FOUNDATION INVESTIGATION REPORT

Cumming's Creek Culvert, Site No. 38S-0375/C0
Highway 129, Algoma District, Gould Township
Ministry of Transportation, Ontario
GWP 5074-07-00, WP 5271-14-01

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PART A

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HIGHWAY 129, TOWNSHIP OF GOULD, ALGOMA DISTRICT
MINISTRY OF TRANSPORTATION, ONTARIO
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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 for the replacement of the Cumming's Creek Culvert (Site 38S-0375/C0). The Cumming's Creek Culvert is located on Highway 129 at about Station 13+831, approximately 3.7 km north of Highway 554 in Algoma District, in the Township of Gould, Ontario. The Key Plan of the general location of this section of Highway 129 and the location of the investigated area is shown on Drawing 1.

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

The Terms of Reference (TOR) and the Scope of Services for the foundation investigation are outlined in MTO's Request for Proposal (RFP), dated March 2018. Golder's proposal April 3, 2018, for Foundation Engineering services associated with the replacement of this structure is contained in Section 7.7 of AECOM's technical proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for Foundation Engineering services for this project, dated July 19, 2018, and subsequent discussions with MTO and AECOM.

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 referenced to project north and therefore may differ from magnetic north shown on the foundations drawing. For the purpose of this report, Highway 129 is oriented in a north-south direction with the culvert on an east-west orientation on a slight skew from perpendicular to the highway.

In general, the topography in the vicinity of the culvert is relatively flat with moderate to thick tree cover beyond the toes of the highway embankment and creek channel. Within the existing culvert channel at both the inlet and outlet, there are visible bedrock outcroppings and a concrete overflow weir located about 10 m to the east of the east end (inlet of the culvert), controlling the Cumming's Lake outflow into the creek. The outlet of the Cumming's Creek culvert directs flow westerly into Tunnel Lake. At the culvert location, the highway grade is approximately Elevation 283.3 m and the highway embankment is about 6 m to 7 m high relative to the existing culvert invert and constructed with the side slopes inclined at about 1.5 horizontal to 1 vertical (1.5H:1V) to 1.75H:1V.

Based on the General Arrangement (GA) drawing provided by AECOM (drawing 60580589-GA-Golder.dwg, received February 19, 2019), the existing Cumming's Creek Culvert consists of a reinforced, cast-in-place open footing concrete structure, which was constructed in 1949. The culvert is 4.3 m wide and 2.7 m high and 30.4 m long. The existing culvert invert is Elevations 276.5 m and 276.4 m at the east (inlet) end and west (outlet) end, respectively. The ground surface conditions at the culvert location are shown on Photographs 1 to 6.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out between August 20 and 22, 2018, during which time three boreholes (Boreholes CC-1 to CC-3) were advanced at approximately the locations shown on Drawing 1. The boreholes were advanced from the roadway platform using a track-mounted CME-55 drilling rig, supplied and operated by Downing Drilling Inc. (Downing) of Grenville-sur-la-rouge, Quebec. Traffic control was performed in accordance with the Ontario Traffic Control Manual Book 7 – Temporary Conditions by LeRoy Construction of Blind River, Ontario.

The boreholes were advanced using HW/NW casing with wash boring techniques and NQ or HQ coring, using water from the local creek for wash boring and coring operations. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). Groundwater conditions and the groundwater level inside the casing were observed during the drilling operations. The boreholes were backfilled to near ground (pavement) surface upon completion in accordance with Ontario Regulation 903 Wells (as amended) and the surface zone was capped with cold patch asphalt.

Field work was monitored 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 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 tests were carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards as applicable.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) and Uniaxial Compressive Strength (UCS) are described based on Table 3.10 and Table 3.5, respectively, of the Canadian Foundation Engineering Manual (CFEM, 2006)[1]. The degree of weathering of the bedrock samples (i.e., fresh) and the strength classification of the intact rock mass based on field identification (i.e., strong to very strong) are described in accordance with table B.3 and B.6, respectively, of the International Society for Rock Mechanics (ISRM)[2] standard classification system.

One sample of sand and gravel fill was obtained during the field exploration at the culvert location on August 22, 2018, using appropriate sampling protocols, and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters including pH, resistivity, conductivity, sulphates, and chlorides.

The as-drilled borehole locations were measured by a member of our technical staff, referenced to the highway centerline, existing culvert structure and highway stationing/chainage, and converted into northing/easting coordinates on the plan drawing. The ground surface elevations were surveyed relative to the centerline of the roadway and the Geodetic elevation of the benchmark was obtained from the plan drawing (B099601290001.dwg) provided by AECOM. The MTM NAD 83 (Zone 12) CSRS CBNv6-2010.0 northing and easting coordinates and World Geodetic System 1984 (WGS 84) 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.

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[1] Canadian Geotechnical Society 2006. Canadian Foundation Engineering Manual, 4th Edition

[2] International Society for Rock Mechanics Commission on Test Method, 1985. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. Vol 22, No. 2. Pp. 51-60.

