FOUNDATION INVESTIGATION AND DESIGN 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

FOUNDATION INVESTIGATION REPORT
CUMMING’S CREEK CULVERT, SITE 38S-0375/C0
HIGHWAY 129, TOWNSHIP OF GOULD, ALGOMA DISTRICT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5074-07-00, WP 5271-14-01

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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PART B

FOUNDATION INVESTIGATION AND DESIGN REPORT
CUMMING'S CREEK (TUNNEL LAKE) CULVERT, SITE 38S-0375/C0
HIGHWAY 129, TOWNSHIP OF GOULD, ALGOMA DISTRICT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5074-07-00, WP 5271-14-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the Cumming's Creek Culvert (Site No. 38S-0375/C0) located at about Station 13+831 on Highway 129. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface exploration. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the structure foundations, as may be required. The foundation investigation report, discussion and recommendations are intended for the use of the MTO and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

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 highway embankment is comprised of granular fill material and is approximately 6 to 7 m high relative to the culvert invert, with approximately 3.5 m to 4 m of soil cover. The existing culvert is a reinforced concrete open-footing structure, 4.3 m wide by 2.3 m high and 30.4 m long. Based on the original drawings provided to us by AECOM, the invert at the inlet and outlet is about Elevation 276.4 m and Elevation 276.3 m, respectively. Based on the encountered conditions in the boreholes along with a visual inspection of the inlet/outlet areas of the culvert, the existing culvert walls (footings) appears to be founded directly on bedrock.

Concrete box and open-footing culverts are both considered feasible alternatives for the replacement culvert. Pipe culverts are also considered feasible; however, given the embankment height, multiple pipe culverts would likely be required to provide a similar flow-through capacity compared to a box or open footing culvert and, if constructed from steel, a pipe culvert (i.e., CSP) will likely have a shorter design life than a concrete structure. From a foundations perspective, a cast-in-place open footing culvert is preferred as it can more readily accommodate variations in the bedrock surface and will likely not require bedrock excavation to achieve the required founding grade compared to a box culvert or pipe culvert option. Consideration could be given to utilizing a cast-in-place footing with pre-cast open-box segments. Other culvert types may be preferred due to construction staging or other considerations (e.g. fisheries requirements related to natural channel substrate). A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 1.

Based on the General Arrangement (GA) drawing provided by AECOM on February 19, 2019, it is understood that the proposed - preferred replacement culvert option is a single cell, rigid frame open footing (RFO) culvert approximately 5.8 m wide by 2.4 m high (interior dimensions) with the invert at Elevations 276.4 m and 276.3 m at the inlet and outlet, respectively (similar to the existing culvert). The precast concrete culvert is to be supported on approximately 1.2 m wide cast-in-place footings founded at or below the proposed invert elevations to take advantage of the presence of bedrock at ground surface or at shallow depth below ground surface at the site. Further, we understand that the culvert is to be replaced utilizing a staged construction approach with temporary roadway protection along the centreline of the roadway (i.e. half-and-half construction)

It is understood that neither embankment widening nor a grade raise are required as part of embankment reinstatement following the culvert replacement.

6.2 Consequence and Site Understanding Classification

As the proposed replacement culvert crosses Highway 129 a “typical consequence level” is considered appropriate as outlined in Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC 2014) and its *Commentary*. Further, given the scope of work of the foundation field exploration and laboratory testing program as presented in Sections 3.0 and 4.0, a “typical degree of site and prediction model understanding” has been utilized. Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ, and geotechnical resistance factors, Φ_{gu} and Φ_{gs}, from Tables 6.1 and 6.2 of the CHBDC have been used for design.

6.3 Culvert Foundation Recommendations

6.3.1 Founding Level and Geotechnical Resistances

The subsoils encountered in the vicinity of the culvert location consist of granular embankment fill underlain by wacke bedrock. Given the proposed culvert invert and the encountered subsurface conditions, the footings for an open footing culvert will be founded directly on the bedrock surface. Levelling of the bedrock by sub-excavation is not expected to be required nor necessary as the culvert footings would be casted in place.

For the proposed 1.2 m wide footings constructed on the properly cleaned and prepared bedrock surface, the factored axial ultimate geotechnical resistance may be taken as 7,500 kPa. The factored axial serviceability geotechnical resistance for 25 mm of settlement will be greater than the factored geotechnical resistance, as the bedrock is considered to be an unyielding material; as such, ULS conditions will govern for an open footing culvert design.

The geotechnical resistances provided above are given for loads applied perpendicular to the surface of the base of the culvert footings. Where loads are not applied perpendicular to the base of the footings, inclination of the loads should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the CHBDC (2014) and its Commentary.

6.3.2 Frost Protection

Strip footings for an open footing culvert if founded on a soil subgrade, should be constructed at a minimum depth of 2.0 m below the lowest surrounding grade to provide adequate protection against frost penetration, as interpreted from OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). However, footings founded on bedrock, following sub-excavation of soil layer(s) that may be present along the culvert footings footprint to bedrock, do not require soil cover for protection from frost penetration.

6.3.3 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the concrete culvert footings and the bedrock surface should be calculated in accordance with Section 6.10.5 of the CHBDC (2014) applying the appropriate consequence and degree of site understanding factors as noted in Section 6.2. For cast-in-place concrete footings founded directly on the bedrock, the coefficient of friction ($\tan \delta$) may be taken as 0.7.

Dowels connecting the concrete footing/bedrock should be incorporated into the design where bedrock is found to be sloping at greater than 10 degrees and/or if additional horizontal resistance is required. The horizontal resistance of the dowels is dependent on the strength of the bedrock, grout and steel. The factored lateral ultimate geotechnical capacity of the rock mass at this site is 7,500 kPa. Where the rock mass is stronger than the concrete (as is the case for this culvert site), the design of the dowels into the rock may be handled in the same way as the dowel embedment into the concrete, for uniaxial compressive strength of the grout similar to that of the concrete. The dowels should have a minimum 1.5 m embedment into the bedrock and the structural strength of the dowels and compressive strength of the grout should not be exceeded. If dowelling into bedrock is incorporated into the design at this site, an NSSP should be included in the Contract Documents to specify the installation, materials and testing of the dowels. An example NSSP for Dowels into Rock is provided in Appendix D.

6.4 Reconstructed Embankment Stability and Settlement

6.4.1 Stability

For the subsurface conditions present at this site and the proposed embankment reconstruction to a height up to about 7 m above the existing ground surface (relative to the embankment toes of slope), granular fill embankments at this site will have a factor of safety greater than 1.5 if constructed at side slopes inclined at 2 horizontal to 1 vertical (2H:1V) or flatter.

6.4.2 Settlement

Given that the proposed replacement culvert will be founded directly on the cleaned and properly prepared bedrock surface following sub-excavation to bedrock, the total settlement of the culvert is estimated to be negligible (i.e., less than 25 mm).

6.4.3 Horizontal Strain

As the culvert will be founded directly on bedrock, horizontal strain along the culvert will be negligible. As a result, culvert construction concurrent with the embankment construction can be carried out without the need for any foundation mitigation measures or culvert camber.

6.5 Lateral Earth Pressures

The lateral earth pressures acting on the side walls of the culvert will depend on the type and method of placement of backfill materials, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the replacement culvert. It should be noted that these design recommendations and parameters are applicable to level backfill and ground surface behind the culvert walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ (Type I or II) should be used as backfill behind the culvert walls.
- A minimum 300 mm thick zone of granular fill should be placed behind the culvert walls and on top of the culvert in a similar configuration to OPSD 803.010 (Backfill and Cover for Concrete Culverts).
- For restrained culvert walls, granular fill may be placed behind the walls in a zone with the width equal to or greater than the equivalent depth of frost penetration, which at this site is 2.0 m as per OPSD 3090.100 – Foundation Frost Penetration Depth); as per Figure C6.20(a) of the Commentary to the CHBDC. For unrestrained wing walls/headwalls, if applicable, the granular backfill should be placed within a wedge-shaped zone defined by a line drawn flatter than 1H:1V extending up and back from base of the wing wall footings as per Figure C6.20(b) of the Commentary to the CHBDC.

Backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting) as amended by SP105S22. The lateral earth pressures acting against the culvert walls are based on the proposed backfill materials and the following parameters (unfactored) may be used:

Fill Type	**Internal Angle of Friction (ϕ)**	**Unit Weight**	**Coefficients of Static Lateral Earth Pressure**		
			Active, Ka	**At Rest, Ko**	**Passive, Kp**
Granular ‘A’	35°	22 kN/m³	0.27	0.43	3.65
Granular ‘B’ Type II	35°	21 kN/m³	0.27	0.43	3.65
Granular ‘B’ Type I	32°	21 kN/m³	0.31	0.47	3.25

The total passive resistance in front of the retaining wall may be calculated based on the values of Kp indicated above but reduced by an appropriate factor that considers the allowable wingwall/headwall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

6.6 Construction Considerations

6.6.1 Construction Staging and Temporary Roadway Protection

Temporary excavations for the culvert replacement will extend through the existing embankment granular fill extending to the bedrock surface. All excavations must be carried out in accordance with Ontario Regulation 213, Ontario Occupational Health and Safety Act for Construction Projects (as amended). The granular fill is considered to be Type 3 soil above the groundwater table and Type 4 soil below the groundwater table. Temporary open-cut excavations in Type 3 soils should remain stable if side slopes are formed no steeper than 1 horizontal to 1 vertical (1H:1V). In Type 4 soils, the side slopes should be formed no steeper than 3H:1V.

Based on discussions with AECOM, we understand that a temporary roadway protection system will be required along the centreline of the highway for the construction of the new culvert to allow for a staged construction approach (i.e. half-and-half). The construction approach includes construction of the new concrete footings on bedrock, followed by removing the existing concrete box culvert in stages. When completed the pre-cast 3-sided open footing culvert will be affixed to the footings and the excavation around the culvert backfilled.

For the temporary roadway protection, installing a sheet piling system will not be feasible given the presence of obstructions encountered within the sand to sand and gravel to gravel embankment fill and the lack of toe support given the shallow depth to bedrock at this site. Soldier piles and lagging (with the piles socketted into bedrock and supported by tiebacks or rakers) may be used for support of the excavation along the roadway and/or the excavation along the structure. However, appropriate excavation and construction procedures must be adopted to mitigate for the potential loss of wet, fine-grained soil from behind the protection system. It is recommended that a Notice to Contractor be included in the contract documents to alert the Contractor to the presence of obstructions; a sample Notice to Contractor is included in Appendix D.

The temporary protection system should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems) and should be designed to achieved Performance Level 2 for any excavation adjacent to existing roadways. Although the design of the temporary protection system will be completed by the contractor, the following parameters are provided to enable the structure designer to develop a conceptual design and assess the approximate construction costs for the protection systems:

Soil Type	**Unit Weight**	**Internal Angle of Friction**	**Coefficient of Earth Pressure**		
	(γ, kN/m3)	**(ϕ, degrees)**	**Active Ka**	**At Rest Ko**	**Passive Kp**
New Granular ‘A’ or Granular B’ Type II Fill (Compact)	21	35	0.27	0.43	3.65
New Granular B’ Type I Fill (Compact)	21	32	0.31	0.47	3.25
Existing Sand to Sand and Gravel Fill (Loose to Very Dense)	20	32	0.31	0.47	3.25

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

6.6.2 Sub-Excavation and Replacement Bedding Below Culvert

6.6.2.1 Sub-Excavation of Existing Soils

Prior to construction of the culvert footings, the existing fill should be sub-excavated to expose the bedrock surface within the plan limits of the culvert footings. It should be noted that the upper 0.6 m zone of bedrock in Borehole CC-3 is considered slightly weathered and as such scaling to remove loose/weathered chunks may be required. As such, it may be necessary to include a provision or providing an additional quantity allowance within the Contract Documents to deal with cleaning, scaling and removing loosened weathered rock at the footing locations and the associated increase in concrete volume for the cast-in-place footing.

Although not anticipated to be required at this site given that the existing culvert footings are visible within the culvert barrel, in the event that bedrock excavation is required, it will likely have to be carried out using controlled blasting excavation techniques as per OPSS.PROV 120 (Explosives) and OPSS.PROV 202 (Rock Removal - Manual or Blasting) as pre-drilling and hoe ramming techniques alone may not be adequate. Pre-shearing, line-drilling or other specialized techniques may be required to maintain the excavation lines and preserve the integrity of the rock mass along the footprint of the footings. The effect of blasting on the existing roadway and temporary protection systems (if required) should be considered by the designer and by the blasting contractor.

The exposed bedrock surface should be inspected by a Foundation Engineering Specialist following sub-excavation to ensure that the bedrock surface is properly cleaned, scaled and all loosened debris has been removed prior to pouring concrete in accordance with OPSS 902 (Excavating and Backfilling Structures).

6.6.3 Control of Groundwater and Surface Water

Temporary excavations along the culvert alignment will be required to remove the existing embankment fill, to expose the bedrock surface. As a result of the excavation, groundwater seepage into the excavation should be expected due to the relatively permeable nature of the adjacent embankment fill and from contact fissures along the soil/bedrock interface and/or from joints within the bedrock itself. Therefore, control of groundwater will be necessary to allow for levelling of the bedrock surface and construction of the footings in “dry” conditions.

Depending on the surface water and groundwater conditions at the time of construction, the creek water flow could be passed through the area by means of a temporary culvert or diverted by pumping from behind a temporary sand bag cofferdam or inflatable bladder placed on the bedrock surface; however, it should be noted that pumping from within the excavation will likely be required as water flow is anticipated below the base of the sand bag and/or inflatable bladder system. To limit the underflow, plastic sheeting could be placed on the riverbed upstream of the cofferdam system. At this site, there is an existing concrete overflow weir (see Photograph 2) which could also be used to assist when developing an appropriate dewatering strategy.

Surface water should be directed away from the excavation areas to prevent ponding of water that could impede footing construction. Unwatering of all excavations should be carried out in accordance with OPSS.PROV 517 (Dewatering).

Provided the creek water flow is diverted during construction, it is anticipated that under the 2018 changes to the *Environmental Protection Act* by the Ministry of the Environment Conservation and Parks (MECP), an Environmental Activity Section Registry for construction dewatering is not required and construction dewatering will be less than 50,000 L/day.

6.6.4 Culvert Backfill and Cover

The backfill requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and of similar configuration to that show on OPSD 803.010 (Backfill and Cover for Concrete Culverts). Backfill material to be placed around and above the culvert should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ (Type I or II). The use of Granular ‘B’ Type II is recommended in wet conditions and/or below the groundwater level. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting) as amended by SP105S22, ensuring that the backfill is placed/compacted as per OPSS 902 (Excavating and Backfilling – Structures).

Backfill placement for reconstruction of the roadway embankments over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

6.6.5 Erosion Protection

The requirements for and design of scour and erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. Based on discussions with AECOM we understand that a clay seal or GCL is not required at the inlet end of the culvert given that the existing culvert does not have a clay seal or GCL and there are no visible signs of erosion or water flow around the existing culvert.

If required from a hydraulic design perspective, to prevent surface water from flowing around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal could be provided on both sides of the culvert at the upstream end of the culvert. Clay material should meet the requirements of OPSS 1205 (Clay Seal) and the seal should be a minimum thickness of 1 m, whether constructed of natural clay or soil-bentonite mix. The clay seal should extend from a depth of 1 m below the scour level or from bedrock surface (whichever is lower) to a minimum vertical height equivalent to the high water level. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening. If a geosynthetic clay liner (GCL) is utilized in lieu of the clay seal, the GCL should be constructed within the embankment slope to allow for a minimum 0.3 m thick granular (embankment) fill cover to be placed over the GCL to provide for protection from the requisite overlying erosion protection material.

