



FINAL REPORT

## Foundation Investigation Report

*Potter Creek Tributary Culvert (Structure No. 11X/0421/C0)*

*Highway 401 Widening from 1 km West of Wallbridge-Loyalist Road to 4.3 km East of Highway 37, Belleville, Ontario*

*MTO GWP 4053-18-00, WP 4095-20-01, Agreement 4020-E-0012*

Submitted to:

**Ministry of Transportation Ontario**

1355 John Counter Boulevard  
Kingston, ON K7K 0E5

Submitted by:

**WSP Canada Inc.**

1931 Robertson Road, Ottawa, Ontario K2M 2J1

**GEOCREs No.: 31C-316**

**Latitude:** 44.180740°

**Longitude:** -77.450490°

20148061B-4100-R1

August 22, 2024



## Distribution List

1 e-copy: MTO Eastern Region

1 e-copy: MTO Foundations Section

1 e-copy: WSP Canada Inc.

# Table of Contents

<b>1.0 INTRODUCTION</b> .....	<b>4</b>
<b>2.0 SITE DESCRIPTION AND GEOLOGY</b> .....	<b>4</b>
2.1 Site Description .....	4
2.2 Regional Geology .....	4
<b>3.0 INVESTIGATION PROCEDURES</b> .....	<b>5</b>
<b>4.0 DESCRIPTION OF SUBSURFACE CONDITIONS</b> .....	<b>6</b>
4.1 General .....	6
4.1.1 Surface Cover/ Surficial Materials .....	6
4.1.2 Glacial Till .....	6
4.2 Bedrock .....	7
4.3 Groundwater Conditions .....	7
4.4 Analytical Laboratory Testing Results .....	8
<b>5.0 CLOSURE</b> .....	<b>9</b>
<b>TABLES</b>	
Table 1: Summary of Borehole Locations .....	6
Table 2: Summary of Bedrock Surface Depths and Elevations .....	7
Table 3: Summary of Groundwater Conditions .....	7
Table 4: Steel Corrosion and Sulphate Attack, Chemical Analysis .....	8
<b>DRAWING</b>	
Drawing 1 Borehole Locations and Soil Strata	

**APPENDICES**

**APPENDIX A**

Borehole Records and Bedrock Core Photographs

**APPENDIX B**

Geotechnical Laboratory Test Resultss

**APPENDIX C**

Results of Chemical Analysis

**APPENDIX D**

Site Photographs

## 1.0 INTRODUCTION

WSP Canada Inc. (WSP, formerly Golder Associates Ltd., amalgamated with WSP in 2023) has been retained by the Ministry of Transportation, Ontario (MTO) to support future procurement-ready design phases of the widening of Highway 401 from 1 km west of Wallbridge-Loyalist Road to 4.3 km east of Highway 37 in Belleville, Ontario as part of GWP 4053-18-00, with foundation investigation services delivered under MTO Agreement No. 4020-E-0012. The overall project includes the replacement of six bridges, several structural and non-structural culverts, and operational improvements and reconfiguration of existing interchanges.

This report presents the results of the detailed foundation investigation carried out for the new Potter Creek Tributary Culvert (Structure Site No. 11X-0421/C0) to be located to the northwest of the Highway 401 / Wallbridge-Loyalist Road interchange. It is noted that the Potter Creek tributary is now planned to follow a different alignment through the interchange, such that the culvert will no longer be constructed at the investigated location.

## 2.0 SITE DESCRIPTION AND GEOLOGY

### 2.1 Site Description

This location for the Potter Creek Tributary Culvert 11X-0421/C0 was to be located in the northwest quadrant of the Highway 401 / Wallbridge-Loyalist Road interchange. The culvert was proposed to pass under the proposed Highway 401 westbound onramp from Wallbridge-Loyalist Road (i.e., the N/S-W Ramp). The site location is shown on Drawing 1.

At this site, Highway 401 has a four-lane cross-section with two eastbound and two westbound through lanes with paved shoulders separated by a concrete median wall. Steel beam guiderails are also present along both sides of the highway in the vicinity of the underpass structure. The existing interchange includes a westbound offramp (existing E-N/S Ramp) and an eastbound onramp (existing W-N/S) at Wallbridge-Loyalist Road. Wallbridge-Loyalist Road is an undivided road with a single travel lane in each direction. Steel beam guide rails are present along both sides of Wallbridge-Loyalist Road in the vicinity of the underpass structure.

At present the area of the proposed culvert alignment is an undeveloped, open field with generally flat topography and is grass-covered. The site is bounded by an industrial property to the north, forested land to the west and the existing Highway 401 on-ramp to the south.

Site photographs showing the general conditions of the site are presented in Appendix D.

### 2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*<sup>1</sup>, the proposed culvert site lies within a physiographic region known as the Napanee Plain which is characterized as a flat-to-undulating plain of limestone of the Gull River and Bobcaygeon Formations overlain by glacially worked thin overburden deposits.

---

<sup>1</sup> Chapman, L. J. and Putnam, D. F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey. Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000. Ontario Ministry of Natural Resources

### 3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out on September 1, 2022, and included advancing two boreholes, (C-09 and C-10) in the general location of the proposed culvert alignment. The borehole locations are shown on Drawing 1.

