September 25, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

SOUTH CURRENT RIVER CULVERTS - SITE NO. 48C-217/C
HIGHWAY 527, DISTRICT OF THUNDER BAY
UNSURVEYED TERRITORY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6826-14-00

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REPORT

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Golder Associates

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PART A

PRELIMINARY FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch Mott MacDonald (HMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the replacement of the South Current River culverts (Site No. 48C-217/C). The South Current River culverts are located in the District of Thunder Bay, Unsurveyed Territory on Highway 527 at STA 16+956, approximately 28.5 km north of the junction of Highway 11/17 and Highway 527. The key plan showing the general location of this section of Highway 527 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The South Current River culverts consists of twin structural plate corrugated steel pipe (SP CSP) arches , the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

In general, the topography in the culvert area is relatively flat with moderate to dense tree cover beyond the highway right-of-way. Highway 527 runs in a north-south direction with the culvert perpendicular to the roadway in a west-east orientation on a slight skew from perpendicular with the roadway. At the culvert location, South Current River flows in a westerly direction. At the culvert location, the highway grade is at Elevation 408.2 m and the culvert invert, as provided by MTO, is at Elevation 403.8 m at both the inlet and outlet ends. The river water level was at Elevation 404.5 m as measured by others in November 2014 and at Elevation 404.9 m as measured by Golder on March 24, 2015. Surface conditions in the culvert inlet and outlet area are shown on Photographs 1 to 4, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between January 17 and 20 and March 24 and 25, 2015, during which time four boreholes (Boreholes SC-1 to SC-4) were advanced at approximately the locations shown on Drawing 1. Boreholes SC-1 to SC-4 were advanced using a track-mounted CME-55 drill rig supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec and a track-mounted CME 850 drill rig supplied and operated by Cartwright Drilling Inc. of Thunder Bay, Ontario.

The boreholes were advanced by utilizing a combination of 108 mm inside diameter hollow stem augers, NW casing and wash boring, and NQ coring. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The groundwater levels in the open boreholes were observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The field work was supervised on a full-time basis by members 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 and cared for the soil and bedrock samples. The soil and bedrock 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 and organic content determinations and grain size distributions were carried out on selected soil samples. In addition, unconfined compressive strength (UCS) tests were carried out on selected specimens of the bedrock core recovered from the boreholes. The geotechnical laboratory testing was completed according to MTO LS standards.

A sample of the river water was obtained during the field investigation (on January 18, 2015) 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 and ground surface elevations were measured and surveyed by member of our technical staff, referenced to the highway centerline and the existing culverts and converted into Northing/Easting on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing provided by MTO (Drawing E4848905271.dwg). The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation m)	Borehole Depth (m)
SC-1	5398992.8	372359.2	405.6	4.6
SC-2	5398993.6	372370.7	408.2	7.2
SC-3	5398982.4	372374.8	408.0	7.4
SC-4	5398999.7	372387.6	405.0	3.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)[1] mapping, the subsoils in the vicinity of the South Current River culvert site generally consist of ground moraine deposits comprised of mainly sand till materials, bordered closely to the south by bedrock plains.

Based on geological mapping by the Ministry of Northern Development and Mines (Map 2542)[2], the site is underlain by bedrock of the Archean Era, comprised of metasedimentary rocks consisting of wacke, arkose, argillite, slate, marble and chert, with iron formations bordering with the massive granodiorite to granite formations.

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 results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ tests (i.e., SPT ‘N’ values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries

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[1] Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52ANW.

[2] Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.

shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment) underlain by an organic deposit of amorphous peat and a deposit of silty sand to sand and gravel, underlain by bedrock. A more detailed description of the soil deposits, bedrock and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	‘N’-Values (blows) Relative Density	Laboratory Testing
Asphalt	SC-2, SC-3	0.075	408.2 – 408.0	n/a	n/a
(FILL) [1] Silty Sand, trace to some gravel to Gravelly Sand, trace clay; brown; frozen to wet	SC-2, SC-3	3.2 – 3.3	408.1 – 407.9	N = 13 [2] **Compact**	w = 4% – 6% 2 - MH (Fig. B1)
Amorphous **Peat** to Sandy **Peat** [1]**,** trace to some sand, trace to some gravel; dark brown; frozen to wet	SC-1, SC-3 and SC-4	1.0 – 1.8	405.6 – 404.7	N = 9 [3] **Stiff**	w = 22% – 105%
Silty Sand to Sand and Gravel [4]**,** trace clay, trace to some organics; dark brown to grey; wet	SC-1 to SC-3	0.9 – 2.2	404.8 – 403.7	N = 4 – 88 [4] **Loose to Very Dense**	w = 8% – 39% 2 – M/MH (Fig. B2) OC = 4.3%

Where:
N = SPT ‘N’-value; number of blows for 0.3 m of penetration
w = Natural Moisture Content (%)
M = Sieve analysis
MH = Combined Sieve and Hydrometer analysis
OC = Organic Content (%)

Notes:

[1] Auger refusal due to the presence of inferred cobbles/boulders within the embankment fill was encountered in Boreholes SC-2 and SC-3 and within the peat deposit in Borehole SC-4 at depths between 1.2 m and 2.7 m below the existing ground surface. Additional boreholes were drilled immediately adjacent to Boreholes SC-2 and SC-3 to penetrate below the encountered refusal conditions.