Borehole Number	Location (MTM NAD 83, Zone 12)		Location (WGS 84)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting	Latitude	Longitude		
CC-1	5146581.0	353849.8	46.457120	-80.361456	283.5	9.5*
CC-2	5146570.2	353857.2	46.457023	-80.361361	282.9	10.4*
CC-3	5146569.5	353849.9	46.457017	-80.361456	283.3	10.0*

Note: *Includes 2.8 m, 2.7 m and 3.2m of bedrock coring, respectively

Golder surveyed the exposed bedrock outcrops near the culvert inlet and outlet and the bedrock surface is at Elevations 276.8 m and 276.2 m, respectively, at the approximate locations shown on Drawing 1.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on the Northern Ontario Engineering Geology Terrain (NOEGTS)[3] mapping, the Cumming's Creek Culvert site is located within jagged, rugged and cliffed bedrock knobs.

Based on geological mapping by the Ontario Ministry of Northern Development and Mines (MNDM)[4], the site is underlain by bedrock of the Cobalt group consisting of conglomerate, wacke, arkose, quartz, arenite and argillite.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the 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) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile and cross-section 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.

In summary, the subsoil conditions encountered at the site consist of sand to sand and gravel to gravel fill containing dispersed cobbles/boulders throughout, underlain by bedrock. A detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided in the following sections.

4.3 Embankment Fill

A 90 mm thick layer of asphalt was encountered at ground surface in all boreholes. Underlying the asphalt in the three boreholes, a 6.6 m to 7.7 m thick layer of granular fill was encountered. The granular fill consists of brown to

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[3] Ministry of Natural Resources, Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41JSW

[4] Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey - Map 2543

grey, moist to wet, sand to sand and gravel to gravel, trace silt. Cobbles and boulders ranging in size from 75 mm to 450 mm in size were encountered within the fill in Borehole CC-1, a 220 mm cobble, wood and gravel fragments were encountered within the fill in Borehole CC-2 and cobbles ranging in size from 75 mm to 500 mm were encountered within the fill in Borehole CC-3, as noted on the Record of Boreholes. These zones of coarse materials required HW/NW casing and/or HQ/NQ coring techniques to advance the borehole through the strata. Further, occasional instances of SPT ‘N’-value testing and sampling resulted in small size samples or empty split-spoon being recovered in Boreholes CC-1 to CC-3, inferred indicative of the potential presence of coarse gravel, cobbles and boulders.

Standard Penetration Test (SPT) ‘N’-values measured within the sand to sand and gravel fill range from 4 blows to 108 blows per 0.3 m of penetration indicating a loose to very dense level of compactness. In three instances, the split spoon sampler did not penetrate the entire SPT depth due to refusal conditions (i.e., split spoon bouncing) on inferred cobbles and/or boulders; show cobble and boulder size material (including rock fill are present) along the existing highway embankment side slopes as shown on Photographs 1 to 4.

The natural moisture content measured on seven samples of the sand to sand and gravel to gravel fill range from 1 per cent to 13 per cent.

The results of the grain size distribution tests completed on seven samples of the sand to sand and gravel to gravel fill are shown on Figure B-1 in Appendix B.

4.4 Bedrock

Bedrock was cored in Boreholes CC-1 to CC-3 and the depth to /elevation of the bedrock surface is presented below.

Borehole No.	Depth to Bedrock (m)	Bedrock Surface Elevation (m)	Bedrock Core Length (m)
CC-1	6.7	276.8	2.8
CC-2	7.2	275.2	2.7
CC-3	6.8	276.5	3.2

Further, as noted above in Section 3.0, the exposed bedrock near the culvert inlet and outlet at the approximate locations shown on Drawing 1 was surveyed at Elevations 276.8 m and 276.2 m, respectively.

The retrieved bedrock core is described as slightly weathered to fresh, very fine to fine grained, dark grey to light grey/pink wacke and conglomerate. Additional details of the bedrock cores are presented in the Record of Drillhole sheets in Appendix A, including data on the discontinuity frequency and type. Photographs of the retrieved bedrock core samples are shown on Figure B-2 in Appendix B and the results of an unconfined compression (UC) tests are presented on Figures B-3A and B-3B also in Appendix B. The bedrock properties, as encountered in the boreholes, are summarized below.

Borehole No. (Run)	Total Core Recovery (TCR)	Rock Quality Designation (RQD)	Quality Classification (Table 3.10 of CFEM 2006[1])	Uniaxial Compressive Strength (MPa)	Strength Classification (Table 3.5 of CFEM 2006)
CC-1 (#2)	91 - 100%	40 - 85%	Poor to Good	39	(R3 – Medium Strong)
CC-2 (#2)	93 - 98%	55 - 60%	Fair	100	(R4 – Strong)
CC-3 (#3)	89 - 94%	15 - 65%	Very Poor to Fair	138	(R5 – Very Strong)

4.5 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes (within the casing) upon completion of drilling are summarized below. The creek water level was measured by others at approximately Elevation 276.5 m, in July 2018. During Golder's August 2018 investigation there was very little flow within the creek channel (see Photographs 1 to 4). Groundwater and creek 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)
CC-1	6.2	277.3*
CC-2	5.9	277.0*
CC-3	4.7	278.6*

Note: As boreholes were advanced using HW/NW casing and wash boring techniques, the measured groundwater level may not be representative of the in-situ groundwater conditions.