The boreholes were advanced with a CME55 rubber track-mounted drill rig. The drilling equipment was supplied and operated by CCC Geotechnical & Environmental Drilling Ltd. (CCC) of Ottawa, Ontario.

Soil samples were obtained using a 50 mm outer diameter split-spoon sampler in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586<sup>2</sup>). Soil samples were obtained at vertical sampling intervals of about 0.76 m. Bedrock core samples were obtained at both borehole locations using rotary diamond drilling technique while retrieving NQ-sized core with a triple-tube core-barrel.

A monitoring well was installed in Borehole C-10, to observe the groundwater level at the site. The monitoring well consists of 52 mm outside diameter PVC tubing with a 1.5 m long slotted screen. Installation details are shown on the borehole record for Borehole C-10 provided in Appendix A.

The borehole without a monitoring well was backfilled with bentonite within the bedrock, and bentonite mixed with soil cuttings within the overburden. The borehole was backfilled in general accordance with the intent of Ontario Regulation (O.Reg.) 903, as amended. The site conditions were restored following the completion of the field work. The monitoring well has been left in place to allow for the monitoring of groundwater levels up to the time of the future design-build assignment. As part of the construction, the monitoring well will need to be decommissioned by qualified personnel in accordance with Ontario Regulation 903 (amended).

The field work was supervised on a full-time basis by members of WSP's technical staff who located the boreholes in the field, directed the drilling, sampling, and in-situ testing operations, and logged the boreholes. The soil and bedrock samples were identified in the field, placed in labelled containers, and transported to WSP's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, grain size distribution analyses, and Atterberg limits testing were carried out on selected soil samples and uniaxial compressive strength (UCS) testing was carried out on selected samples of the bedrock. The laboratory tests were carried out to MTO LS and/or ASTM Standards, as applicable at WSP's Ottawa laboratory.

Two soil samples were sent to Eurofins Environmental Testing Canada Inc. (Eurofins) for basic chemical analysis related to potential corrosion of buried steel elements and sulfate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by WSP using a Trimble R10 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The Trimble R10 GPS data has a vertical accuracy of approximately 0.1 m and a horizontal accuracy of approximately 0.5 m. The borehole locations, including northing and easting coordinates, ground surface elevations, and drilled depths are summarized in Table 1.

---

<sup>2</sup> ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

**Table 1: Summary of Borehole Locations**

Borehole	NAD83 CSRS CBNv6-2010.0 MTM Zone 9		Ground Surface Elevation (m)	Drilled Depths (m)	Comments
	Northing (m) (Latitude)	Easting (m) (Longitude)			
C-09	4893854.7 (44.180740°)	228804.5 (-77.450490°)	105.0	9.0	Bedrock Cored
C-10	4893819.7 (44.180420°)	228822.3 (-77.450260°)	102.6	6.1	Bedrock Cored

## 4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

### 4.1 General

The subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ testing from the investigation are shown on the borehole and drillhole records presented in Appendix A. The results of the in-situ field tests as presented in the borehole records and in Section 4.0, are uncorrected and are based on the use of an automatic hammer for the SPT. The results of the geotechnical laboratory testing carried out during the investigation are presented on the borehole records as well as on Figures B1 to B3 in Appendix B.

Photographs of the core recovered from the underlying bedrock at the boreholes are shown on Figures A1 to A4, provided in Appendix A. The results of the analytical testing completed on select soil samples are provided in Appendix C.

The borehole locations and the interpreted stratigraphic profiles projected along the proposed culvert alignment are provided in Drawing 1.

The stratigraphic boundaries shown on the borehole and drillhole records and on the interpreted stratigraphic section in Drawing 1 are inferred from observations of the drilling progress and noncontinuous soil sampling and therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

At the borehole locations, the subsurface conditions generally consist of topsoil over glacial till, underlain by bedrock.

A more detailed description of the overburdened soil deposits, and bedrock geology conditions encountered during the field investigation is provided in the following sections.

#### 4.1.1 Surface Cover/ Surficial Materials

Topsoil with a thickness of approximately 80 mm was encountered at the surface of both boreholes.

#### 4.1.2 Glacial Till

A glacial till deposit generally consisting of a soil matrix of silty clayey sand, containing some gravel as well as cobbles and boulders, was encountered below the topsoil at both boreholes. Coring techniques were required to advance through the cobbles and boulders at Borehole C-09. The top of this layer was encountered at Elevations 104.9 m and 102.5 m at Boreholes C-09 and C-10 respectively. The thickness of this layer ranges from about 3.0 m to 5.2 m. The Standard Penetration Test (SPT) N-values recorded in the till ranged from 5 to greater than 100 blows per 0.3 m of penetration indicating a firm to hard consistency or loose to very dense state of

compactness. Typically, the lower SPT N-values were measured in the upper portion of the deposit. The higher blow counts (e.g., 90/200 mm) recorded in the till may have been influenced by the presence of cobbles or boulders within the till, rather than the compactness of the soil matrix.

The measured water content of three samples of the glacial till ranged from 5% to 20%. The results of grain size analysis testing carried out on three samples of this material are provided in Figure B1 in Appendix B. The results of Atterberg limits testing completed on a single sample of the till material indicate a liquid limit of 39%, a plastic limit of 20%, and a plasticity index of 19. The Atterberg Limits analysis results are provided on Figure B2 in Appendix B and indicate that the fines portion of the till are silty clay of intermediate plasticity (CI).