[2] In the granular fill layer, one SPT ‘N’-value of 135 blows per 0.3 m of penetration was measured, indicative of the frozen state of the material and is not representative of the relative density of this material. In addition, one SPT ‘N’-value of 67 blows per 0.3 m of penetration was noted, however, this is inferred to be due to the presence of coarse gravel and cobbles/boulders within the fill. Further, two split-spoon samples did not penetrate the entire SPT depth inferred to be due to the presence to coarse gravel and cobbles/boulders. Coarse gravel and a 0.4 m thick boulder were encountered within the fill deposit in Borehole SC-2. NW casing and NQ coring techniques were required to advance boreholes through the fill deposit.

[3] In the peat deposit, one SPT ‘N’-value of 10 blows per 0.3 m of penetration was measured in Borehole SC-2, which may be indicative of the frozen nature of the material. Additionally, two split spoon samples did not penetrate the entire SPT depth in Borehole SC-4, inferred to be due to presence of cobbles within the peat deposit; and a 0.5 m, size boulder was encountered underlying the peat deposit.

[4] 100 mm thick cobbles were encountered within the sand and gravel deposit in Borehole SC-2. NW casing and NQ coring techniques were required to advance the borehole through this deposit. In one instance the split spoon sample did not penetrate the entire SPT depth; however it was likely due to the close proximity to the bedrock surface.

Bedrock Conditions

Bedrock was cored in Boreholes SC-1 to SC-4 and the retrieved bedrock core is described as dark grey to brown, fine grained, fresh, strong to very strong greywacke with minor metamorphic banding, as presented on the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B3. A more detailed description of the depth to the bedrock surface, elevations and bedrock properties encountered in the boreholes is provided below.

Borehole No.	**Depth to Bedrock[1] (m)**	**Bedrock Surface Elevation (m)**	**Core Length (m)**	**TCR (%)**	**RQD (%)**	**Rock Quality [2]**	**UCS Strength (MPa)**	**Strength Classification [3]**
SC-1	2.4	403.2	2.2	100	85 – 96	Good	96	(R4) Strong
SC-2	5.6	402.6	1.6	100	78 – 100	Good to Excellent	68	(R4) Strong
SC-3	5.6	402.4	1.8	98 – 100	91 – 100	Excellent	158	(R5) Very Strong
SC-4	2.3	402.7	1.5	100	54 – 69	Fair	80	(R4) Strong

Notes:

[1]Below ground surface

[2]Table 3.10 of CFEM 2006[3]

[3]Table 3.5 of CFEM 2006[3]

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[3] Canadian Geological Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The river ice level was measured at Elevation 404.9 m on March 24, 2015. Groundwater and river water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
SC-1	0.7	404.9
SC-2	1.3	406.9
SC-3	1.9	406.1
SC-4	0.0	405.0

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle and Mr. Jim Mucklow, under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng., and Mr. David Muldowney, P.Eng., provided a technical review of the report. Mr. Jorge M.A. Costa, P.Eng., the Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.

Report Signature Page

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT
SOUTH CURRENT RIVER CULVERTS – SITE NO. 48C-217/C
HIGHWAY 527, DISTRICT OF THUNDER BAY
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides preliminary foundation design recommendations for the proposed replacement of the South Current River culverts. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the replacement culverts. Further investigation and analysis may be required during detail design, once the configuration of the proposed culvert and replacement strategy is finalized, to confirm and expand on the preliminary foundation recommendations provided in this report.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

It is assumed that the culverts will be replaced with a culvert(s) of similar dimensions, along the same alignment and at similar invert elevations to that of the existing twin culverts. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the new culvert(s) as part of the Hwy 527 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The South Current River culverts are located in the District of Thunder Bay, Unsurveyed Territory on Highway 527 at STA 16+956, approximately 28.5 km north of the junction of Highway 11/17 and Highway 527. The highway embankment is constructed of granular fill material and is approximately 4.4 m high relative to the culvert invert with approximately 2 m of cover over the existing culvert. The existing culvert consists of twin Steel Plate Corrugated Steel Pipes (SP CSP) arches, the details of which (i.e., width, height, length, etc.) are summarized in Table 1. In addition, there are two sets of twin 1200 mm diameter CSP overflow culverts located about 10 m and 25 m south of the South Current River arch culverts.

Based on discussions with HMM and review of the preliminary General Arrangement (GA) drawings, we understand the following culvert types are being considered at this location:

- Twin pre-cast concrete boxes;
- A pre-cast open footing culvert with either pre-cast concrete arch or metal box; and
- A pre-cast concrete cap supported on sheet-pile abutments.

In this report we have considered the following options feasible/practical:

- Single or twin pre-cast concrete box culvert(s);

- An open footing box or arch culvert support in either cast-in-place or pre-cast footings; and
- Pipe culverts.