4.6 Analytical Testing of Soil

The results of the analytical testing of one sample of sand and gravel fill from Borehole CC-3, submitted to Maxxam Analytics Inc. an accredited analytical testing laboratory, are detailed laboratory test report (Certificate of Analysis) is included in Appendix C and summarized in the table below:

Parameter	Units	Results CC-3, Sample 3*
Resistivity	ohm-cm	7200
Conductivity	µmho/cm	139
pH	pH	6.79
Sulphate	µg/g	Not Detected (RDL<20)**
Chloride	µg/g	48

Notes: *Sample obtained August 22, 2018. ** Concentration is lower that Reportable Detection Limit (RDL).

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Tibor Berecz under the overall direction of Mr. David Muldowney, P.Eng. This Foundation Investigation Report was prepared by Ms. Aronne-Kay De Souza, EIT, and Mr. Adam Core, P.Eng. provided a technical review of the report. Mr. Jorge M. A. Costa, P. Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

Signature Page

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Table 1: Comparison of Alternative Culvert Types

Option	Advantages	Disadvantages	Risks/Consequences
Open Footing Culvert on Cast-In-Place Footings	■ More accommodating to variations in bedrock elevation. ■ Minimized bedrock excavation requirements compacted to a box culvert option. ■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Readily suitable for construction using precast concrete or metal sections connected to concrete footings. ■ No settlement expected as footings are founded on bedrock.	■ Will take longer to construct cast-in-place footings. ■ Will require water diversion of the creek water away from footing footprint and pumping for construction of footing in dry conditions.	■ Low risk related to settlement performance.
Box Culvert	■ Concrete levelling pad/backfill/bedding under the culvert may be placed in water or in wet conditions (i.e., Granular ‘B’ Type II) minimizing or reducing water pumping requirements. ■ Allows faster construction resulting in shorter duration for dewatering and surface water pumping. ■ Variations in bedrock elevation can be accounted for with mass concrete or by a granular bedding layer.	■ Bedrock excavation or levelling course of concrete or granular bedding required across the full width/length of the culvert. ■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Cut-off wall (or clay seal) required at inlet end if granular bedding used to level culvert footprint and potentially at the outlet end, to mitigate potential scour under culvert.	■ Low risk related to settlement performance as box segments can accommodate some total and differential settlement. ■ Moderate risk bedrock excavation may be required to reach desired invert elevations.
Pipe Culvert(s)	■ Variations in bedrock elevation can be accounted for with mass concrete or by a granular bedding layer. ■ Allows for faster construction resulting in shorter duration for dewatering and surface pumping compared to an open footing culvert.	■ Bedrock excavation required to reach desired grade/invert elevations. ■ Reduced flow-through capacity compared to box culvert and open footing options with a similar span – additional flow through capacity may have to be provided by multiple pipes. ■ Cut-off wall or clay seal may be required at inlet to mitigate potential scour under culvert(s) if	■ Low risk related to anticipated differential settlement compared to open footing option. ■ Moderate risk bedrock excavation may be required to reach desired invert elevations.

Option	Advantages	Disadvantages	Risks/Consequences
	▪ More tolerant of total and differential settlement if subgrade footprint is levelled by granular bedding of varying thickness transitions from bedrock to engineered fill overlying bedrock. ▪ Backfill/bedding under the culvert (if applicable) may be placed in water or in wet conditions (i.e., Granular 'B' Type II) minimizing or reducing water pumping requirements.	granular bedding is used to create founding pad on design grade/invert. ▪ Difficult to shape and compact backfill materials to level of culvert springline, particularly if seepage water is present. ▪ CSP does not have as long of design life compared to concrete options.	

Photograph 1: East End (Inlet) and Exposed Bedrock (August 2018)

Photograph 2: East End (Inlet) and Concrete Weir near Right-of-Way (August 2018)

Photograph 3: West End (Outlet) (August 2018)

Photograph 4: West End (Outlet) and Exposed Bedrock at Invert (August 2018)

Photograph 5: Hwy 129 in Culvert area, facing North (August 2018)

Photograph 6: Hwy 129 in Culvert area facing South (August 2018)

APPENDIX A

Record of Boreholes and Drillholes

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

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

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d:

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

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils

Consistency

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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

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

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, 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 90º 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		

RECORD OF BOREHOLE No CC-1

1 OF 1 **METRIC**

PROJECT 1898445

G.W.P. 5074-07-00

LOCATION N 5146581.0; E 353849.8 NAD83 MTM ZONE 12 (LAT. 46.45712; LONG. -80.361456)