## 4.2 Bedrock

The overburden materials are underlain by limestone bedrock. Bedrock core samples were obtained in both boreholes using an NQ-sized, triple-tube coring equipment.

Table 2 summarizes the depths and the elevations of the bedrock surface as encountered at the borehole locations.

**Table 2: Summary of Bedrock Surface Depths and Elevations**

Borehole	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
C-09	105.0	5.3	99.7
C-10	102.6	3.1	99.5

Rock Quality Designation (RQD) values measured on the recovered limestone bedrock core samples range from about 0% to 90%, but are typically 75% to 92%, indicating a good to excellent rock quality. The UCS testing carried out on two limestone bedrock core samples indicates compressive strength values of 84 MPa and 128 MPa, indicating a strong to very strong bedrock. The results of UCS testing are provided in Appendix B.

## 4.3 Groundwater Conditions

A monitoring well was installed in Borehole C-10 to measure the stabilized groundwater level at the site. The groundwater levels measured in the monitoring well are presented in Table 3.

It is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

**Table 3: Summary of Groundwater Conditions**

Borehole	Screened Interval	Ground Surface Elevation (m)	Groundwater Depth (m)	Groundwater Elevation (m)	Date
C-10	Glacial Till	102.6	0.9	101.7	September 20, 2022
			0.1	102.5	December 14, 2022

## 4.4 Analytical Laboratory Testing Results

Two soil samples were submitted to Eurofins for chemical testing/analysis related to the potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix C and are summarized in Table 4.

**Table 4: Steel Corrosion and Sulphate Attack, Chemical Analysis**

Borehole	Sample Depth (m)	Chloride (%)	Sulphate (%)	Electrical Conductivity (mS/cm)	pH	Resistivity (ohm-cm)
C-09	1.5-2.1	0.005	0.04	0.44	7.87	2,270
C-10	1.5-2.1	0.002	0.02	0.17	8.23	5,880

## 5.0 CLOSURE

This report was prepared by Ben Waechter, EIT, and reviewed by Kenton Power, P.Eng., a Senior Geotechnical Engineer with WSP. Lisa Coyne, P.Eng., a Geotechnical Engineering Fellow and MTO Principal Foundations Contact for WSP conducted an independent technical and quality review of this report.

### WSP Canada Inc.



Ben Waechter, EIT  
*Geotechnical Engineer-in-training*



Kenton Power, P.Eng.  
*Senior Geotechnical Engineer*



Lisa Coyne, P.Eng.  
*Fellow, MTO Principal Foundations Contact*

BW/KCP/LCC/yj

**DRAWING**

# **Drawing 1 – Borehole Locations and Soil Strata**



**APPENDIX A**

**Borehole Records and Bedrock Core Photographs**

# 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	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
SAND	Coarse	2.00 to 4.75	(10) to (4)
	Medium	0.425 to 2.00	(40) to (10)
	Fine	0.075 to 0.425	(200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

## MODIFIERS FOR SECONDARY COMPONENTS<sup>1,2</sup>

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)

- Only applicable to components not described by Primary Group Name.
- 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 cm<sup>2</sup> 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 <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_r$	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 <sub>4</sub>	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

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

## COARSE-GRAINED SOILS

### Compactness<sup>1</sup>

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

- 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.
- 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' <sup>1,2</sup> (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

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

$\pi$	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**

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta\sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	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 = $(w_L - w_P)$
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
$C_{\alpha(e)}$	secondary compression index
$C_{\alpha}$	rate of secondary compression
$C_{\alpha(e)}$	modified 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
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

**(d) Shear Strength**

$\tau_p, \tau_r$	peak and residual shear strength
$c'$	effective cohesion
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c_u, s_u$	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 or $q'$	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

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

**Notes:** 1  
2

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

# LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

## WEATHERING CLASSIFICATION

**Fresh (W1):** no visible sign of rock material weathering.

**Slightly Weathered (W2):** discoloration indicates weathering of rock mass material on discontinuity surfaces. **Less than 5%** of rock mass is altered or weathered.

**Moderately Weathered (W3): less than 50%** of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

**Highly Weathered (W4): more than 50%** of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

**Completely Weathered (W5): 100%** of the rock mass is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.

**Residual Soil (W6): all rock material is converted to soil.** The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

## BEDDING THICKNESS

Description	Bedding Plane Spacing
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

Description	Spacing
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

Term	Size*
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, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

## 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

AXJ Axial Joint	KV Karstic Void
BD Bedding	K Slickensided
BC Broken Core	LC Lost Core
CC Continuous Core	MB Mechanical Break
CL Closed	PL Planar
CO Contact	PO Polished
CU Curved	RO Rough
CT Coated	SA Slightly Altered
FLT Fault	SH Shear
FOL Foliation	SM Smooth
FR Fracture	SR Slightly Rough
GO Gouge	SY Stylolite
IN Infilled	UN Undulating
IR Irregular	VN Vein
JN Joint	VR Very Rough