Given the shallow depth to bedrock below the culvert invert, a culvert comprised of a pre-cast concrete cap supported on sheet pile abutments is not considered to be a feasible option at this site. Pipe culverts, including elliptical culverts and/or flexible arch culverts, similar to the existing culvert configuration, are considered feasible but would provide less flow through capacity compared to a box culvert option. If a pipe culvert(s) is selected, a concrete structure would be preferred as a CSP culvert generally has a shorter design life. Open footing arch culverts could be considered but the flow-through capacity could be limited or restricted due to the need to provide adequate soil cover including the required roadway pavement structure and the overall performance of such structures over the longer term is not known. From a foundation perspective, an open footing culvert sufficiently wide to handle the flow is preferred over a pre-cast box culvert based on the following:

- The proposed culvert invert will be close to the existing bedrock surface such that strip footings could be founded on bedrock;
- Open footing construction can easily accommodate differences in bedrock surface elevation;
- Open footing construction compared to pre-cast box culverts will likely require similar excavation and groundwater controls at this site; and
- While pre-cast box culvert segments can often be installed more expeditiously than open footing culverts, on-site construction of an open footing culvert will be easier than transporting large size box-culvert sections.

Other culvert types may be preferred due to construction staging or other considerations such as ease of construction associated with the pre-cast sections (transportation, cost) and simulating the natural channel substrate to that of the existing culverts. A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 2.

6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 Open Footing Culvert

Strip footings for an open footing culvert should be founded at a minimum depth of 2.4 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). However, at this site the footing will be founded on the bedrock and as such, soil cover for protection from frost penetration is not considered necessary. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

6.2.2.2 Box Culvert

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as a box structure is tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement box culvert be founded on the native silty sand to sand and gravel stratum. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3. In this regard, the culvert should be founded on a bedding of granular fill replacing any organics (i.e., peat) that may be present under the culvert, as detailed in Section 6.4.2.

The bedrock surface as encountered in the boreholes is between 0.6 m and 1.4 m below the assumed invert. However, depending on the bedrock surface elevation along the entire culvert alignment, levelling/lowering of the bedrock may be required to accommodate bedding placement as discussed further in Section 6.4.2., especially if it is required to lower the culvert invert to accommodate flow considerations. If it is not required to lower the culvert invert, then mass concrete or engineered fill may be required in places to raise the foundation level to the level of the underside of the granular bedding layer, depending on the elevation of the bedrock surface (see Section 6.4.3.2).

6.2.2.3 Pipe Culvert

It is not necessary to found a pipe culvert at the standard depth for frost protection purposes, as such a culvert is tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement pipe culvert(s), if adopted, be founded on the native silty sand to sand and gravel stratum. Recommended founding elevations and foundation conditions for a pipe culvert are provided in Table 3. Additional engineered fill may be required to raise the subgrade to the invert elevation prior to placing the granular levelling layer.

6.2.3 Geotechnical Resistances

6.2.3.1 Open Footing Culvert

Strip footings placed on the properly prepared bedrock surface, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical axial resistance at ULS provided in Table 3; the geotechnical reaction at SLS, for 25 mm of settlement does not apply in this case. These recommendations are based on the assumed footing width of 0.6 m or 1.2 m but will apply equally to other footing widths given that the founding stratum is bedrock.

6.2.3.2 Box Culvert

A box culvert, placed on the properly prepared subgrade and/or properly placed granular pad/backfill at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement as provided in Table 3. These recommendations are based on a box culvert width of 10 m (or twin boxes each 5 m wide) as provided in Table 3.

The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the culvert; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Design Code (CHBDC 2006) and it's Commentary.

6.2.4 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of the box culvert and granular bedding material or between the base of the strip footing and bedrock should be calculated in accordance with Section 6.7.5 of the CHBDC. Table 4 provides the coefficients of friction between the base of the culvert/footing and potential interface materials.

Depending on the slope of the bedrock and condition of the bedrock once exposed, dowelling of the footings into the bedrock may be required to increase sliding resistance. The horizontal resistance of the dowels is dependent on the strength of the bedrock, grout and steel. Where the rock mass is stronger than the concrete, the design of the dowels into the rock may be handled in the same way as the dowel embedment into the concrete as the UCS of the grout is similar to that of the concrete. The dowels should have a minimum length within the very strong bedrock of 1 m, and the structural strength of the grout should not be exceeded. A Non Standard Special Provision (NSSP) for construction of anchors (dowels) into bedrock can be developed at the detail design stage, if required depending on final culvert design and construction staging.

6.2.5 Stability and Settlement

Given that an embankment grade raise or widening is not proposed as part of the culvert replacement and highway embankment reconstruction, the existing native soils will not experience additional load, and therefore, settlement of the culvert if founded on a soil subgrade after embankment reconstruction is estimated to be less than 25 mm.

For the subsurface conditions and the proposed embankments height up to about 4.4 m relative to the culvert invert, granular fill embankments at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

Further, given the soil conditions and shallow depth to bedrock at this site, stability and/or settlement or stability issues are not anticipated should a grade raise or widening be required within the immediate vicinity of the culvert, assuming that all organics along the widened embankment footprint and under the culvert are removed below the embankment.

