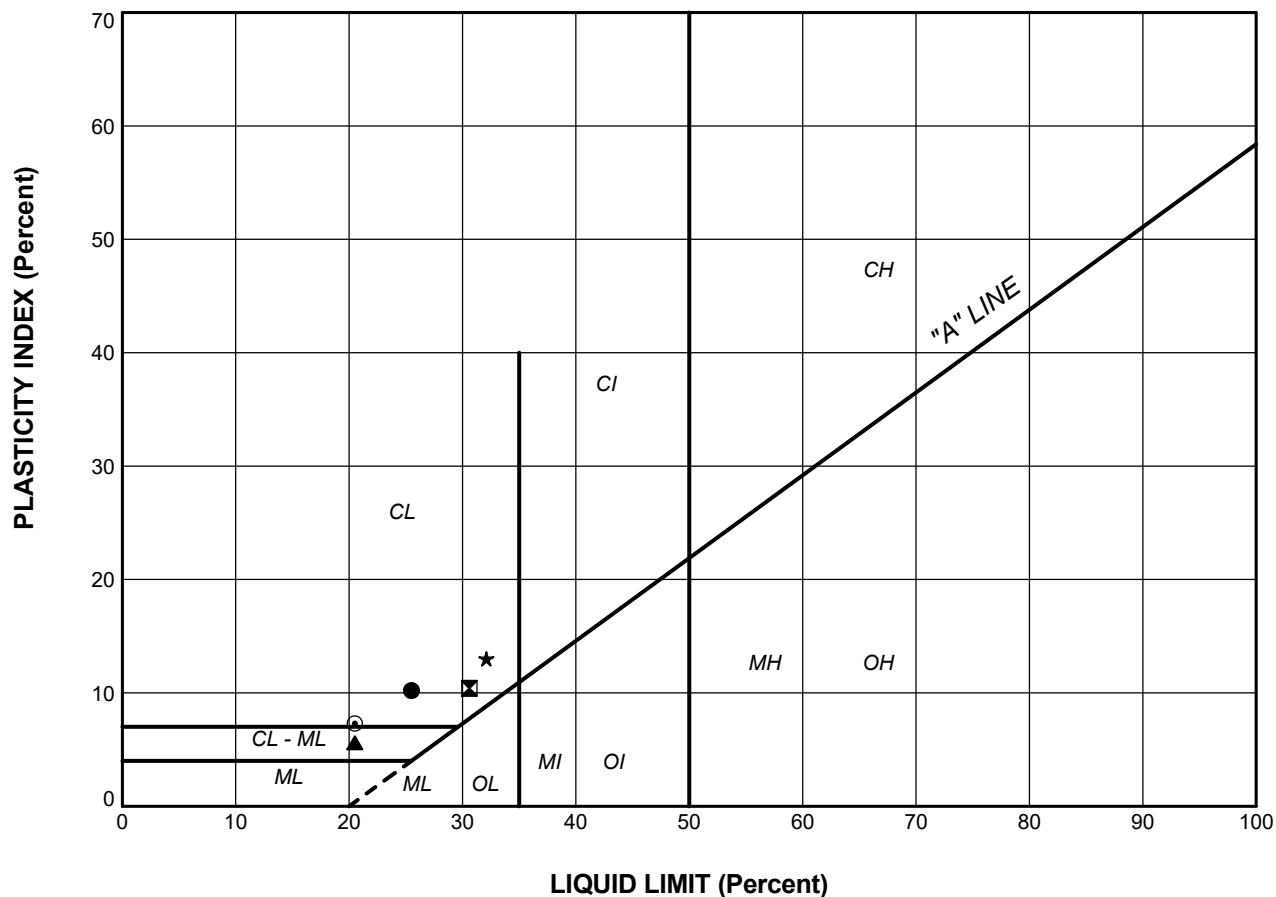


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-1	5	318.1

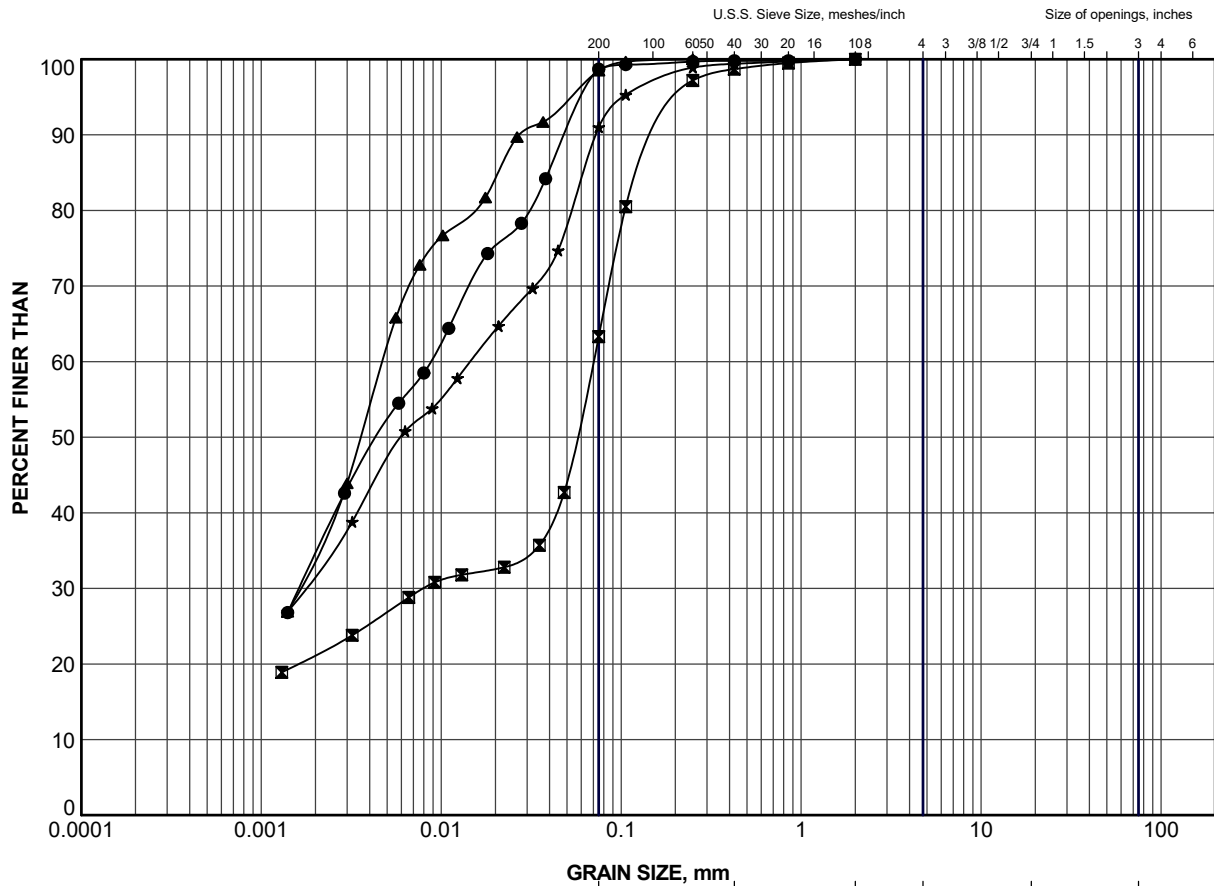
PROJECT						HIGHWAY 66 STATION 12+290 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Silt (Upper Deposit)					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Dec 2019	SCALE	N/A	REV.						
CHECK	AB	Dec 2019									
APPR	JMAC	Dec 2019									
 GOLDER SUDBURY, ONTARIO						FIGURE B-2					