## ISRM Intact Rock Material Strength Classification

Grade	Description	Approx. Range of Uniaxial Compressive Strength (MPa)
R0	Extremely weak rock	0.25 – 1.0
R1	Very weak rock	1.0 – 5.0
R2	Weak rock	5.0 – 25
R3	Medium strong rock	25 – 50
R4	Strong rock	50 -100
R5	Very strong rock	100 -250
R6	Extremely strong rock	>250



**RECORD OF BOREHOLE No C-09**      SHEET 1 OF 2      **METRIC**

PROJECT 20148061B      G.W.P. 4053-18-00      LOCATION N 4893854.7; E 228804.5 MTM NAD 83 ZONE 9 (LAT. 44.180740; LONG. -77.450490)      ORIGINATED BY BW

DIST Eastern      HWY 401      BOREHOLE TYPE Power Auger, 200 mm Dia. (Hollow Stem), NQ Coring      COMPILED BY RS

DATUM Geodetic      DATE September 2, 2022      CHECKED BY KCP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)						
						20	40	60	80	100	20	40	60	80	100	25	50	75	GR	SA	SI	CL	
105.0	GROUND SURFACE																						
0.0	TOPSOIL Brown Moist		1	SS	6																		
	CLAYEY SAND (SC) some gravel contains cobbles and boulders (TILL) Loose to dense Dark brown to brown Moist		2	SS	5																		18 39 25 18
			3	SS	7																		
	- Cobbles and boulders from 2.5 m to 5.3 m		4	SS	73/0.23																		
			5	SS	94/0.20																		17 38 33 12
			1	RC	-																		
			6	SS	55/0.08																		
			2	RC	-																		
			3	RC	-																		
99.7	LIMESTONE (BEDROCK)																						
5.3	Bedrock cored from 5.3 m to 9.0 m  For rock coring details see Record of Drillhole C-09		4	RC	REC 79%																		RQD = 79%
			5	RC	REC 100%																		RQD = 92%
			6	RC	REC 100%																		RQD = 75%
96.0	END OF BOREHOLE																						
9.0																							

GTA-MTO 001 S:\CLIENTS\MT\HWY\_401\_BELLEVILLE\02\_DATA\GINT\HWY\_401\_BELLEVILLE.GPJ GAL-GTA.GDT 8/20/24

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE





**RECORD OF BOREHOLE No C-10**      SHEET 1 OF 2      **METRIC**

PROJECT 20148061B      G.W.P. 4053-18-00      LOCATION N 4893819.7; E 228822.3 MTM NAD 83 ZONE 9 (LAT. 44.180420; LONG. -77.450260)      ORIGINATED BY BW

DIST Eastern      HWY 401      BOREHOLE TYPE Power Auger, 200 mm Dia. (Hollow Stem), NQ Coring      COMPILED BY RS

DATUM Geodetic      DATE September 1, 2022      CHECKED BY KCP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			20	40	60	80	100						20	40	60	80	100	25
102.6	GROUND SURFACE																					
0.9	TOPSOIL Dark brown Moist	1	SS	5																		
	CLAYEY SAND (SC) some gravel contains cobbles and boulders (TILL) Loose to dense Dark brown to brown Moist	2	SS	20																		
		3	SS	73																		
	- Cobbles and boulders from 2.5 m to 3.1 m	4	SS	50/0.20																		14 36 35 15
99.6	LIMESTONE (BEDROCK)																					
3.1	Bedrock cored from 3.1 m to 6.1 m  For rock coring details see Record of Drillhole C-10	1	RC	REC 96%																		RQD = 0%
		2	RC	REC 100%																		RQD = 90%
		3	RC	REC 95%																		RQD = 84%
96.5	END OF BOREHOLE																					
6.1	NOTE:  1. Water level measured in monitoring well:  Date      Depth (m)      Elev. (m) 20-Sep-22      0.9      101.7 14-Dec-22      0.1      102.5																					