6.3 Lateral Earth Pressures

The lateral earth pressures acting on the side walls (or head/wing walls if required) of the culvert will depend on the type and method of placement of backfill materials, the nature of 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 culverts and any wing or head walls. It should be noted that these design recommendations and parameters are applicable to level backfill and ground surface behind the 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, II or III, but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of up to 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness. Weep holes should be installed to allow for positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- The granular fill may be placed either in a zone with the width equal to at least 2.4 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC).
- The following parameters (unfactored) may be used to calculate the lateral earth pressures acting on the culvert:

Fill Type	Internal Angle of Friction (ϕ, degrees)	Unit Weight (kPa)	Coefficients of Static Lateral Earth Pressure	
			At-Rest, K_o	Active, K_a
Granular 'A'	35	22	0.43	0.27
Granular 'B' Type II	35	21	0.43	0.27
Granular 'B' Type I or III	32	21	0.47	0.30

If the structure allows for lateral yielding, active earth pressures may be used in the design of the structure(s). If the structure does not allow for lateral yielding, at-rest earth pressures should be assumed for design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

6.4 Construction Considerations

6.4.1 Temporary Roadway Protection

The temporary excavation for the culvert replacement will be made through the existing embankment granular fill comprised of compact gravelly sand to silty sand and boulders in places and into native soils which are comprised of peat and loose to very dense silty sand to sand and gravel also inferred to include cobbles and boulders in places, underlain by bedrock. 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 fills and native soils are considered to be Type 3 soil above the groundwater table and Type 4 soil below. Temporary open-cut excavations in Type 3 soils should remain stable if side slopes are formed no steeper than 1H:1V. In Type 4 soils, the side slopes should be formed no steeper than 3H:1V.

Temporary protection support systems may be required along the highway to facilitate construction staging and maintain traffic during culvert replacement work. As this site, due to the relatively shallow depth to bedrock, a temporary support system comprised of sheet-piling will not be feasible. Soldier piles and lagging (with the piles socketed into bedrock or supported by tiebacks or rakers) may be used for support of the excavation along the structure, as well as along the roadway. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.

The installation of the sheet-piles for temporary shoring may be impeded by the presence of cobbles/boulders, inferred to be present within the fill material in Boreholes SC-2 and SC-3, within the sand and gravel deposit in Borehole SC-2, and within the peat deposit in Borehole SC-4. It may be necessary to excavate and replace the existing fill material and peat in the areas of sheet-pile installation in a series of limited length and narrow trenches. In general, the narrowest suitable excavator bucket should be used. The replacement fill could consist of excavated fill material or imported granular material such as OPSS.PROV 1010 Granular 'A' or Granular 'B' Type I, II or III provided that 100 per cent of the material passes the 75 mm size and less than 5 per cent passes the 75 µm size. The excavated fill material may be re-used to backfill the excavation after removing any cobbles/boulders that would otherwise impede the sheet-pile installation. Excavation and replacement should be carried out on the same day to avoid leaving any trench open overnight. Consideration should be given to include an NSSP in the contract to address obstructions; a sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

6.4.2 Excavation and Replacement Fill Below Culvert

Prior to placement of any bedding material, engineered fill or concrete, all organics (including peat and mixed organic materials) and any softened/loosened or disturbed soils, should be sub-excavated from below the plan limits of the proposed works to the founding levels provided in Table 3. For footings placed directly on bedrock, the surface should be cleaned, scaled, loosened debris removed and inspected before placing concrete.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for an open footing culvert. For a box culvert replacement, the sub-excavated area should be backfilled with granular material meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III that is placed and compacted in accordance with OPSS.PROV 501 (Compacting). The use of Granular 'B' Type II is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps). For a pre-cast open footing culvert option, uneven bedrock surfaces should be backfilled with mass concrete. An NSSP for mass concrete placement should be provided at the detail design stage, if required depending on final culvert design.

The bedrock surface elevation is relatively consistent between boreholes, with the exception of the west end, which is about 0.6 m higher. Although not anticipated to be present, localized areas of higher bedrock may require excavation to found the culvert at the depths given in Table 3. As the bedrock is classified as strong to very strong, bedrock excavation would require pre-drilling and/or hoe ramming to allow it to be excavated. Should lowering of the bedrock be required over a large extent of the open base area, depending on the final invert elevation, pre-drilling and hoe ramming alone may not be feasible nor practical. Consideration should be given to controlled blasting excavation techniques as per OPSS.PROV 120 (Explosives) and OPSS.PROV 202 (Rock Removal - Manual or Blasting) in order to preserve the integrity of the rock mass in the area of the rock excavation. 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.

6.4.3 Culvert Bedding and Backfill

6.4.3.1 Open Footing Culvert

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and also in similar configuration to that shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

Should a pre-cast open footing culvert be the selected replacement option, a bedding layer and levelling pad will be required above the bedrock surface. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed in Section 6.4.3.2 for the box culvert replacement option.

A frost taper should be constructed in a similar configuration to that shown in OPSD 803.010. Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable.

6.4.3.2 Box Culvert

The bedding and levelling pad requirements for a pre-cast box culvert should be accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the adjacent granular fill during excavation to the invert and bedding level, it is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular ‘B’ Type II material be used for bedding purposes. The bedding should be placed in maximum 200 mm thick loose lifts and be compacted to 98 per cent of the SPMDD as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided similar to that shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

A frost taper should be constructed in a similar configuration as that shown in OPSD 803.010. Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 10 m wide box culvert (or twin 5 m wide box culverts) replacement option.