ORIGINATED BY TB

DIST ______ HWY 129

BOREHOLE TYPE NW Casing and NQ Coring

COMPILED BY TR

DATUM GEODETIC

DATE August 21, 2018

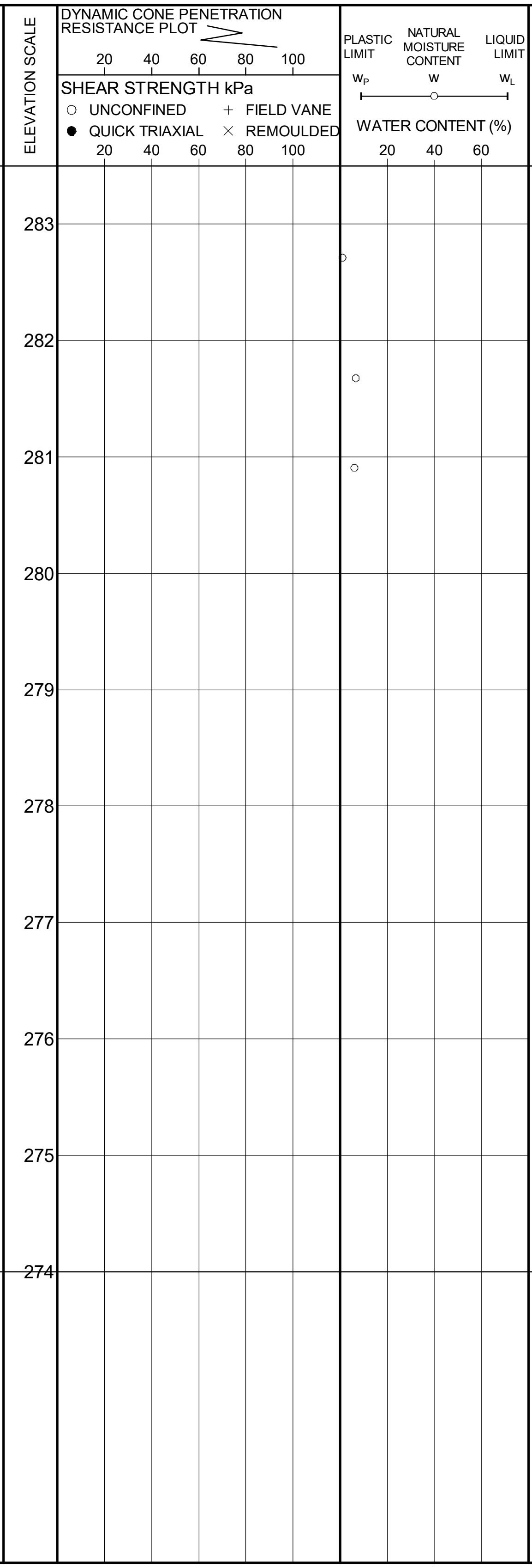
CHECKED BY AC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
283.5	GROUND SURFACE					
0.0 0.1	ASPHALT (90 mm)					
	Sand and gravel to gravel, trace to some sand (FILL) Dense to very dense Brown to grey Moist to wet	1	SS	68		
		2	SS	56/0.1		88 10 (2)
	Split-spoon refusal (i.e. hammer bouncing) at 0.8 m depth. Switched to NQ Coring at 0.8 m depth.	-	RC	REC=67%		
	Cobbles and boulders encountered as follows:	3	SS	53		41 51 (8)
		-	RC	REC=50%		
		4	SS	66		34 55 (11)
		-	RC	REC=100%		
		5	SS	34		
	Limited recovery in Samples 5 and 6.	-	RC	REC=73%		
		6	SS	65		
		-	RC	REC=34%		
		-	RC	REC=15%	▽	
276.8 6.7	WACKE (BEDROCK) Bedrock cored from 6.7 m to 9.5 m depth. For coring details see Record of Drillhole CC-1.	1	RC	REC 91%		RQD = 40%
		2	RC	REC 93%		RQD = 75%
		3	RC	REC 100%		RQD = 85%
274.0 9.5	END OF BOREHOLE					

Depth (m)	Size (mm)
1.1	450
2.4	75
3.1	180
4.0	110
4.4	90
4.6	420
6.4	90

Note:

1. Water level at a depth of 6.2 m below ground surface (Elev. 277.3 m) inside casing upon completion of coring.



UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

PROJECT: 1898445
LOCATION: N 5146581.0; E 353849.8
NAD83 MTM ZONE 12 (LAT. 46.45712; LONG. -80.361456)
INCLINATION: -90° AZIMUTH: ---

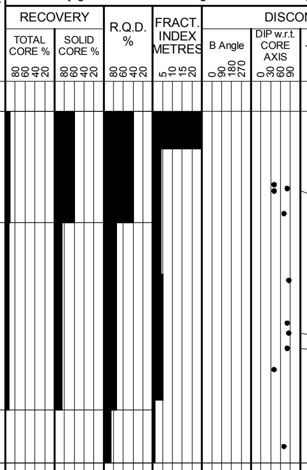
RECORD OF DRILLHOLE: CC-1

DRILLING DATE: August 21, 2018
DRILL RIG: CME55 - Track Mount
DRILLING CONTRACTOR: George Downing Estate Drilling

SHEET 1 OF 1
DATUM: GEODETIC

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN / FLUSH	TYPE AND SURFACE DESCRIPTION		
		BEDROCK SURFACE		276.8					
7	NW NQ Coring August 21, 2018	WACKE Medium Strong Fresh Fine grained Dark grey		6.7	1	Grey	BR 6.7m to 7.0m JNIRRo JNIRRo JNIRRo		
8					2	Grey	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo		UCS = 39 MPa
9				274.0 9.5	3	Grey	JNIRRo		
10		END OF DRILLHOLE							
11									
12									
13									
14									
15									
16									
17									
18									



Jr Ja Jn

HYDRAULIC CONDUCTIVITY k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}

Diametral Point Load Index (MPa) 2 4 6

RMC -Q' AVG.