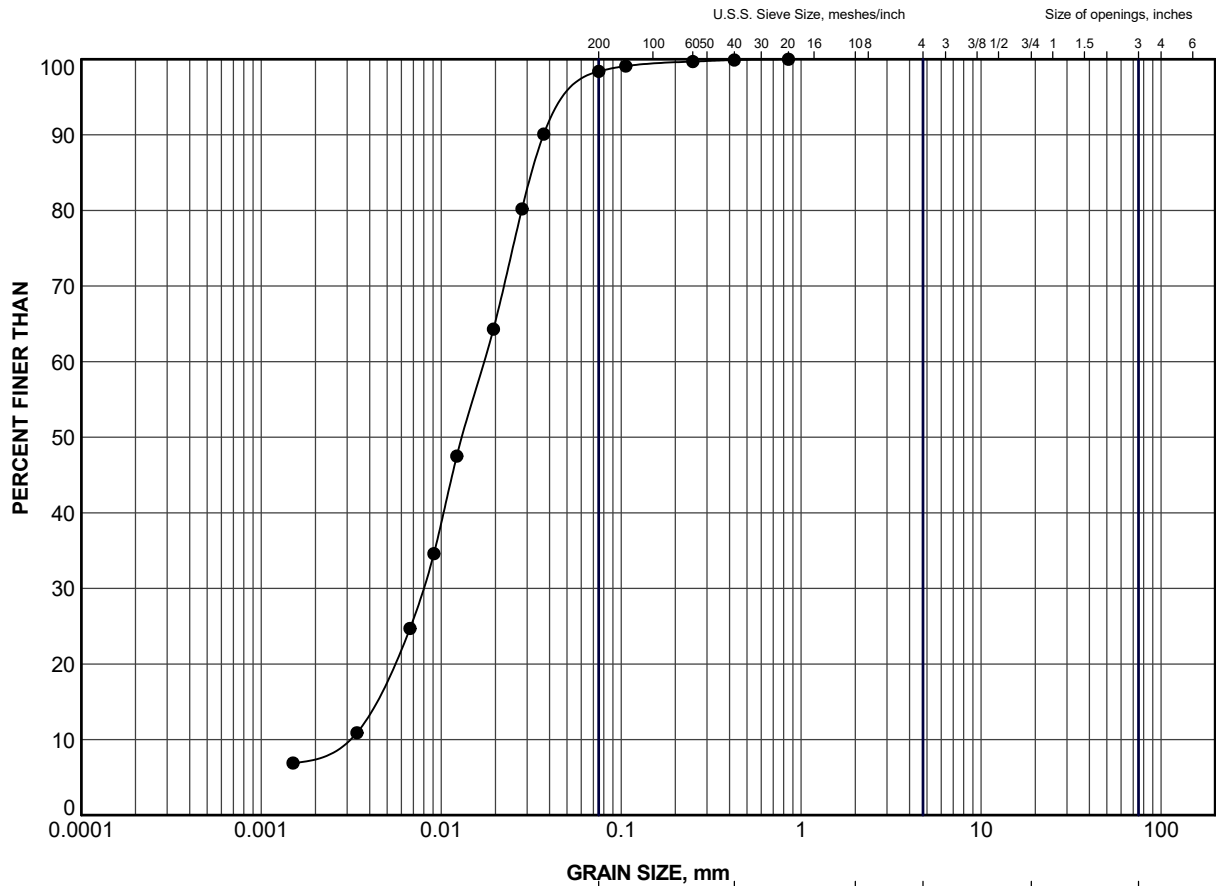


LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C207-1	6	25.5	15.3	10.2
⊠	C207-1	8	30.6	20.2	10.4
▲	C207-2	4	20.5	14.9	5.6
★	C207-2	7	32.1	19.1	13.0
⊙	C207-3	4	20.5	13.2	7.3

PROJECT						HIGHWAY 66 STATION 12+290 TOWNSHIP OF LEBEL CULVERT					
TITLE						PLASTICITY CHART Clayey Silt					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN		TR		Dec 2019		SCALE		N/A		REV.	
CHECK		AB		Dec 2019							
APPR		JMAC		Dec 2019							
GOLDER SUDBURY, ONTARIO						FIGURE B-3					