As a minimum, rip-rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment). Erosion protection for the inlet of the culvert should also follow the standard presented in OPSD 810.010 (Rip-Rap Treatment) similar to the outlet but with the rip rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay seal or GCL (if required).

6.6.6 Obstructions

The contractor should be alerted to the presence of cobbles and boulders within the embankment fill soils as encountered and confirmed by coring through the fill in all of the boreholes. The extent and depth of the cobble and boulder obstructions may vary beyond and between the borehole locations. A sample Notice to Contractor is included in Appendix D (as noted in section 6.6.1).

6.6.7 Analytical Testing for Construction Materials

The results of analytical tests on a sample of sand and gravel fill obtained at the culvert site are presented in Section 4.6. The suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

The analytical test results were compared to Table 3 in CSA A23.1-14. The sulphate concentration measured in the sand and gravel fill sample is less than 0.002 per cent, which is below the exposure class S-3 “Moderate”; and may be considered negligible according to Table 7.2 of the MTO Gravity Pipe Design Guidelines (2004). However, given that the location of the culvert location is on Highway 129 and will be exposed to de-icing salts it is recommended that a “C” type exposure class as defined by CSA A23.1 -14 Table 1 concrete be considered for the pre-cast culvert units.

The fill sample has a pH of about 6.8 and resistivity of 7,200 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability as it is less than a pH of 8.0. The resistivity is greater than 6,000 ohm-cm which indicates that the soil corrosiveness is very low (10,000>R> 6,000) as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014).

It should be noted that the creek water levels in the area are subject to seasonal fluctuations and variations due to the precipitation events and the water chemistry could also be variable. These recommendations are provided as guidance only; the structural designer should take the results of the laboratory testing, the potential for corrosion and the corrosion susceptibility of pipe materials in Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014) into consideration of the ultimate selection for materials.

7.0 CLOSURE

This Foundation Design 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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AD/AC/JMAC/PD/sb

https://golderassociates.sharepoint.com/sites/1898445/deliverables/foundations/2. reporting/r01 - cumming's creek culvert/3. final/1898445-r-rev0-mto 5017-e-0048 hwy 129 final fidr 26jun_19.docx

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Canadian Standards Association (CSA), 2014. *Canadian Highway Bridge Design Code* and *Commentary* on CAN/CSA S6-14.

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Ministry of Natural Resources, *Northern Ontario Engineering Geology Terrain Study*. Ontario Geological Society Electronic Mapping. Map 41JSE

Ministry of Northern Development of Mines. *Bedrock Geology of Ontario* – Southern Sheet, Ontario Geological Survey – Map 2544.

Ministry of Transportation, *MTO Gravity Pipe Design Guidelines*, MTO Drainage and Hydrology Design and Contract Standards Office, May 2014

Occupational Health and Safety Act and Regulation, Ontario Regulation 213for Construction Projects (as amended).

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 120	General Specification for the Use of Explosives
OPSS.PROV 202	Construction Specification for Rock Removal by Manual Scaling, Machine Scaling, Trim Blasting, or Controlled Blasting
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 902	Construction Specification for Excavating and Backfilling - Structures
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS 1205	Material Specification for Clay Seal

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903Wells (as amended)

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. ■ More tolerant of total and differential settlement if subgrade footprint is	■ 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
	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.	

MINISTRY OF TRANSPORTATION, ONTARIO

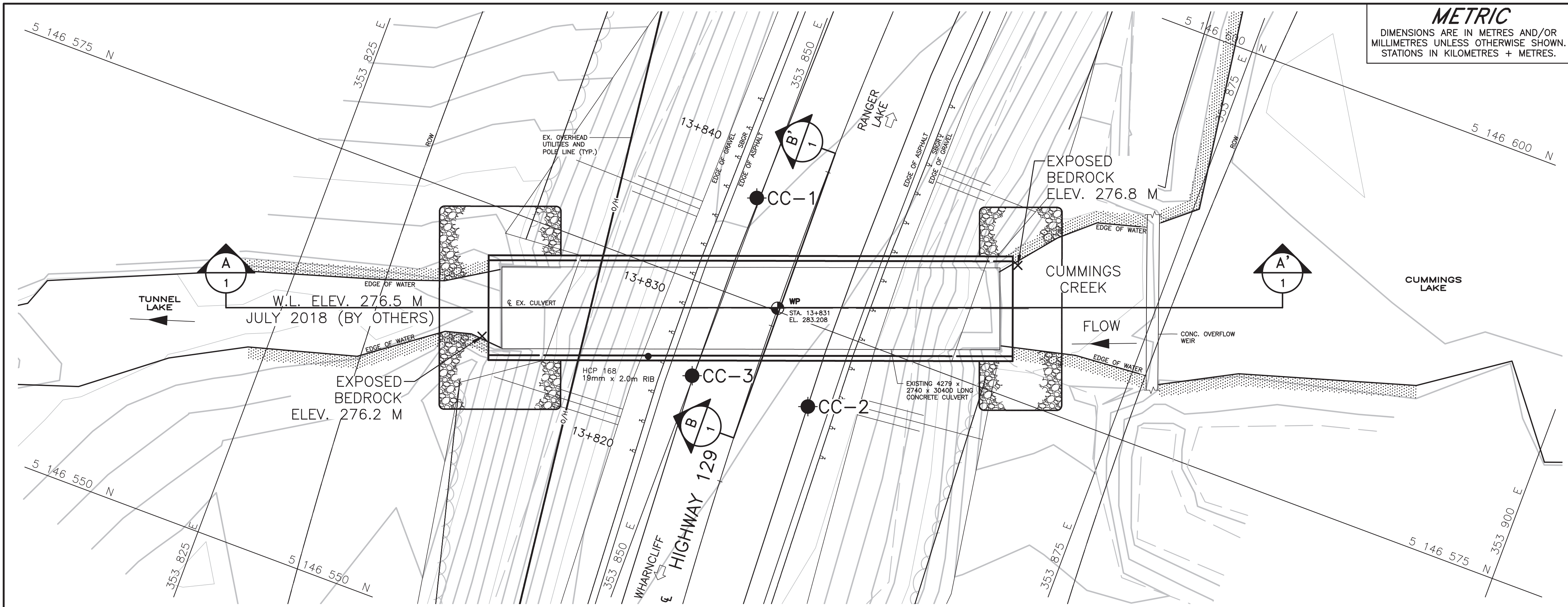
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5074–07–00

SHEET
.

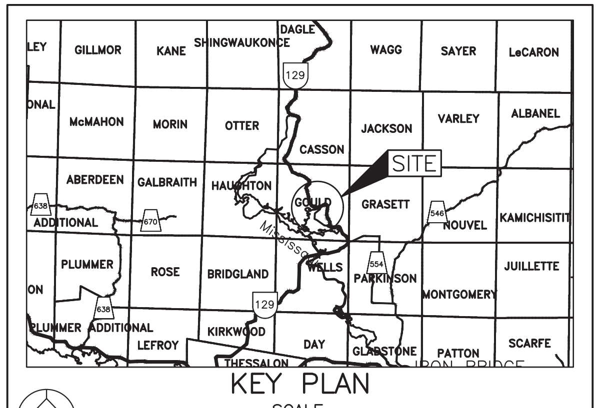
HIGHWAY 129
CUMMING'S CREEK CULVERT AT STA. 13+831
BOREHOLE LOCATIONS AND SOIL STRATA

GOLDER



PLAN

SCALE
3 0 3 6 m



KEY PLAN

SCALE
10 0 10 20 Km

LEGEND

●	Borehole
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
REC	Recovery (%)
▽	WL upon completion of drilling