GTA-MTO 001 S:\CLIENTS\MTOWHY\_401\_BELLEVILLE\02\_DATA\INT\HWY\_401\_BELLEVILLE.GPJ GAL-GTA.GDT 8/20/24

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE



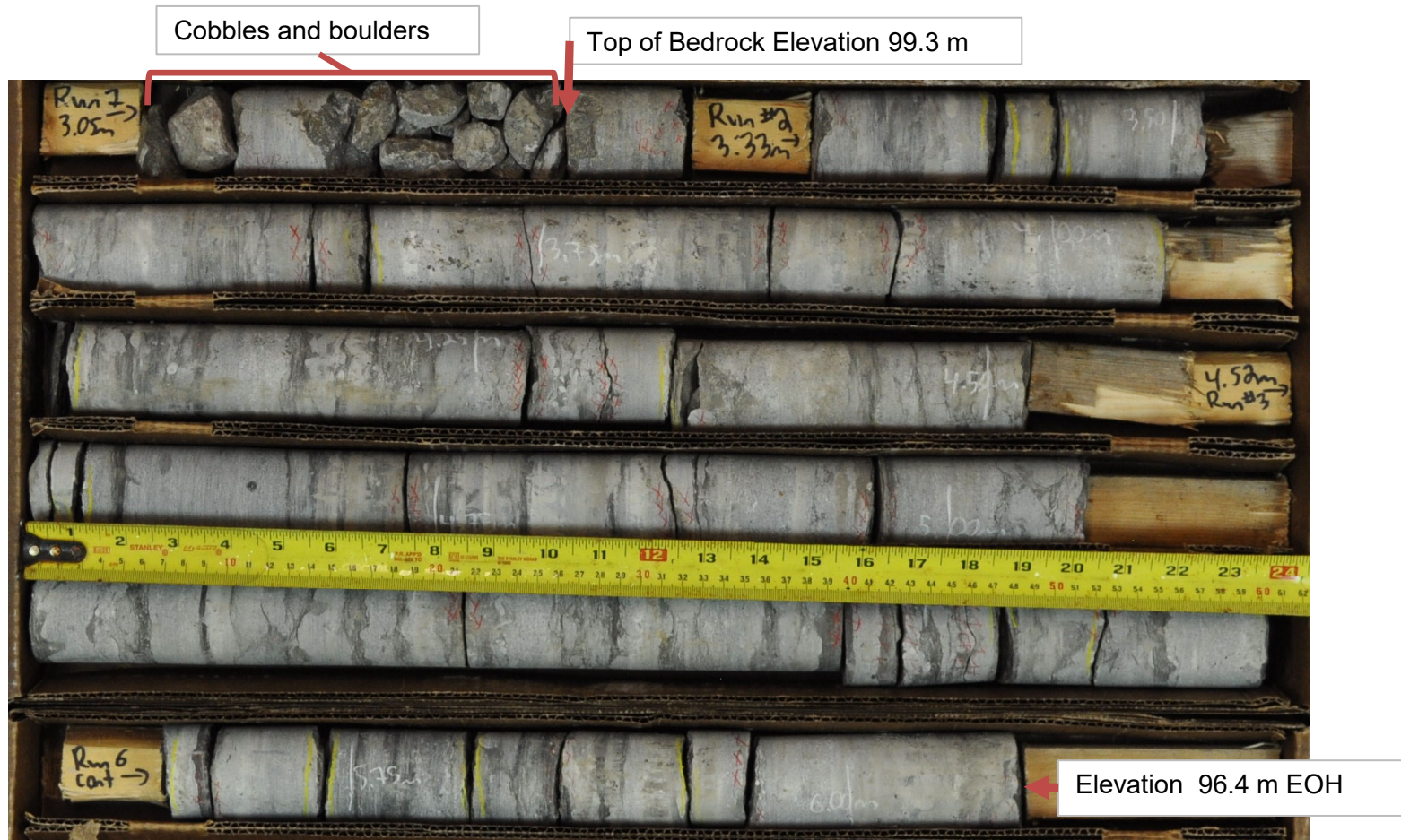
BH C-09 (Dry)  
Core Box 1 & 2 of 2



**BH C-09 (Wet)  
Core Box 1 & 2 of 2**



BH C-10 (Dry)  
Core Box 1 & 2 of 2



Foundations Investigation  
Structural Culvert 11X-0421/CO  
WP 4095-20-01

Highway 401 & Wallbridge-Loyalist Road, Belleville, Ontario

Project No.	20148061B
Drawn:	BW
Date:	2022-10-13
Checked:	KCP
Review:	LCC

Figure A3

BH C-10 (Wet)  
Core Box 1 & 2 of 2



Foundations Investigation  