DEPTH SCALE
1 : 60

GOLDER

LOGGED: TB
CHECKED: AC

RECORD OF BOREHOLE No CC-2

1 OF 1 **METRIC**

PROJECT 1898445

G.W.P. 5074-07-00

LOCATION N 5146570.2; E 353857.2 NAD83 MTM ZONE 12 (LAT. 46.457023; LONG. -80.361361)

ORIGINATED BY TB

DIST ______ HWY 129

BOREHOLE TYPE NW Casing and NQ Coring

COMPILED BY TR

DATUM GEODETIC

DATE August 22, 2018

CHECKED BY AC

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
282.9	GROUND SURFACE										
0.0	ASPHALT (90 mm)										
0.1	Sand, some gravel to gravel, some sand, trace silt (FILL) Loose to dense Brown to grey Moist to wet		1	SS	24						
			2	SS	34		282		○		64 35 (1)
			3	SS	31		281				
			4	SS	16		280		○		80 17 (3)
			5	SS	52/0.08						
	Split-spoon refusal (i.e. hammer bouncing) at 3.2 m depth. Switched to NQ Coring.		-	RC	REC=22%		279				
	A 220 mm diameter cobble encountered at 4.2 m depth.										
			6	SS	9		278		○		18 78 (4)
						∇	277				
	Wood fragments encountered at 6.1 m depth.		7	SS	33						
	Gravel fragments encountered from 6.7 m to 7.2 m depth.		-	RC	REC=60%		276				
	A 500 mm diameter boulder encountered at 7.2 m depth.		1	RC	REC 93						
275.2 7.7	WACKE (BEDROCK) Bedrock cored from 7.2 m to 10.4 m depth. For coring details see Record of Drillhole CC-2.		2	RC	REC 98%		275				RQD = 55%
							274				
			3	RC	REC 94%		273				RQD = 60%
272.5 10.4	END OF BOREHOLE Note: 1. Water level at a depth of 5.9 m below ground surface (Elev. 277.0 m) upon completion of drilling.										

$+^{3}, \times^{3}$: Numbers refer to Sensitivity

$\bigcirc^{3\%}$ STRAIN AT FAILURE

PROJECT: 1898445

RECORD OF DRILLHOLE: CC-2

SHEET 1 OF 1

LOCATION: N 5146570.2; E 353857.2
NAD83 MTM ZONE 12 (LAT. 46.457023; LONG. -80.361361)
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: August 22, 2018
DRILL RIG: CME55 - Track Mount
DRILLING CONTRACTOR: George Downing Estate Drilling

DATUM: GEODETIC

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	
		BEDROCK SURFACE		275.2											
8	NQ Coring August 22, 2018	WACKE, strongly brecciated from 7.7 m to 8.2 m, weakly brecciated from 8.2 m to 9.1 m Strong Fresh Very fine to fine grained Dark grey		7.7	2	Grey 100		JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo							USC = 100 MPa
9 10				272.5 10.4	3	Grey 100		JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo BR 10.0m to 10.2m JNIRRo							
11 12 13 14 15 16 17 18 19		END OF DRILLHOLE													

DEPTH SCALE
1 : 60

LOGGED: TB
CHECKED: AC

GOLDER

RECORD OF BOREHOLE No CC-3

1 OF 1 **METRIC**

PROJECT 1898445			
G.W.P. 5074-07-00	LOCATION N 5146569.5; E 353849.9 NAD83 MTM ZONE 12 (LAT. 46.457017; LONG. -80.361456)		ORIGINATED BY TB
DIST	HWY 129	BOREHOLE TYPE HW Casing and NQ/HQ Coring	COMPILED BY TR
DATUM GEODETIC		DATE August 20, 2018	CHECKED BY AC

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
283.3	GROUND SURFACE										
0.0	ASPHALT (90 mm)										
0.1	Sand and gravel (FILL) Loose to very dense Brown to grey Moist to wet		1	SS	55		283		○		45 49 (6)
	Split-spoon refusal (i.e. hammer bouncing) at 1.0 m depth. Switched to HQ coring. Cobbles encountered as follows:		2	SS	26/0.30						
			-	RC	REC=51%		282				
	Depth (m) Size (mm) 1.2 160 1.4 75 2.8 110		3	SS	108						
	Poor sample recovery within samples 4 to 7.		4	SS	39		281				
			-	RC	REC=73%						
			5	SS	32		280				
			6	SS	12		279				
			7	SS	7	▽	278				
			8	SS	4		277				
276.5 6.8	WACKE (BEDROCK) Bedrock cored from 6.8 m to 10.0 m depth. For coring details see Record of Drillhole CC-3.		1	RC	REC 89%		276				RQD = 15%
			2	RC	REC 89%		275				RQD = 60%
			3	RC	REC 94%		274				RQD = 65%
273.3 10.0	END OF BOREHOLE Note: 1. Water level at a depth of 4.7 m below ground surface (Elev. 278.6 m) upon completion of drilling.										