J.M.A. COSTA
JUNE 26, 2019

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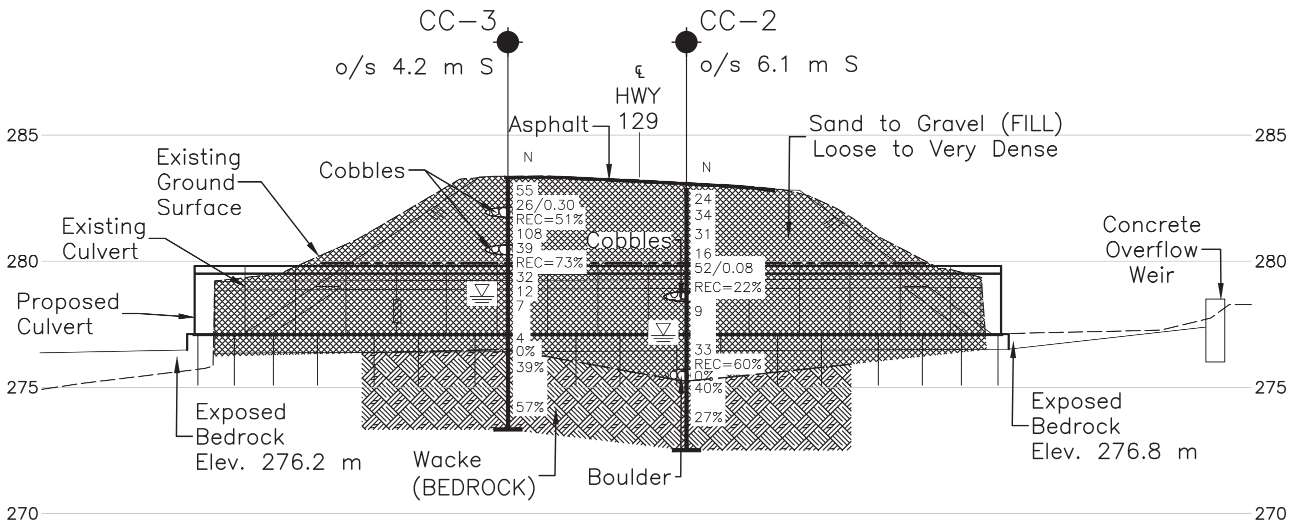
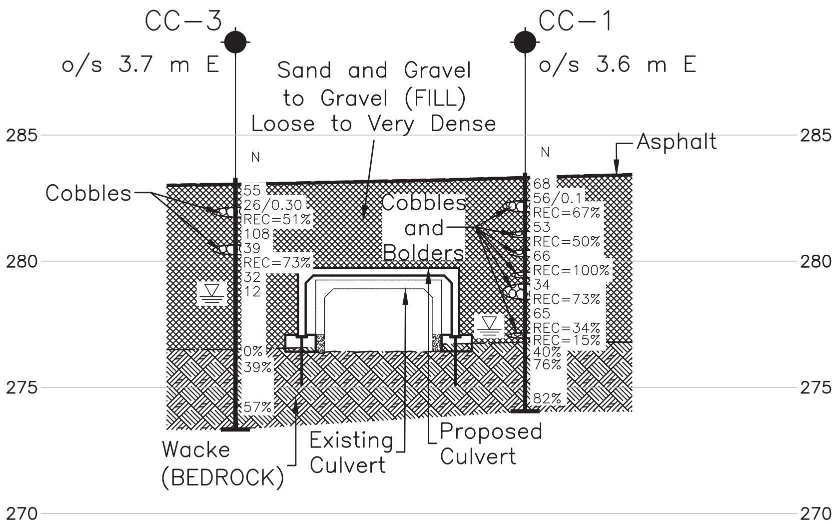
JUNE 26, 2019



A–A'
1

PROFILE

HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m
VERTICAL SCALE



B–B'
1

CROSS–SECTION

HORIZONTAL SCALE
3 0 3 6 m
3 0 3 6 m
VERTICAL SCALE

BOREHOLE CO–ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
CC–1	283.5	5146581.0	353849.8
CC–2	282.9	5146570.2	353857.2
CC–3	283.3	5146569.5	353849.9

NOTES

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

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

REFERENCE

Base plans provided in digital format by AECOM, drawing file nos. 60580589–GA.dwg, received FEB 19, 2019.

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 41I–362

HWY. 129	PROJECT NO. 1898445–R01		DIST. .
SUBM'D. AD	CHKD. AD	DATE: 6/26/2019	SITE: 38S–0375/C0
DRAWN: TR	CHKD. AC	APPD. JMAC	DWG. 1

PLOT DATE: June 26, 2019
FILENAME: S:\Clients\MTO\Hwy129&546\99_PROJ\1898445\40_PROD\0001–Cummings_Creek\1898445–0001–BG–0001.dwg

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, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

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

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 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	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	Sand and Gravel
	With (cohesive)	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 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

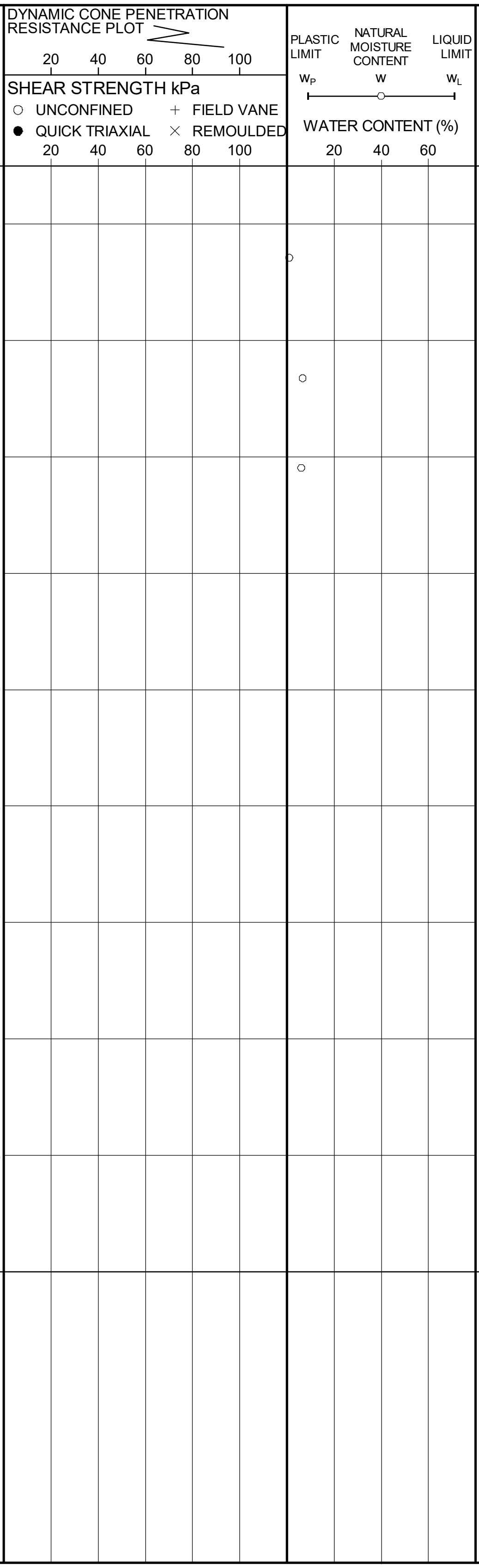
JN	Joint
FLT	Fault
SH	Shear
VN	Vein
FR	Fracture
SY	Stylolite
BD	Bedding
FO	Foliation
CO	Contact
AXJ	Axial Joint
KV	Karstic Void
MB	Mechanical Break
PL	Planar
CU	Curved
UN	Undulating
IR	Irregular
K	Slickensided
PO	Polished
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very Rough