6.4.3.3 Pipe Culvert

The bedding, levelling and backfill for a circular concrete pipe, CSP culvert or SP CSP arch should be in accordance with OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment), OPSD 802.014 (Flexible Pipe, Embedment in Embankment) or OPSD 802.024 (Flexible Pipe Arch, Embedment in Embankment), respectively, and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted. The pipe culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 Granular ‘A’ or Granular ‘B’ Type II material for bedding purposes, however this layer thickness should be confirmed at the detail design stage for the actual culvert type and size selected and to verify whether bedrock excavation is required to accommodate such a bedding layer.

A frost taper should be constructed in accordance with OPSD 803.031 (Frost Treatment) to mitigate potential for differential heave between the embankment fill and the pipe trench granular backfill.

6.4.3.4 Backfill

Backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm.

Backfill placement for reconstruction of the roadway embankments along and 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.

6.4.4 Subgrade Protection

The native silty sand subgrade, encountered towards the west end of the culvert, may be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance and as an alternative to the 300 mm compacted bedding layer, a concrete working slab should be placed on the subgrade if the box culvert or pipe culverts are not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa. Consideration should be given to include an NSSP in the contract to address subgrade protection at this site. An NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

6.4.5 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the box culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the box culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m, if constructed of natural clay or soil bentonite mix. The clay seal should extend from a depth of 1 m below the scour level 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. Given the observed width of the South Current River and river bed substrata, a clay blanket, extending upstream of the culvert and along the adjacent river banks/slopes is not considered suitable at this site.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. 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 embankment slope level.

6.4.6 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove embankment fill, organics and a portion or all of the native silty sand to sand and gravel stratum prior to placement of backfill, bedding material and the culvert structure. As a result of the excavation, groundwater flow into the excavation can be expected due to the relatively permeable nature of the embankment fill and native soils and along the soil/bedrock interface. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

Depending on the river flow, surface water flow conditions and groundwater level at the time of construction, water flow could be passed through the area by means of a temporary culvert, the existing overflow culverts located to the south of the culvert, using one or both of the existing twin-cell SP CSP arch culverts, or diverted by pumping from behind a temporary cofferdam; a sheet-pile cofferdam is not feasible at this location. Standard pumping from behind a cofferdam may not be adequate at this site given the permeability of the native soils and careful consideration should be given to the dewatering and channel diversion to allow for the foundations soils/bedrock to be exposed in-the-dry.

Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering). Consideration should be given to including an NSSP in the contract to address unwatering at this site. An NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the flow rate would be dependent on construction methods adopted by the contractor. However, it is considered that groundwater pumping volumes will likely exceed 50 m^3/day during initial drawdown stages and/or during periods of heavy precipitation. For this pumping volume, a Permit to Take Water (PTTW) would be required.

6.4.7 Obstructions

The Contractor should be alerted to the presence of cobble and boulder size material within the granular fill and the native soils, as encountered in Boreholes SC-2 and SC-3 and at the interface of the overburden/bedrock in Borehole SC-4. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the presence of such obstructions.

6.4.8 Analytical Testing for Construction Materials

The results of an analytical test on a sample of river water taken at the culvert site are presented in Table B1 in Appendix B. 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.

6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). Due to the shallow depth to bedrock at this site and the size of the proposed culverts, consideration should be given to advancing additional boreholes across the proposed footprint to further delineate the bedrock surface during detail design. Probeholes are not recommended to delineate the bedrock surface due to the presence of cobbles and boulders in the subsoils. In addition, if temporary shoring is required as part of the construction staging, additional boreholes are recommended to provide soils and bedrock information along the length of the roadway protection system. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. Further, the need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Mr. Adam Core, P.Eng. and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. Mr. Jorge M.A. Costa, P.Eng., Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.

Report Signature Page

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REFERENCES

Canadian Geological Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

Canadian Standards Association (CSA), 2006. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 06. CSA Special Publication, S6.1 06.

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

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.

Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52ANW.

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS)

OPSS 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 902	Construction Specification for Excavating and Backfilling – Structures
OPSS 1205	Material Specification for Clay Seal

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

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 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1002	Material Specification for Aggregates - Concrete
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 802.014	Flexible Pipe, Embedment in Embankment, Original Ground: Earth of Rock
OPSD 802.024	Flexible Pipe Arch, Embedment in Embankment Original Ground: Earth or Rock

OPSD 802.034	Rigid Pipe Bedding and Cover in Embankment Original Ground: Earth or Rock
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 803.031	Frost Treatment – Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade
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 903	Wells (as amended)

Table 1: Summary of Culvert Details

Culvert Location	Site #	Approximate Height of Embankment [1] (m)	Existing Culvert			Approximate Invert Elevation[2]	
			Type	Approximate Dimension[2]	Approximate Length (m)	West End of Culvert (m)	East End of Culvert (m)
Hwy 527 STA 16+956	48C-217/C	4.4	Twin SP CSP Arch	2.2 m high by 3.3 m wide (each)	22	403.8	403.8

Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the invert elevation of the culverts.
2. Culvert dimensions are based on the field review performed by HMM and the culvert invert elevations are based on the plan and profile drawings provided by MTO (Drawing E4848905271.dwg).