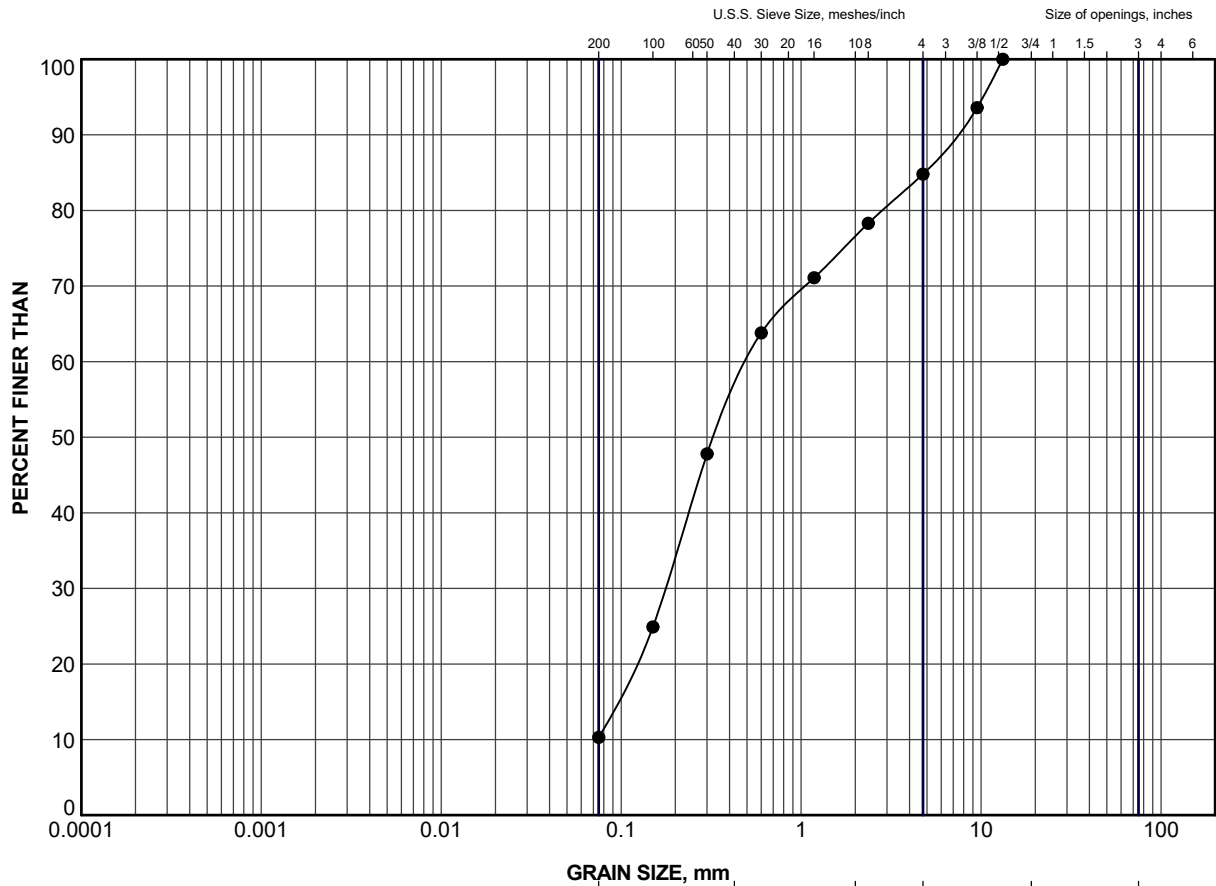


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-3	7	313.6

PROJECT						HIGHWAY 66 STATION 12+290 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Silt (Lower Deposit)					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Dec 2019	SCALE	N/A	REV.						
CHECK	AB	Dec 2019									
APPR	JMAC	Dec 2019									
 GOLDER SUDBURY, ONTARIO						FIGURE B-5					



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

LEGEND

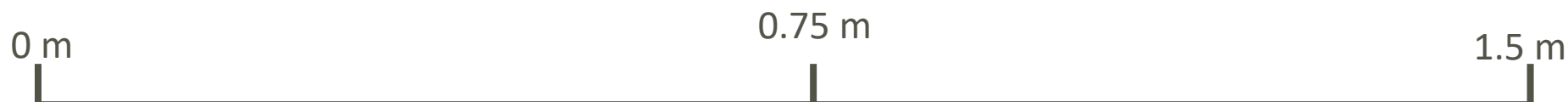
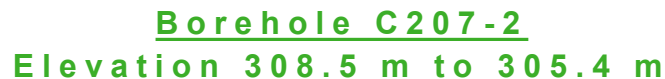
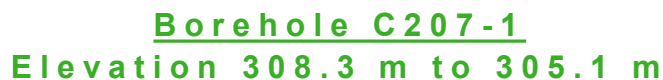
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C207-2	10	310.9

PROJECT						HIGHWAY 66 STATION 12+290 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Sand (Lower Deposit)					
PROJECT No.				1896349		FILE No.				1896349.GPJ	
DRAWN	TR	Dec 2019		SCALE	N/A	REV.					
CHECK	AB	Dec 2019									
APPR	JMAC	Dec 2019									
GOLDER				FIGURE B-6							
SUDBURY, ONTARIO											



Figure B-7

Highway 66, Station 12+290, Township of Lebel Culvert



RESULTS OF ANALYSES OF SOIL

Maxxam ID		IOM456			IOM456			IOM457		
Sampling Date		2018/12/12 11:15			2018/12/12 11:15			2018/12/12 10:30		
COC Number		62181			62181			62181		
	UNITS	C209-1A SA1	RDL	QC Batch	C209-1A SA1 Lab-Dup	RDL	QC Batch	C207-1 SA1	RDL	QC Batch
CONVENTIONALS										
Sulphide	ug/g	1.49 (1)	0.50	5910060				<0.50 (1)	0.50	5910060
Calculated Parameters										
Resistivity	ohm-cm	2300		5892786				5000		5892786
CONVENTIONALS										
Redox Potential	mV	240	N/A	5899469				240	N/A	5899469
Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g	220	20	5896372				39	20	5896372
Conductivity	umho/cm	443	2	5898721	447	2	5898721	201	2	5898721
Available (CaCl2) pH	pH	6.65		5898742				7.19		5898742
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5896374				<20	20	5896374
Physical Testing										
Moisture-Subcontracted	%	20	0.30	5910059				18	0.30	5910059
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable (1) The soil extract was prepared in the Maxxam Burnaby facility. The analysis was performed in the Maxxam Calgary facility.										

Maxxam ID		IOM457	
Sampling Date		2018/12/12 10:30	
COC Number		62181	
	UNITS	C207-1 SA1 Lab-Dup	QC Batch
Inorganics			
Available (CaCl2) pH	pH	7.24	5898742
QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate			



golder.com