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	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
283.5	GROUND SURFACE									
0.0	ASPHALT (90 mm)									
0.1	Sand and gravel to gravel, trace to some sand (FILL) Dense to very dense Brown to grey Moist to wet Split-spoon refusal (i.e. hammer bouncing) at 0.8 m depth. Switched to NQ Coring at 0.8 m depth. Cobbles and boulders encountered as follows: 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 Limited recovery in Samples 5 and 6.	1	SS	68		283				
		2	SS	56/0.1			88	10	(2)	
		-	RC	REC=67%		282				
		3	SS	53			41	51	(8)	
		-	RC	REC=50%						
		4	SS	66		281	34	55	(11)	
		-	RC	REC=100%						
		5	SS	34		280				
		-	RC	REC=73%						
		6	SS	65		279				
		-	RC	REC=34%		278				
		-	RC	REC=15%	▽	277				
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%		276	RQD = 40%			
		2	RC	REC 93%		275	RQD = 75%			
		3	RC	REC 100%			RQD = 85%			
274.0 9.5	END OF BOREHOLE Note: 1. Water level at a depth of 6.2 m below ground surface (Elev. 277.3 m) inside casing upon completion of coring.					274				



UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

PROJECT: 1898445

RECORD OF DRILLHOLE: CC-1

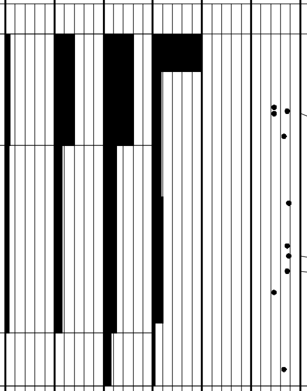
SHEET 1 OF 1

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

DRILLING DATE: August 21, 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	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN / FLUSH	DISCONTINUITY DATA 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		276.8										
7	NW	WACKE Medium Strong Fresh Fine grained Dark grey		6.7	1	Grey	BR 6.7m to 7.0m JNIRRo JNIRRo JNIRRo							
8	NQ Coring August 21, 2018				2	Grey	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo							UCS = 39 MPa
9				274.0 9.5	3	Grey	JNIRRo							
		END OF DRILLHOLE												

10
11
12
13
14
15
16
17
18

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
DIST
HWY 129
DATUM GEODETIC

LOCATION N 5146570.2; E 353857.2 NAD83 MTM ZONE 12 (LAT. 46.457023; LONG. -80.361361)
BOREHOLE TYPE NW Casing and NQ Coring
DATE August 22, 2018

ORIGINATED BY TB
COMPILED BY TR
CHECKED BY AC

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	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
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)
	Split-spoon refusal (i.e. hammer bouncing) at 3.2 m depth. Switched to NQ Coring.		5	SS	52/0.08						
			-	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				
275.2	A 500 mm diameter boulder encountered at 7.2 m depth.		1	RC	REC 93						
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%		275 274				RQD = 55%
272.5			3	RC	REC 94%		273				RQD = 60%
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, ×³: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

RECORD OF DRILLHOLE: CC-2

PROJECT: 1898445
LOCATION: N 5146570.2; E 353857.2
NAD83 MTM ZONE 12 (LAT. 46.457023; LONG. -80.361361)
INCLINATION: -90° AZIMUTH: ---

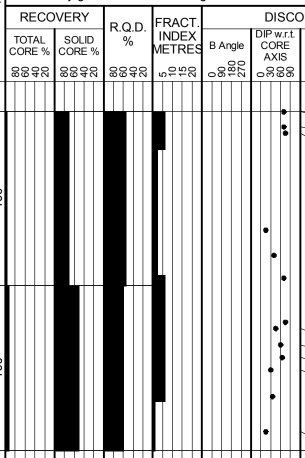
DRILLING DATE: August 22, 2018
DRILL RIG: CME55 - Track Mount
DRILLING CONTRACTOR: George Downing Estate Drilling

SHEET 1 OF 1
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	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN	FLUSH	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	
		BEDROCK SURFACE		275.2											
8 9	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
10				272.5 10.4	3	Grey 100		JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo BR 10.0m to 10.2m JNIRRo							
		END OF DRILLHOLE													



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19

SUD-MTO-RCK S:\CLIENTS\MTO\HWY129&546\02_DATA\GINT\1898445.GPJ GAL-MISS.GDT 5/14/19 TR

DEPTH SCALE
1 : 60

GOLDER

LOGGED: TB
CHECKED: AC

RECORD OF BOREHOLE No CC-3

1 OF 1 **METRIC**

PROJECT 1898445
G.W.P. 5074-07-00
DIST
HWY 129
DATUM GEODETIC
LOCATION N 5146569.5; E 353849.9 NAD83 MTM ZONE 12 (LAT. 46.457017; LONG. -80.361456)
BOREHOLE TYPE HW Casing and NQ/HQ Coring
DATE August 20, 2018
ORIGINATED BY TB
COMPILED BY TR
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE			kN/m³	GR	SA	SI	CL
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.		2	SS	26/0.30									
	Cobbles encountered as follows:		-	RC	REC=51%		282							
	Depth (m) Size (mm) 1.2 160 1.4 75 2.8 110		3	SS	108									
							281							
	Poor sample recovery within samples 4 to 7.		4	SS	39									
			-	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.													

$+^3$, $\times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

PROJECT: 1898445
LOCATION: N 5146569.5; E 353849.9
NAD83 MTM ZONE 12 (LAT. 46.457017; LONG. -80.361456)
INCLINATION: -90° AZIMUTH: ---

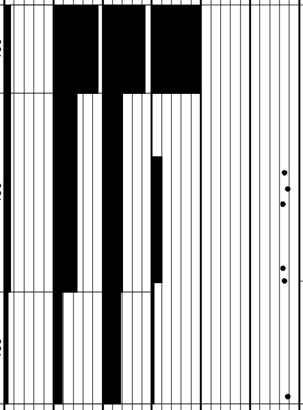
RECORD OF DRILLHOLE: CC-3

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

SHEET 1 OF 1
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	DISCONTINUITY DATA 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	
9						JNIRRo JNIRRo	
			273.3 10.0	3	Grey 100	JNIRRo	UC = 138 MPa
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.