SUD-MTO 001 S:\CLIENTS\MTO\HWY129&546\02_DATA\GINT\1898445.GPJ GAL-MISS.GDT 5-3-19 TR

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

PROJECT: 1898445

RECORD OF DRILLHOLE: CC-3

SHEET 1 OF 1

LOCATION: N 5146569.5; E 353849.9
NAD83 MTM ZONE 12 (LAT. 46.457017; LONG. -80.361456)
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: August 20, 2018
DRILL RIG: CME55 - Track Mount
DRILLING CONTRACTOR: George Downing Estate Drilling

DATUM: GEODETIC

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

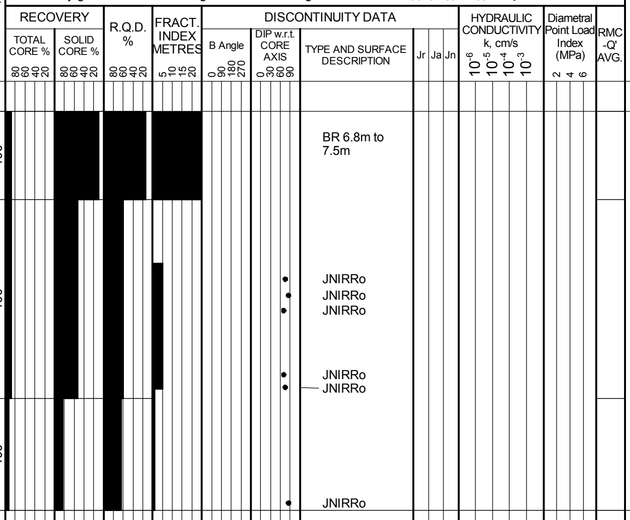
BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

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.



DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN (FLUSH)	TYPE AND SURFACE DESCRIPTION	
		BEDROCK SURFACE	276.5				
7	HW	WACKE Very strong Slightly weathered above 7.4 m, fresh below 7.4 m Fine grained Light grey / pink	6.8	1	Grey 100	BR 6.8m to 7.5m	
8	NQ Coring August 20, 2018			2	Grey 100	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo	
9				3	Grey 100	JNIRRo	UC = 138 MPa
10		END OF DRILLHOLE	273.3 10.0				
11							
12							
13							
14							
15							
16							
17							
18							