Structural Culvert 11X-0421/CO  
WP 4095-20-01

Highway 401 & Wallbridge-Loyalist Road, Belleville, Ontario

Project No.	20148061B
Drawn:	BW
Date:	2022-10-13
Checked:	KCP
Review:	LCC

Figure A4

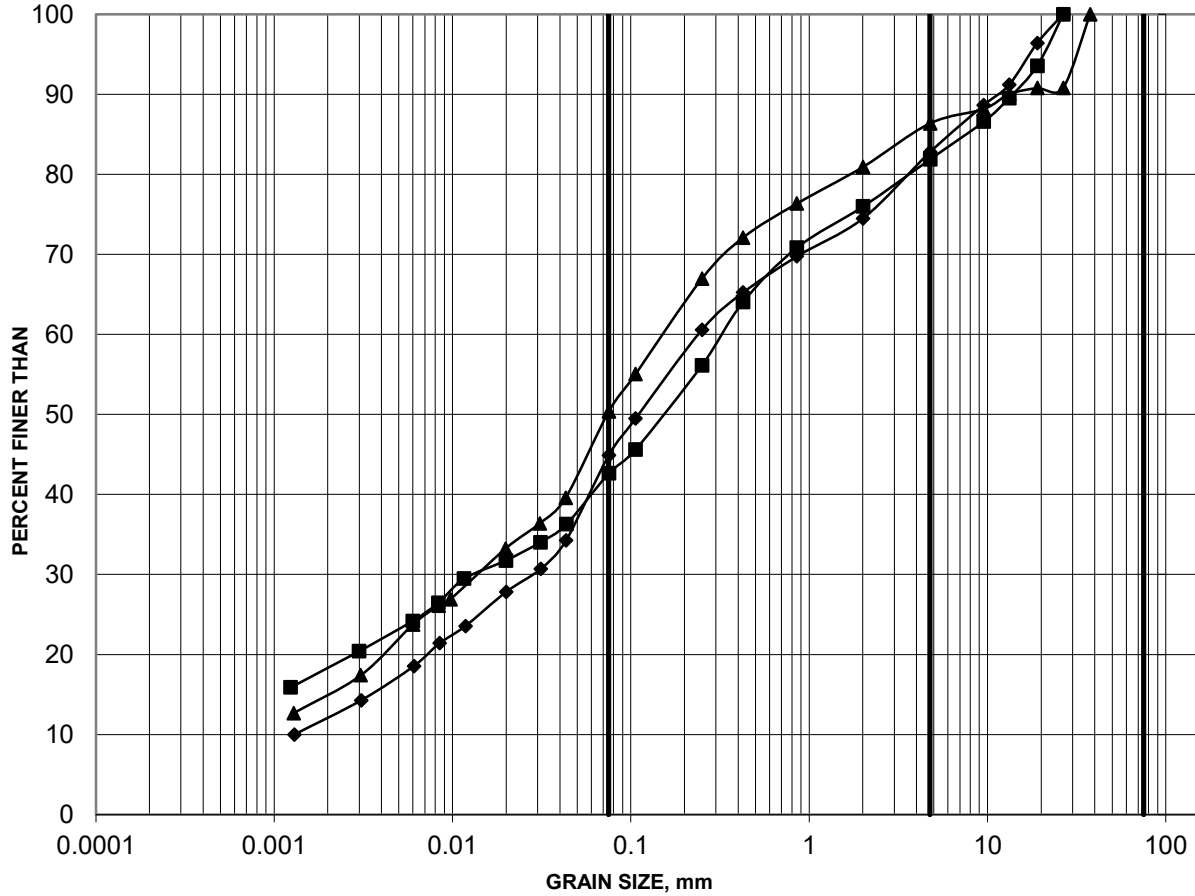
**APPENDIX B**

**Geotechnical Laboratory Test Results**

GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY CLAYEY SAND TO CLAYEY SAND AND SILT (TILL)



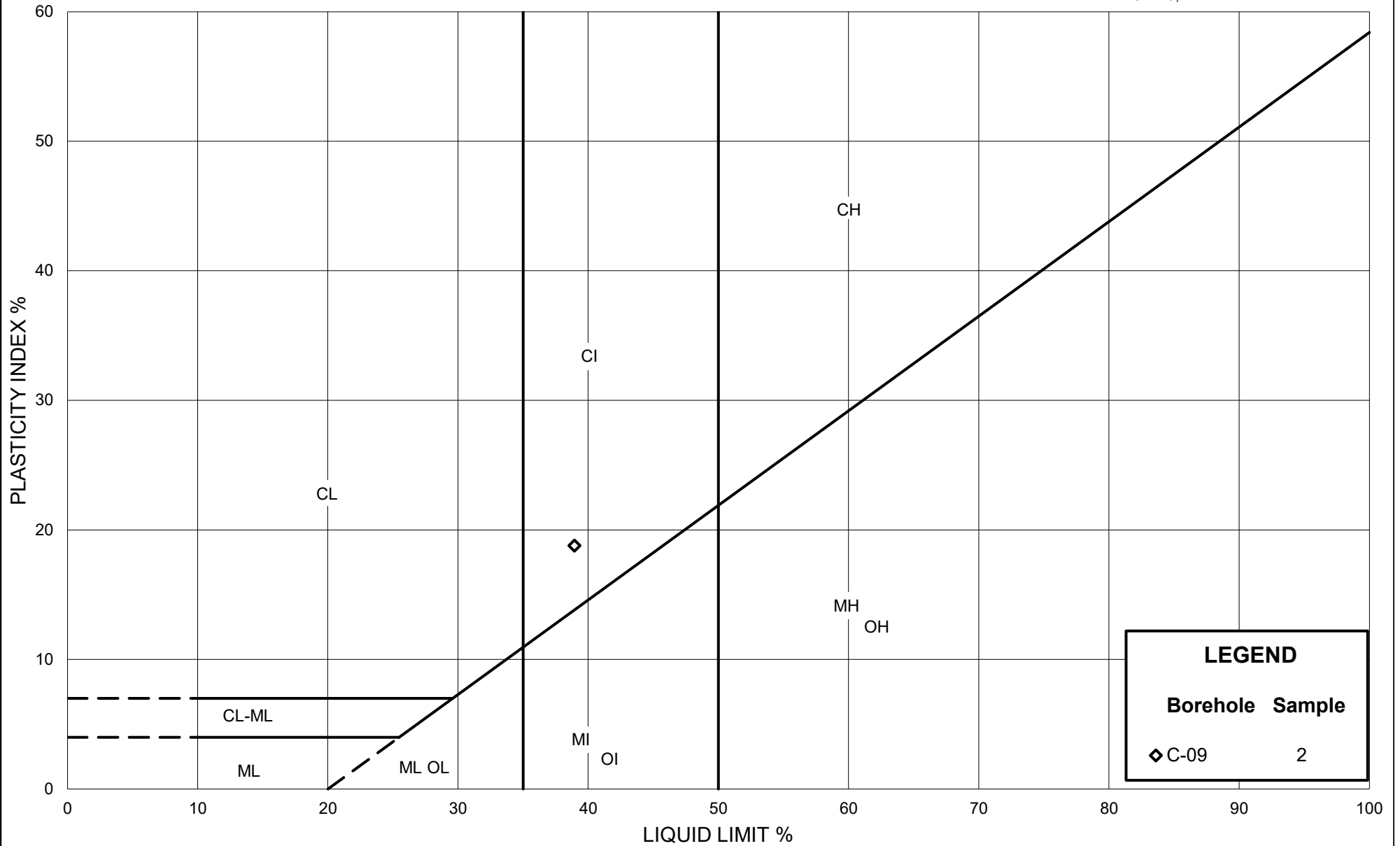
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)	Constituents (%)				
			Gravel	Sand	Silt	Clay	
■	C-09	2	0.76-1.37	18	39	25	18
◆	C-09	5	3.05-3.66	17	38	33	12
▲	C-10	4	2.29-2.90	14	36	35	15