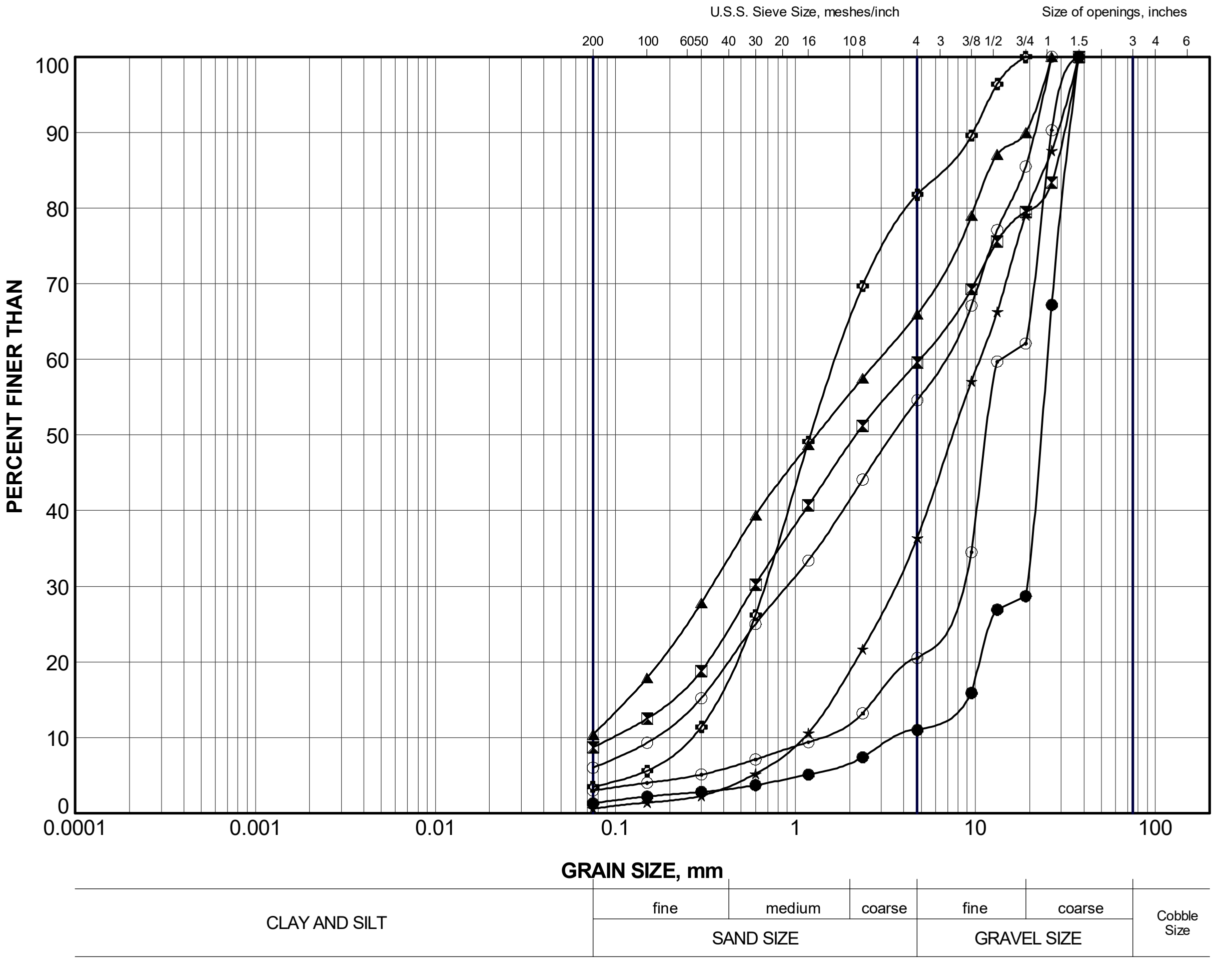
DEPTH SCALE
1 : 60

GOLDER

LOGGED: TB
CHECKED: AC

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		
APPR	JMAC	May 2019	**FIGURE B-1**	

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

Approximate Scale

PROJECT

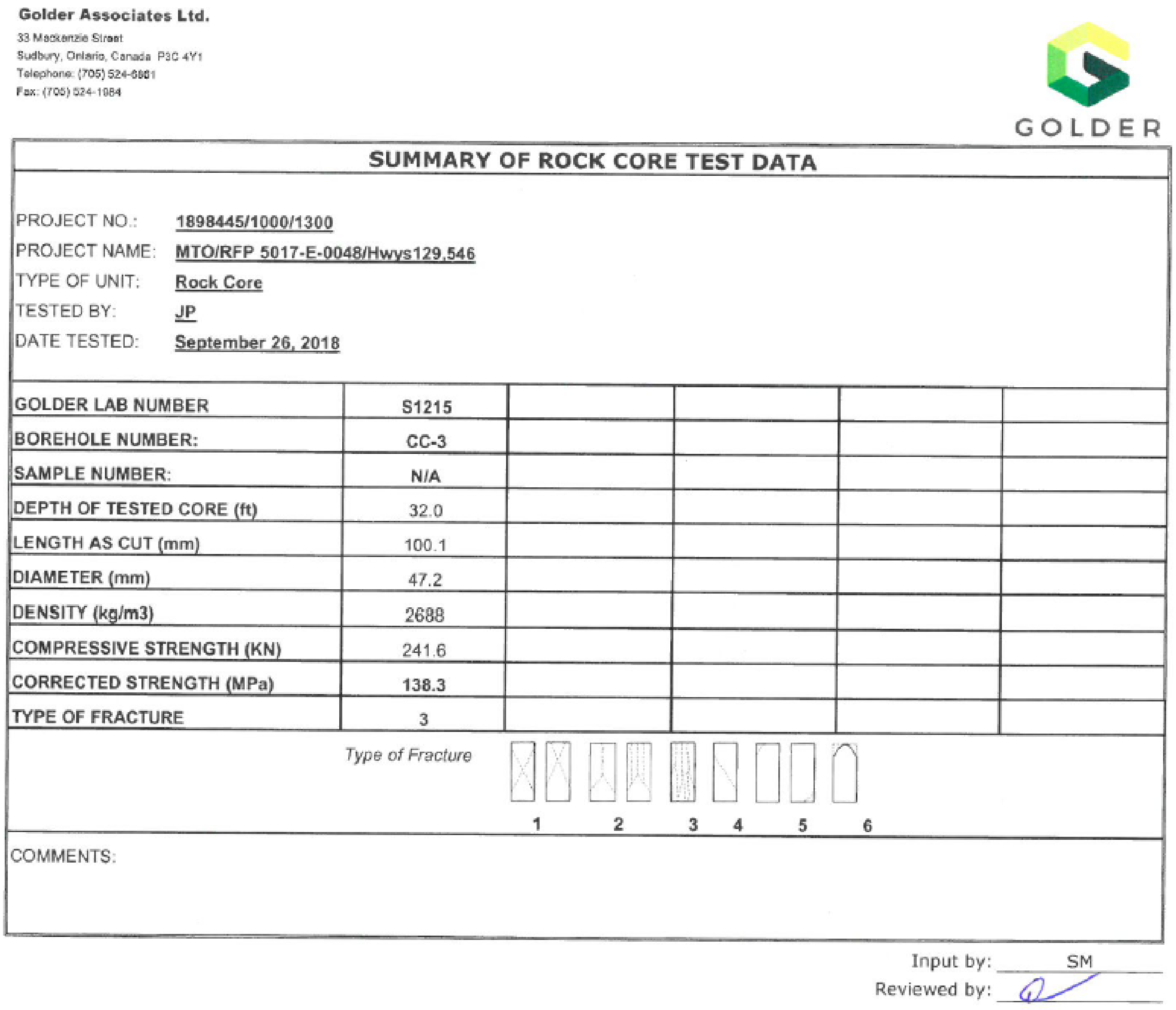
Highway 129
Cumming's Creek Culvert

TITLE

Bedrock Core Photographs

GOLDER

PROJECT No.	1898445		FILE No.	----
DESIGN	AD	Apr 19	SCALE NTS	REV.
CADD	-- --			
CHECK	AC	Apr 19	**FIGURE B-2**	
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:

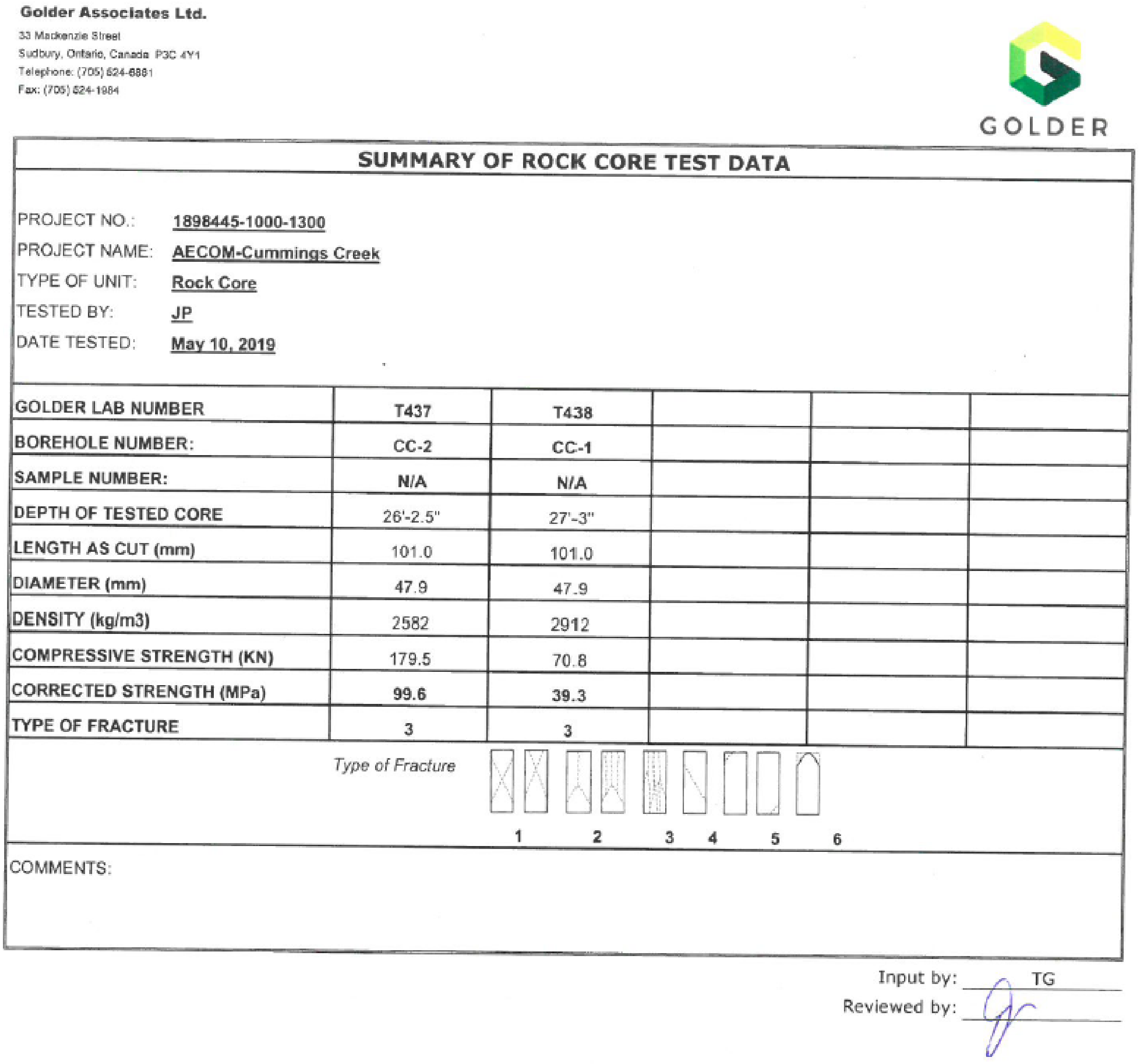
Input by: SM
Reviewed by:

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	-- --			
CHECK	AC	Apr 19	**FIGURE B-3A**	
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: 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

1 2 3 4 5 6

COMMENTS:

Input by: TG
Reviewed by:

PROJECT	Highway 129 Cumming's Creek Culvert				
TITLE	Summary of Rock Core Test Data				
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

APPENDIX C

Analytical Test Results

Your Project #: 1898445/1000/1300
Site Location: CUMMINGS CREEK
Your C.O.C. #: 681851-01-01

Attention: David Muldowney

Golder Associates Ltd
33 Mackenzie Street
Suite 100
Sudbury, ON
Canada P3C 4Y1

Report Date: 2018/09/19
Report #: R5405585
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8N0764
Received: 2018/09/05, 14:00

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	1	N/A	2018/09/10	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2018/09/10	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	1	2018/09/07	2018/09/07	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2018/09/06	2018/09/10	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	1	N/A	2018/09/10	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing. Maxxam is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested. When sampling is not conducted by Maxxam, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

Your Project #: 1898445/1000/1300
Site Location: CUMMINGS CREEK
Your C.O.C. #: 681851-01-01

Attention: David Muldowney

Golder Associates Ltd
33 Mackenzie Street
Suite 100
Sudbury, ON
Canada P3C 4Y1

Report Date: 2018/09/19
Report #: R5405585
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B8N0764
Received: 2018/09/05, 14:00

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Alisha Williamson, Project Manager
Email: AWilliamson@maxxam.ca
Phone# (905) 817-5700
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Golder Associates Ltd
Client Project #: 1898445/1000/1300
Site Location: CUMMINGS CREEK
Sampler Initials: TB

RESULTS OF ANALYSES OF SOIL

Maxxam ID		HRB575		
Sampling Date		2018/08/20		
COC Number		681851-01-01		
	UNITS	**CC-3 SA#3 CUMMINGS CREEK**	**RDL**	**QC Batch**
Calculated Parameters				
Resistivity	ohm-cm	7200		5717192
Inorganics				
Soluble (20:1) Chloride (Cl-)	ug/g	48	20	5722093
Conductivity	umho/cm	139	2	5722010
Available (CaCl2) pH	pH	6.79		5719326
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5722108

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

TEST SUMMARY

Maxxam ID: HRB575
Sample ID: CC-3 SA#3 CUMMINGS CREEK
Matrix: Soil

Collected: 2018/08/20
Shipped:
Received: 2018/09/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5722093	N/A	2018/09/10	Deonarine Ramnarine
Conductivity	AT	5722010	N/A	2018/09/10	Tahir Anwar
pH CaCl2 EXTRACT	AT	5719326	2018/09/07	2018/09/07	Gnana Thomas
Resistivity of Soil		5717192	2018/09/10	2018/09/10	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5722108	N/A	2018/09/10	Alina Dobreanu

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	6.7°C

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**UNITS**	**Value (%)**	**QC Limits**
5719326	Available (CaCl2) pH	2018/09/07			100	97 - 103			0.15	N/A
5722010	Conductivity	2018/09/10			104	90 - 110	<2	umho/cm	0	10
5722093	Soluble (20:1) Chloride (Cl-)	2018/09/10	NC	70 - 130	105	70 - 130	<20	ug/g	3.2	35
5722108	Soluble (20:1) Sulphate (SO4)	2018/09/10	NC	70 - 130	110	70 - 130	<20	ug/g	6.7	35

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Eva

CHARTERED
Eva Pranjic
CHEMIST

Ewa Pranjic, M.Sc., C.Chem, Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics International Corporation o/a Maxxam Analytics
6740 Campobello Road, Mississauga, Ontario Canada L5N 2L8 Tel:(905) 817-5700 Toll-free:800-563-6266 Fax:(905) 817-5777 www.maxxam.ca

CHAIN OF CUSTODY RECORD

Page of

INVOICE TO:

Company Name: #7575 Golder Associates Ltd
Attention: Accounts Payable
Address: 33 Mackenzie Street Suite 100
Sudbury ON P3C 4Y1
Tel: (705) 524-6861 Fax: (705) 524-1984
Email: AP_CustomerService@golder.com

REPORT TO:

Company Name: GOLDER ASSOCIATES
Attention: ~~Andre Bom~~ DAVID MULDOWNEY
Address:
Tel: Fax:
Email: ~~abom@golder.com~~ dmuldowney@golder.com

PROJECT INFORMATION:

Quotation #: B80683
P.O. #:
Project: ~~1898586-3000~~ 1898445/1000/1300
Project Name:
Site #: Cummings Creek
Sampled By: Tibor Berecz

Laboratory Use Only:

Maxxam Job #:	Bottle Order #:
	681851
COC #:	**Project Manager:**
C#681851-01-01	Alisha Williamson

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011)

☐ Table 1 ☐ Res/Park ☐ Medium/Fine
☐ Table 2 ☐ Ind/Comm ☐ Coarse
☐ Table 3 ☐ Agri/Other ☐ **For RSC**
☐ Table ___

Other Regulations

☐ CCME ☐ Sanitary Sewer Bylaw
☐ Reg 558 ☐ Storm Sewer Bylaw
☐ MISA Municipality ______
☐ PWQO
☐ Other ______

Special Instructions

Include Criteria on Certificate of Analysis (Y/N)? ______

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

Turnaround Time (TAT) Required:

Please provide advance notice for rush projects

Regular (Standard) TAT: ☒
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
Date Required: ______ Time Required: ______ ☐
Rush Confirmation Number: ______ *(call lab for #)*

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered (please circle):	Metals / Hg / Cr VI	Soil Corrosivity Package	# of Bottles	Comments
1	CC-3 Sa#3	Cummings Creek	2018/08/20		Soil			X	2	
2										
3										
4										
5										
6										
7										
8										
9										
10										

Received in Sudbury
05-Sep-18 14:00
Alisha Williamson
B8N0764
THP ENV-1392

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
A. DeSouza / Aronne-Kay DeSouza	18/09/05	2pm	Bradley Tapper	2018/09/05	14:00	
			TRUSHNA PATEL	2018/09/06	08:39	

Laboratory Use Only

Time Sensitive	Temperature (°C) on Recei	Custody Seal	Yes	No
	6,6,8°C	Present		✓
		Intact		

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxa Yellow: Client

3|3|5

Maxxam Analytics International Corporation o/a Maxxam Analytics

APPENDIX D

Non-Standard Special Provision and Notice to Contractors

DOWELS INTO ROCK - Item No.