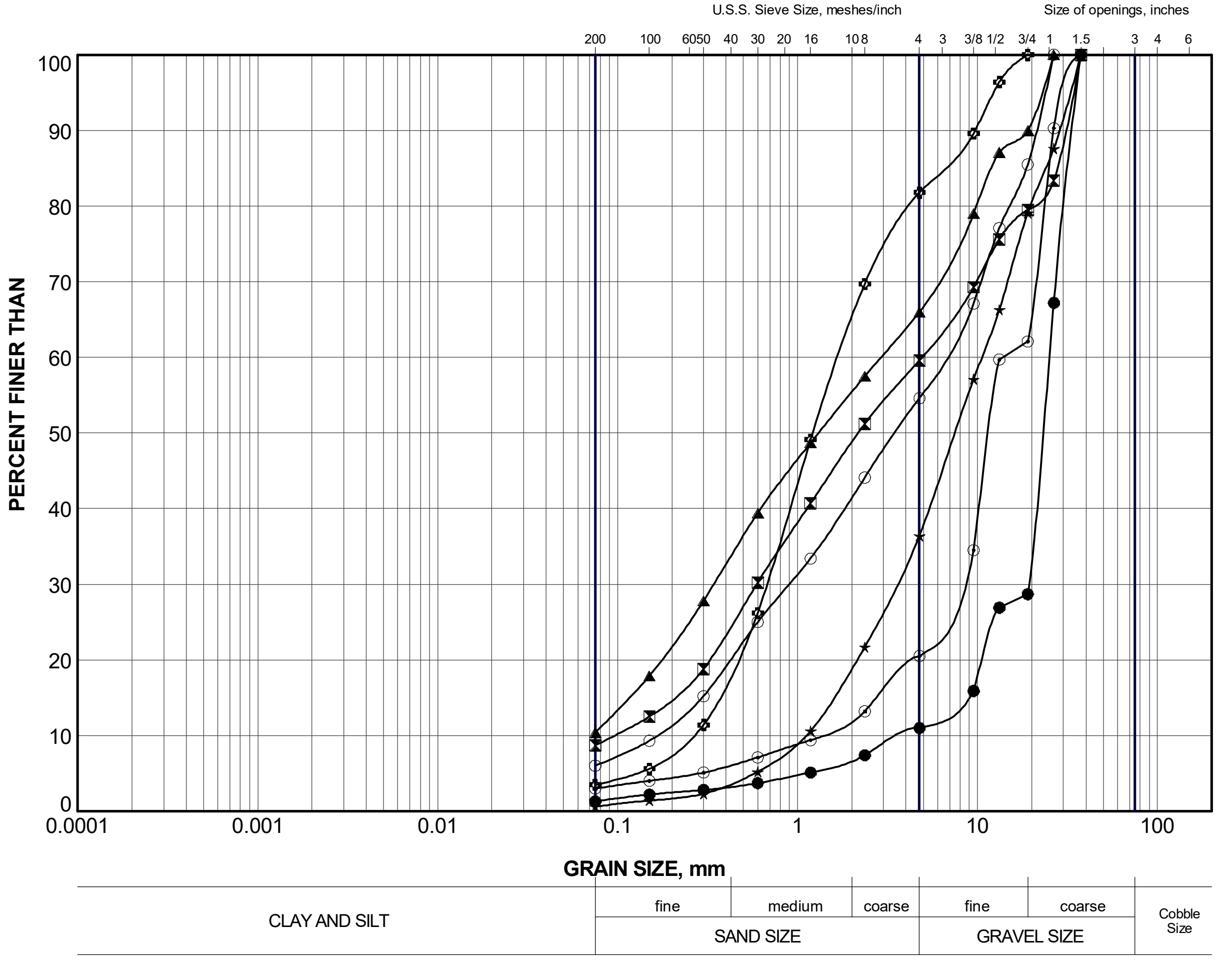
DEPTH SCALE
1 : 60

GOLDER

LOGGED: TB
CHECKED: AC

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-1	2	282.7
⧗	CC-1	3	281.7
▲	CC-1	4	280.9
★	CC-2	2	281.8
⊙	CC-2	4	280.3
✪	CC-2	6	278.0
○	CC-3	1	282.8

PROJECT

HIGHWAY 129
CUMMING'S CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

SAND to GRAVEL (FILL)

GOLDER
SUDBURY, ONTARIO

PROJECT No.		1898445	FILE No.	1898445.GPJ
DRAWN	TR	May 2019	SCALE N/A	REV.
CHECK	AD	May 2019	**FIGURE B-1**	
APPR	JMAC	May 2019		

SUD-MTO GSD GLDR_LDN.GDT

Borehole CC-1

Run 1: 6.7 m – 7.6 m

Run 2: 7.6 m – 9.1 m

Run 3: 9.1 m – 9.5 m

Borehole CC-2

Run 1: 7.2 m – 7.6 m
(Boulder)

Run 2: 7.6 m – 9.1 m
(7.5 – 7.6 m Boulder)