Project: 20148061B/4100

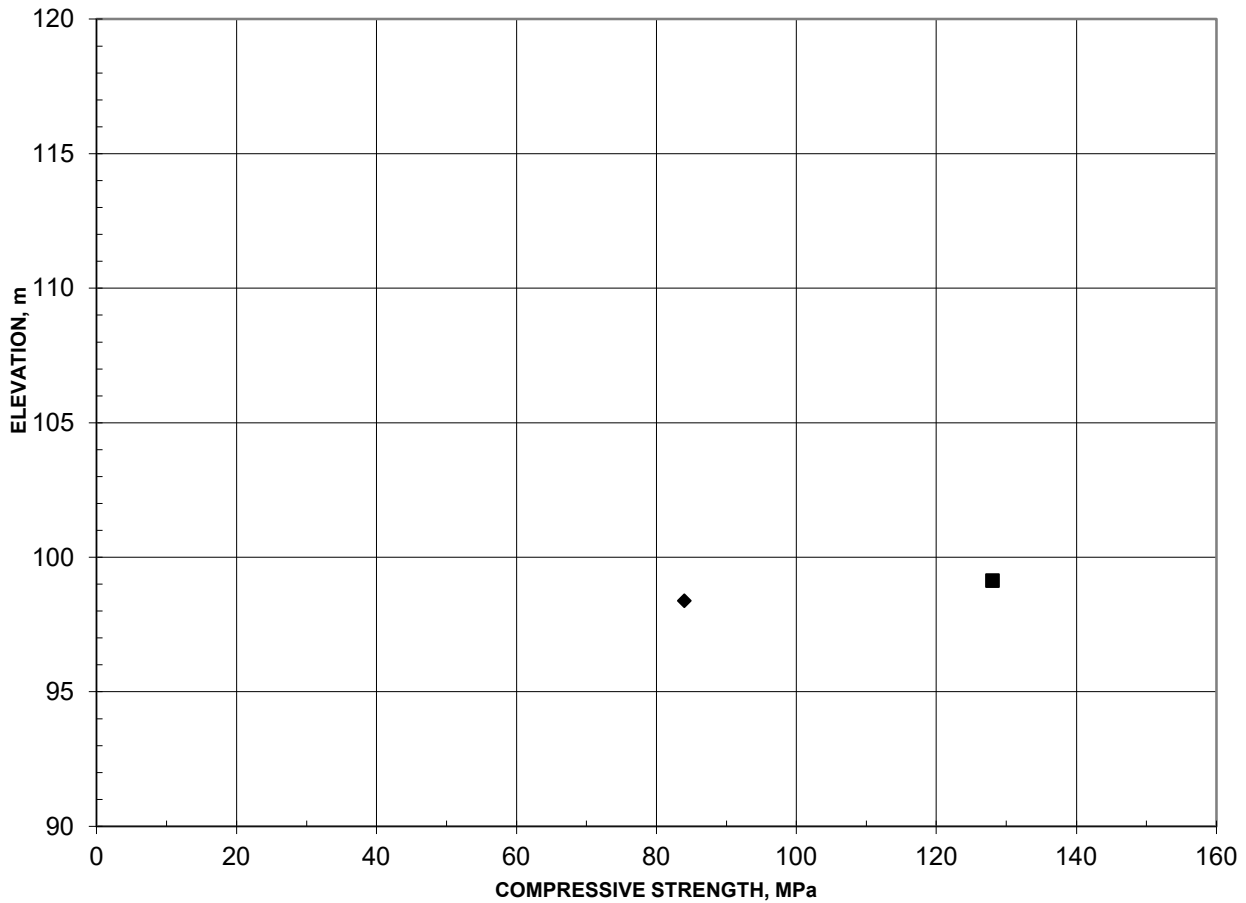


Created by: BW  
Checked by: MI



**ASTM D7012 - Method C**  
**UNIAXIAL COMPRESSIVE STRENGTH OF ROCK CORE**  
**SUMMARY OF LABORATORY TEST RESULTS**

**FIGURE B3**



	Borehole	Depth (m)	L/D	Bulk Density (kg/m <sup>3</sup> )	Lithology	UCS (MPa)	Failure Type
■	BHC-09 RC1	5.8	2.4	2668	Limestone	128	1
◆	BHC-10 RC1	4.2	2.4	2638	Limestone	84	1

**Notes:**

**Failure Types**

1. Well formed cones on both ends
2. Well formed cones on one end, vertical cracks through cap
3. Columnar vertical cracking through both ends
4. Diagonal fracture with no cracking through ends
5. Side fractures at top or bottom
6. Side fractures at both sides of top or bottom

**Remarks**

- Cores tested in vertical direction.
- Cores tested in air-dry condition.
- Time to failure > 2 and < 15 minutes.