Special Provision

CONSTRUCTION SPECIFICATION FOR THE SUPPLY, INSTALLATION AND TESTING OF DOWELS INTO ROCK

1.0 SCOPE

The work for the above noted tender item shall be in accordance with OPSS 904, including all Special Provisions, except as extended herein. This document specifies additional requirements for the supply, installation and testing of Dowels into Rock.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications, or publications:

ASTM International D1143M Standard Test Methods for Deep Foundations Under Static Axial Compressive Load

3.0 DEFINITIONS

For the purpose of this Special Provision, the following definitions apply:

Dowels into Rock means reinforcing steel dowels and non-shrink grout.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Working Drawings

The Contractor shall submit Working Drawings two weeks prior to construction to the Contract Administrator as follows:

a) All Working Drawings shall be sealed and signed by the design Engineer and design check Engineer

b) A plan illustrating the layout of the dowels

c) Detail drawing of the dowel into bedrock.

d) The method for constructing of the holes, maintaining the holes, and placing reinforcing steel dowels, grout and other materials in the holes, including casing sizes, bit sizes and tremie grouting methods.

e) The procedures to verify hole length. Records of measurements that verify the hole length.

f) Records of all drilling procedures, rock conditions encountered, and installation times.

g) Test procedures for Dowels into Rock. Test results verifying the 28 day strength of non-shrink grout.

h) Drawings and design calculations for a suitable reaction system for the applied test loads.

i) Drawings and details for reference system arrangement.

j) Calibration curves for all gauges.

5.0 MATERIALS

5.01 Non-Shrink Grout

The non-shrink grout shall be an approved product from the MTO's Pre-Qualified Products List.

5.02 Anti-Washout Agent

The anti-washout agent shall be used with the non-shrink grout for the Dowels into Rock.

5.03 Manufacturer Information

The Contractor shall provide the following information from the manufacturer for non-shrink grout and anti-washout agent:

a) Data sheets for the non-shrink grout and anti-washout agent,

b) Technical information that proves that the non-shrink grout and anti-washout agent are compatible, and

c) Installation procedures.

5.04 Steel Dowels

Steel dowels shall conform to the requirements of OPSS 905.

6.0 EQUIPMENT

All equipment for the installation of the Dowels into Rock shall be suitable for the intended purposes and capable of working on the site under the prevailing access and clearance conditions.

The equipment shall not cause damage to the reinforcing steel dowels.

7.0 CONSTRUCTION

7.01 General

The Contractor shall supply equipment, materials and skilled personnel to install production Dowels into Rock. The Contractor shall conduct the specified acceptance tests under the direction of the Contractor's Engineer.

The Contractor is responsible for materials and workmanship. Any remedial measures, required because of defects in materials or workmanship, shall be completed by the Contractor at no cost to the Owner.

7.02 Subsurface Conditions

The subsurface conditions at the site are described in the Foundation Investigation Report for this Contract.

The Owner warrants the data in the Foundation Investigation Report, except that interpretations of the data and opinions expressed in the Foundation Investigation Report are not warranted.

7.03 Construction of Holes

The sides and end of the hole shall not be disturbed. The Contractor shall construct the holes, maintain the holes, and place reinforcing steel dowels, grout and other materials in the holes.

The hole diameters and hole length for this project are as specified on the Contract Drawings.

At all times, the Contractor shall keep a record of all drilling procedures, rock conditions encountered, and installation times. The Contractor shall submit these records to the Contract Administrator upon completion of the work.

7.04 Installation of Reinforcing Steel Dowels

Reinforcing steel dowels shall be installed in strict accordance with the Contract Drawings and installation procedures.

Centering devices shall be provided to ensure that the reinforcing steel dowels are located centrally in the hole.

Dowels shall extend into sound bedrock.

7.05 Grout and Anti-Washout Agent

The non-shrink grout shall entirely fill the annular space between the reinforcing steel dowels and side for the dowel hole.

Anti-washout agent shall be used in accordance with the specifications of the manufacturer.

7.06 Installation of Dowels

Upon completion of installation for each group of dowels, the Contractor shall submit to the Contract Administrator a Request to Proceed. The testing shall be conducted by the Contractor and inspected by the Contract Administrator.

The next operation after the completion of testing shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

8.0 QUALITY ASSURANCE

In each group, 10% of the dowels rounded up to the next whole number, but no fewer than two dowels, shall be tested.

8.01 General Testing Requirements

The testing of Dowels into Rock shall be inspected by a Foundation Engineering Specialist retained by the Contract Administrator. The Contractor shall refer to the Contract Drawings for specific test details.

The Contractor shall supply materials and equipment to conduct the tests for the dowels into rock. The equipment and materials shall be capable of stressing the dowels into rock to the specified loads. It shall be the responsibility of the Contractor to constantly monitor the test, maintain specified test loads and to record test measurements.

The Contract Administrator shall supervise the testing of the Dowels into Rock. The Contractor shall notify the Contract Administrator of the testing schedule at least 10 working days prior to commencement of the testing program. Testing for Dowels into Rock shall be conducted as scheduled by the Contract Administrator.

8.01.01 Testing Equipment

The Dowels into Rock will be carried out generally in accordance with the prevailing requirements of ASTM International D1143M superseded where applicable by the procedures specified in the Contract Drawings.

Jacks must be secured with chains to provide adequate protection for the personnel in the event of breakage of the reinforcing steel dowels or stressing system.

The Contractor shall construct suitable enclosures to provide complete protection for all equipment from variations in the weather conditions and disturbances.

8.01.02 Testing for Dowels into Rock, and Report

At all times, the Contractor shall keep records of vertical and horizontal movements of the reaction system, elongation of reinforcing steel dowels, and the record of test enclosure temperature. The movements shall be recorded with respect to an independent fixed reference point. The Contractor shall submit the above noted records to the Contract Administrator.

The dial gauges shall be placed on smooth bearing surfaces mounted perpendicular to the direction of movement. All gauges, scales or reference points attached to the test anchor shall be mounted so as to prevent movement relative to the test anchor during the test. Longer gauge stems or sufficient gauge blocks shall be provided to allow for greater travel if required. The precision of gauges and the minimum ram dimension of the jack shall be as per the Contract Drawings. The Contractor shall submit details for current calibration and curves for all gauges to the Contract Administrator.

8.01.03 Testing Loading

The testing procedures and loading shall be in accordance with the requirement and specifications in Contract Drawings.

8.02 Acceptance Criteria

The following acceptance criteria apply:

a) The inspection of dowels shall be carried out by the Contractor's Engineer in advance of the installation of Dowels into Rock.

b) The Contractor shall submit the Request to Proceed to the Contract Administrator for the acceptance of the Dowels into Rock.

9.0 MEASUREMENT FOR PAYMENT

For measurement purposes, a count shall be made of the number of dowels installed.

10.0 BASIS OF PAYMENT

Payment at the contract unit price for the above tender item shall include full compensation for all labour, equipment, and materials to do the work.

WARRANT: Use only in consultation with Regional Structural Section with the above non-standard tender item.

NOTICE TO CONTRACTOR - Obstructions

Special Provision

The Contactor is hereby notified that at the existing embankment fill overlying bedrock contains gravel, cobbles and boulders, which could affect excavations and the installation of temporary protection systems. As encountered within Borehole CC-2, the embankment fill was also noted to contains pieces of wood. Consideration of the presence of these obstructions must be made in selection of appropriate equipment and procedures for installation of the foundations, and for excavation and construction of temporary works as may be required.

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