Prepared by: AC
Checked by: DAM
Reviewed by: JMAC

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Open Footing Culvert	■ Minor variations in bedrock surface elevation can easily be accommodated with cast-in-place open footing option or mass concrete. ■ May be feasible to build culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water. ■ Existing culvert(s) can likely be used for water diversion while new footings are being constructed adjacent to the culvert. ■ Readily suitable for construction using concrete or metal sections. ■ No settlement anticipated for footings founded directly on bedrock or mass concrete over bedrock. ■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Can be designed to readily accommodate greater loadings from a grade raise or widening of the embankment.	■ Excavations depths are about 1 m greater than for a concrete box culvert option, resulting in increased additional spoils material to be disposed off-site. ■ Will require water diversion of a relatively wide river channel and/or pumping from behind a cofferdam required to allow for unwatering for construction of footing in dry conditions. ■ For a pre-cast footing option, if bedrock is encountered higher than the desired invert, bedrock excavation may be required. ■ Concrete or metal arch sections supported on concrete open (strip) footings may not allow for adequate soil cover to be placed for ordinary construction.	■ Higher risk of unwatering issues related to footing construction in the dry as water seepage is anticipated within the relatively permeable embankment fill and native soils as well as along the native soil/bedrock interface.
Pre-Cast Box Culvert	■ Reduced excavation and off-site disposal of spoil material compared to open footing option. ■ Allows faster construction compared to cast-in-place options resulting in shorter duration for dewatering and surface water pumping. ■ Backfill/bedding under the culvert may be placed underwater (i.e. Granular ‘B’ Type II) minimizing or eliminating water pumping requirements. ■ Existing culvert(s) can likely be used for water diversion if multiple parallel boxes are constructed. ■ Tolerant of total and differential settlement due to frost penetration into the subgrade soils and if the highway embankment is raised or widened at the culvert site, or remnants of the peat deposit are not fully removed.	■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Concrete cut-off wall (or clay blanket) typically required at inlet to mitigate potential scour under culvert. ■ Transportation to and on-site lifting of large pre-cast sections will be required. ■ Will require water diversion of a relatively wide river channel of pumping but bedding material can be placed in the wet conditions. ■ Pre-cast box will be founded on the slightly weak native soils but these could be sub-excavated and replaced to found the culvert on engineered fill over bedrock extended construction period.	■ Should bedrock surface be encountered higher than anticipated, bedrock excavation will be required to reach desired invert elevation. ■ Some risk of disturbance of the native sand and gravel to silty sand deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad. ■ Limited risk related to settlement performance. ■ Increase in construction costs if the culvert is founded on bedrock (i.e., on a bedding layer over bedrock).

Option	Advantages	Disadvantages	Risks/Consequences
Circular Pipe Culvert	■ Allows faster construction compared to cast-in-place options resulting in shorter duration for dewatering and surface water pumping. ■ Backfill under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements. ■ More tolerant of total and differential settlement if the highway embankment is raised or widened.	■ Reduced flow-through capacity for the same overall culvert span compared to box culvert options. Multiple CSPs likely required to achieve required flow. ■ Cut-off wall or clay seal may be required at inlet to mitigate potential scour under culvert. ■ CSP does not have as long of a design life compared to concrete culvert options.	■ Some risk of disturbance of the native silty sand to sand and gravel deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad. ■ Limited risk of adequate performance due to settlement.

Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Open Footing Culvert Replacements

Culvert Location	Approximate Invert Elevation [1]	Culvert Type	Approximate Backfill/Bedding Founding Elevation	Founding Condition	Factored Geotechnical Axial Resistance at ULS [2]	Geotechnical Reaction at SLS for 25 mm of Settlement [2]
Hwy 527 STA 16+956	403.8 m	Open Footing [2]	402.4 m – 403.2 m (variable)	Bedrock / Mass Concrete on Bedrock	1000 kPa	N/A
		Pre-Cast Box [2]	403.4 m	Replacement Fill/Bedding over Loose to Very Dense Silty Sand to Sand and Gravel Stratum	250 kPa	200 kPa
		Pipe [3]	403.5 m	Replacement Fill/Bedding over Loose to Very Dense Silty Sand to Sand and Gravel Stratum	N/A	N/A

Notes: 1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing E4848905271.dwg).

2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 10 m wide box culvert (or twin boxes each 5 m wide) and a 0.6 m or 1.2 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.

3. The foundation elevation may need to be adjusted based on the type and size of the pipe culvert and required bedding thickness.

Prepared by: AC
Checked by: DAM
Reviewed by: JMAC

Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Culvert Replacements

Culvert Location	**Pre-Cast Box Culvert or Pre-cast Open Footing**		**Cast-in-place Open Footing**	
	Interface Material	**Coefficient of Friction[1] (tan δ)**	**Interface Material**	**Coefficient of Friction[1] (tan δ)**
Hwy 527 STA 16+956	Compacted Granular Fill (Backfill/Levelling Pad)	0.45	Bedrock Surface / Mass Concrete on Bedrock	0.70

Notes: 1. These values are unfactored. In accordance with CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistances.