Run 3: 9.1 m – 10.4 m

Borehole CC-3

Run 1: 6.8 m – 7.4 m

Run 2: 7.4 m – 9.1 m

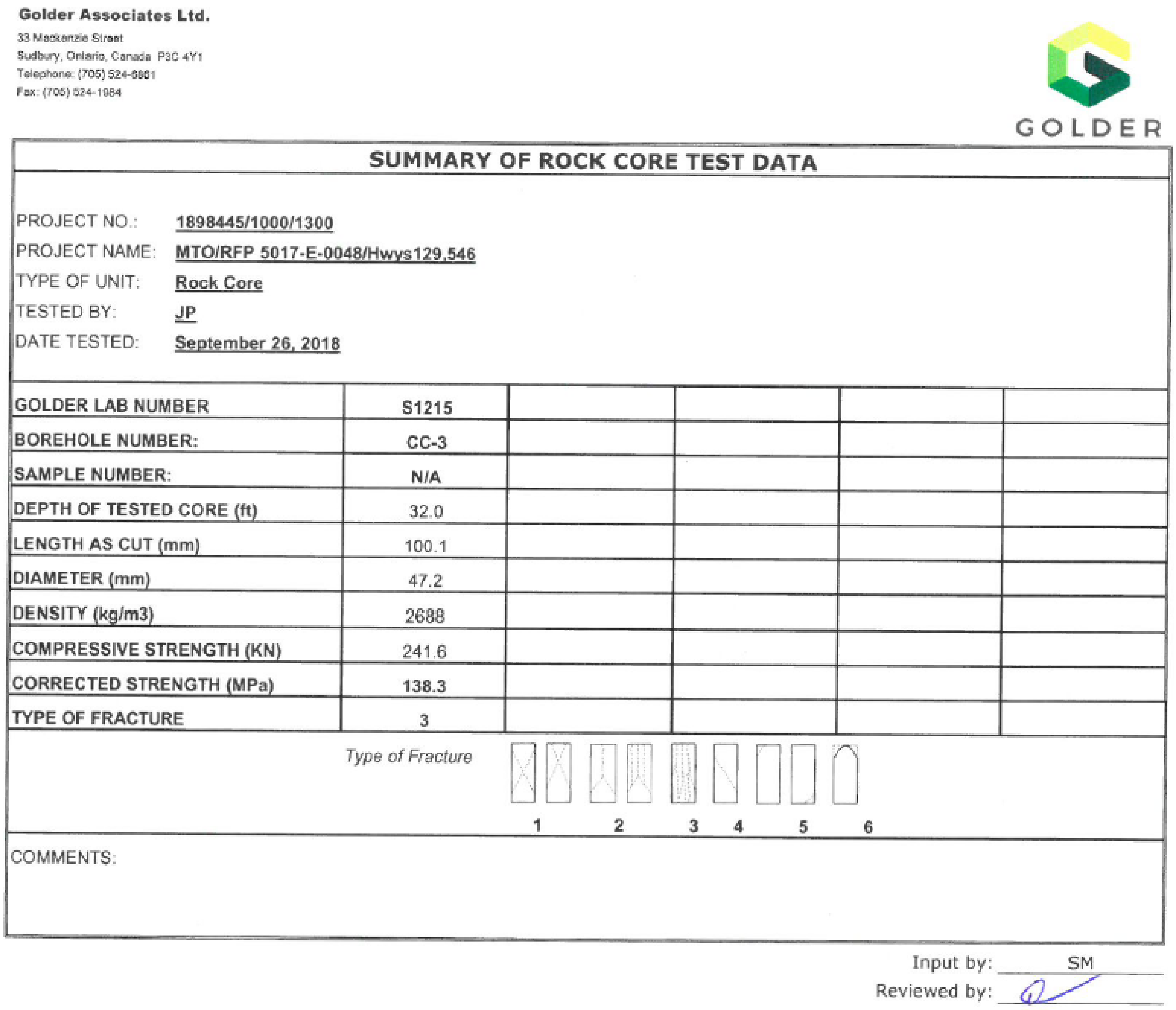
Run 3: 9.1 m – 10.0 m

0

0.3 m

Approximate Scale

PROJECT	**Highway 129** **Cumming's Creek Culvert**			
TITLE	**Bedrock Core Photographs**			
GOLDER	PROJECT No.	1898445		FILE No. ----
	DESIGN	AD	Apr 19	SCALE NTS REV.
	CADD	-- --		**FIGURE B-2**
	CHECK	AC	Apr 19	
	REVIEW	JMAC	Apr 19	



Golder Associates Ltd.
33 Mackenzie Street
Sudbury, Ontario, Canada P3C 4Y1
Telephone: (705) 524-6861
Fax: (705) 524-1984

GOLDER

SUMMARY OF ROCK CORE TEST DATA

PROJECT NO.: 1898445/1000/1300
PROJECT NAME: MTO/RFP 5017-E-0048/Hwys129,546
TYPE OF UNIT: Rock Core
TESTED BY: JP
DATE TESTED: September 26, 2018

GOLDER LAB NUMBER	S1215				
BOREHOLE NUMBER:	CC-3				
SAMPLE NUMBER:	N/A				
DEPTH OF TESTED CORE (ft)	32.0				
LENGTH AS CUT (mm)	100.1				
DIAMETER (mm)	47.2				
DENSITY (kg/m3)	2688				
COMPRESSIVE STRENGTH (KN)	241.6				
CORRECTED STRENGTH (MPa)	138.3				
TYPE OF FRACTURE	3				

Type of Fracture

COMMENTS:

Input by: SM
Reviewed by:

PROJECT					
Highway 129 **Cumming's Creek Culvert**					
TITLE					
Summary of Rock Core Test Data					
GOLDER	PROJECT No.	1898445		FILE No.	----
	DESIGN	AD	Apr 19	SCALE NTS	REV.
	CADD	-- --		**FIGURE B-3A**	
	CHECK	AC	Apr 19		
	REVIEW	JMAC	Apr 19		

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33 Mackenzie Street
Sudbury, Ontario, Canada P3C 4Y1
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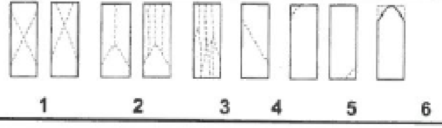
GOLDER

SUMMARY OF ROCK CORE TEST DATA

PROJECT NO.: 1898445-1000-1300
PROJECT NAME: AECOM-Cummings Creek
TYPE OF UNIT: Rock Core
TESTED BY: JP
DATE TESTED: May 10, 2019

GOLDER LAB NUMBER	T437	T438			
BOREHOLE NUMBER:	CC-2	CC-1			
SAMPLE NUMBER:	N/A	N/A			
DEPTH OF TESTED CORE	26'-2.5"	27'-3"			
LENGTH AS CUT (mm)	101.0	101.0			
DIAMETER (mm)	47.9	47.9			
DENSITY (kg/m3)	2582	2912			
COMPRESSIVE STRENGTH (KN)	179.5	70.8			
CORRECTED STRENGTH (MPa)	99.6	39.3			
TYPE OF FRACTURE	3	3			

Type of Fracture



COMMENTS:

Input by: TG
Reviewed by:

PROJECT	
Highway 129 **Cumming's Creek Culvert**	

TITLE

Summary of Rock Core Test Data

GOLDER

PROJECT No.	1898445		FILE No.	----
DESIGN	AD	Apr 19	SCALE NTS	REV.
CADD	-- --			
CHECK	AC	Apr 19	**FIGURE B-3B**	
REVIEW	JMAC	Apr 19		

GOLDER

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