Project: 20148061B/4100



Created by:	BW
Checked by:	MI

**APPENDIX C**

**Results of Chemical Analysis**

Client: Golder Associates Ltd (Ottawa)  
1931 Robertson Road,  
Ottawa, Ontario

Attention: Mr. Kenton Power

PO#:

Invoice to: Golder Associates Ltd

Report Number: 1986686  
Date Submitted: 2022-09-22  
Date Reported: 2022-09-29  
Project: Belleville 20148061B-1-162  
COC #: 900600

Page 1 of 3

---

**Dear Kenton Power:**

**Please find attached the analytical results for your samples. If you have any questions regarding this report, please do not hesitate to call (613-727-5692).**

Report Comments:

APPROVAL: \_\_\_\_\_

Emma-Dawn Ferguson, Chemist

All analysis is completed at Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) unless otherwise indicated.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by CALA, Canadian Association for Laboratory Accreditation to ISO/IEC 17025 for tests which appear on the scope of accreditation. The scope is available at: <https://directory.cala.ca/>.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is licensed by the Ontario Ministry of the Environment, Conservation, and Parks (MECP) for specific tests in drinking water (license #2318). A copy of the license is available upon request.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by the Ontario Ministry of Agriculture, Food, and Rural Affairs for specific tests in agricultural soils.

Please note: Field data, where presented on the report, has been provided by the client and is presented for informational purposes only. Guideline values listed on this report are provided for ease of use (informational purposes) only. Eurofins recommends consulting the official provincial or federal guideline as required. Unless otherwise stated, measurement uncertainty is not taken into account when determining guideline or regulatory exceedances.

**Certificate of Analysis**

Client: Golder Associates Ltd (Ottawa)  
1931 Robertson Road,  
Ottawa, Ontario

Attention: Mr. Kenton Power  
PO#: .  
Invoice to: Golder Associates Ltd

Report Number: 1986686  
Date Submitted: 2022-09-22  
Date Reported: 2022-09-29  
Project: Belleville 20148061B-1-162  
COC #: 900600

Group	Analyte	MRL	Units	Guideline	1652793 Soil 2022-09-08 H62-01 SS6 12.5-14.5'	1652794 Soil 2022-09-08 H62-09 SS3 5-7'	1652795 Soil 2022-09-15 C-01 SS2 2.5-4.5'	1652796 Soil 2022-09-14 C-08 SS4 7.5-9.5'
Anions	Cl	0.002	%		0.135	0.005	0.093	0.009
	SO4	0.01	%		0.03	0.02	0.02	0.02
General Chemistry	Electrical Conductivity	0.05	mS/cm		2.93	2.03	0.22	0.30
	pH	2.00			8.55	8.89	8.36	8.50
	Resistivity	1	ohm-cm		341	493	4540	3330

Group	Analyte	MRL	Units	Guideline	1652797 Soil 2022-08-31 C-09 SS3 5-7'	1652798 Soil 2022-09-07 C-10 SS3 5-6.75'	1652799 Soil 2022-09-13 H-37-02 SS2 2.5-4.5'	1652800 Soil 2022-09-13 H37-01 SS3 5-7'
Anions	Cl	0.002	%		0.005	0.002	0.002	0.014
	SO4	0.01	%		0.04	0.02	0.02	0.03
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.44	0.17	0.17	0.17
	pH	2.00			7.87	8.23	8.20	8.56
	Resistivity	1	ohm-cm		2270	5880	5880	2130

**Guideline =** \* = **Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.  
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

**Certificate of Analysis**

Client: Golder Associates Ltd (Ottawa)  
1931 Robertson Road,  
Ottawa, Ontario

Attention: Mr. Kenton Power  
PO#:

Invoice to: Golder Associates Ltd

Report Number: 1986686  
Date Submitted: 2022-09-22  
Date Reported: 2022-09-29  
Project: Belleville 20148061B-1-162  
COC #: 900600

**QC Summary**

Analyte	Blank	QC % Rec	QC Limits
<b>Run No</b> 430396 <b>Analysis/Extraction Date</b> 2022-09-27 <b>Analyst</b> IP <b>Method</b> Cond-Soil			
Electrical Conductivity	<0.05 mS/cm	101	90-110
pH	7.85	100	90-110
Resistivity			
<b>Run No</b> 430430 <b>Analysis/Extraction Date</b> 2022-09-28 <b>Analyst</b> AA <b>Method</b> C CSA A23.2-4B			
Chloride	<0.002 %		90-110
<b>Run No</b> 430473 <b>Analysis/Extraction Date</b> 2022-09-28 <b>Analyst</b> IP <b>Method</b> AG SOIL			
SO4	<0.01 %	98	70-130

**Guideline =**

**\* = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.  
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

**APPENDIX D**

**Site Photographs**



*Photograph 1: Looking north from Borehole C-09*



*Photograph 2: Looking southeast from Borehole C-10 towards Highway 401 westbound on-ramp.*

wsp

wsp.com