Prepared by: AC
Checked by: DAM
Reviewed by: JMAC

MINISTRY OF TRANSPORTATION, ONTARIO

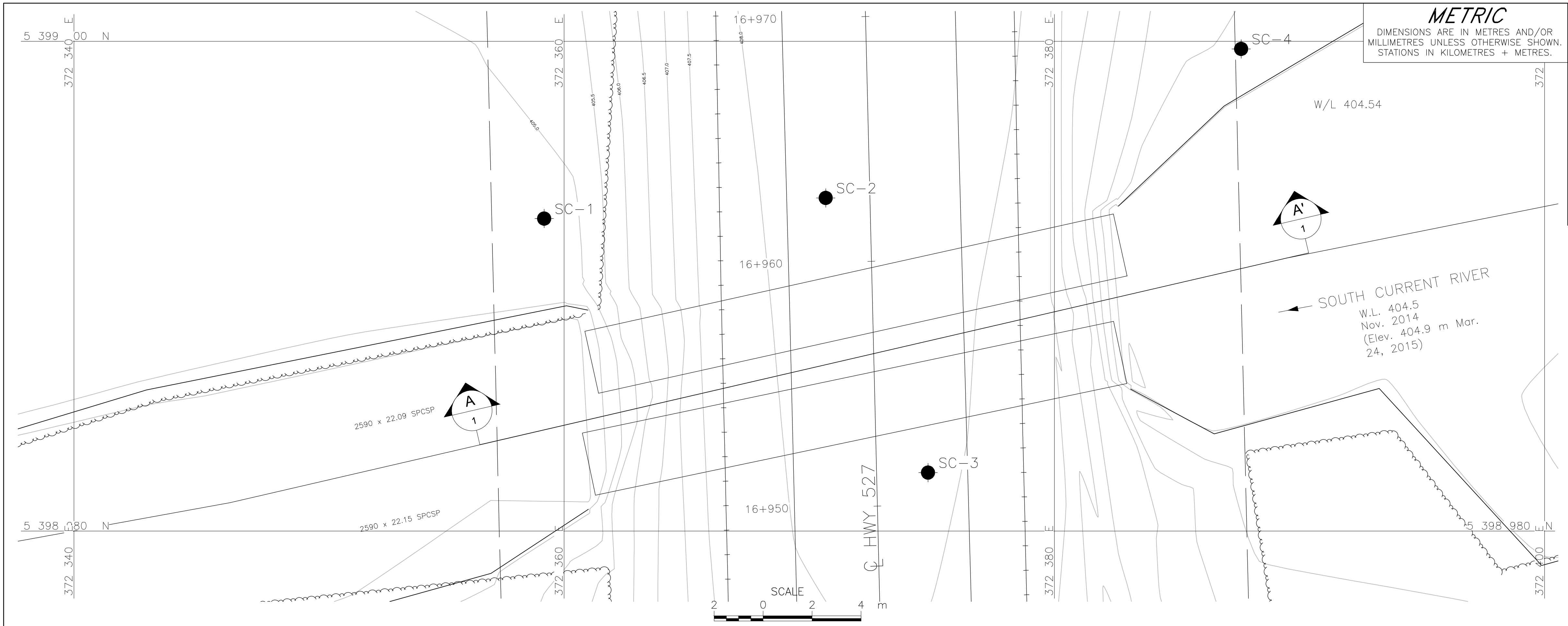
CONT No.
GWP No. 6826-14-00

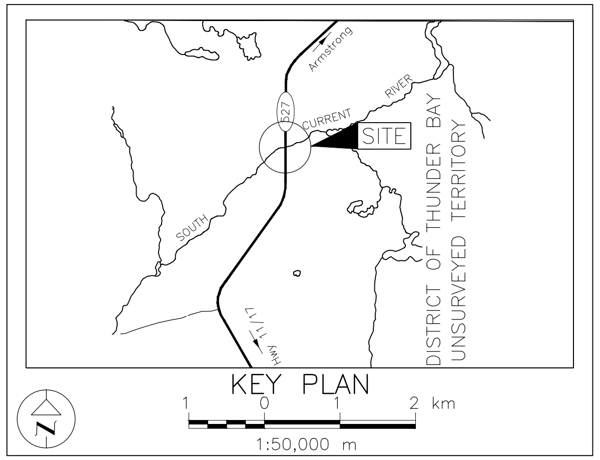
SHEET

HIGHWAY 527
SOUTH CURRENT RIVER CULVERT STA 16+956
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates

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





KEY PLAN

1 0 1 2 km

1:50,000 m

LEGEND

●	Borehole
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling
REC	Recovery
97%	Rock Quality Designation (RQD)

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
SC-1	405.6	5398992.8	372359.2
SC-2	408.2	5398993.6	372370.7
SC-3	408.0	5398982.4	372374.8
SC-4	405.0	5398999.7	372387.6

NOTES

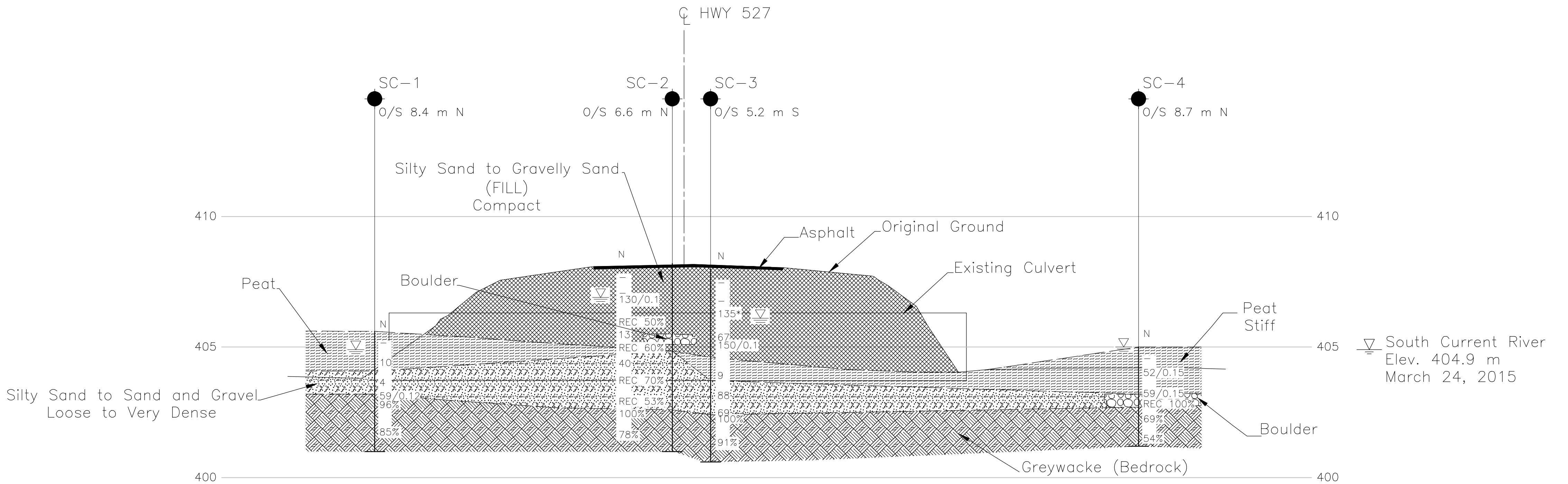
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MTO, drawing file no. E4848905271, dated NOV 2014, received FEB 20 2015.



PROFILE

A-A'
1

HORIZONTAL SCALE
2 0 2 4 m
2 0 2 4 m
VERTICAL SCALE

D.A. MULDOWNEY
100164716
SEP 25, 2015

J.M.A. COSTA
SEP 25, 2015

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 52A-201

HWY.	PROJECT NO. 1411523	DIST.
SUBM'D. AC	CHKD. / DATE: 9/28/2015	SITE: 48C-217/C
DRAWN: JJL/TB	CHKD. DAM / APPD. JMAC	DWG. 1

PLOT DATE: September 28, 2015
FILENAME: \\golder.gds\gal\Sudbury\CAD-GIS\CAD\Projects\2014\1411523 HWM 26 Culverts Thunder Bay\CIVIL 3D\1411523_South Current River.dwg

Photograph 1: South Current River Culverts
East End – Inlet (Taken from MTO, OSIM _08-27-2013)

Photograph 2: South Current River Culverts
West End – Outlet (Taken from MTO, OSIM _08-27-2013)

Photograph 3: South Current River Culverts East End – Inlet (Golder – March 23, 2015)

Photograph 4: South Current River Culverts West End – Outlet (Golder – March 23, 2015)

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

Density Index Relative Density	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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

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^{o} 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 SC-1

1 OF 2 **METRIC**

PROJECT 1411523

G.W.P. 6826-14-00

LOCATION N 5398992.8; E 372359.2

ORIGINATED BY MR

DIST

HWY 527

BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers, NW Casing and NQ Coring

COMPILED BY AC

DATUM GEODETIC

DATE March 25, 2015

CHECKED BY DAM

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				
405.6	GROUND SURFACE										
0.0	Amorphous PEAT, trace sand, trace gravel Dark brown Frozen*		1	AS	-				○ 105		
			2	SS	10*	∇	405				
404.1 1.5	Silty SAND, trace gravel, trace organics Loose Dark brown Wet		3	SS	4		404		○	OC=4.3%	
403.2			4	SS	59/0.13						
2.4	GREYWACKE (BEDROCK) Bedrock cored from 2.4 m depth to 4.6 m depth. For coring details see Record of Drillhole SC-1.		1	RC	REC 100%		403				RQD = 96%
			2	RC	REC 100%		402				RQD = 85%
401.0 4.6	END OF BOREHOLE Note: 1. Water level at a depth of 0.7 m below ground surface (Elev. 404.9 m) upon completion of drilling.						401				

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 17/09/15 DATA INPUT:

PROJECT: 1411523

RECORD OF DRILLHOLE: SC-1

SHEET 2 OF 2

LOCATION: N 5398992.8 ;E 372359.2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 25, 2015

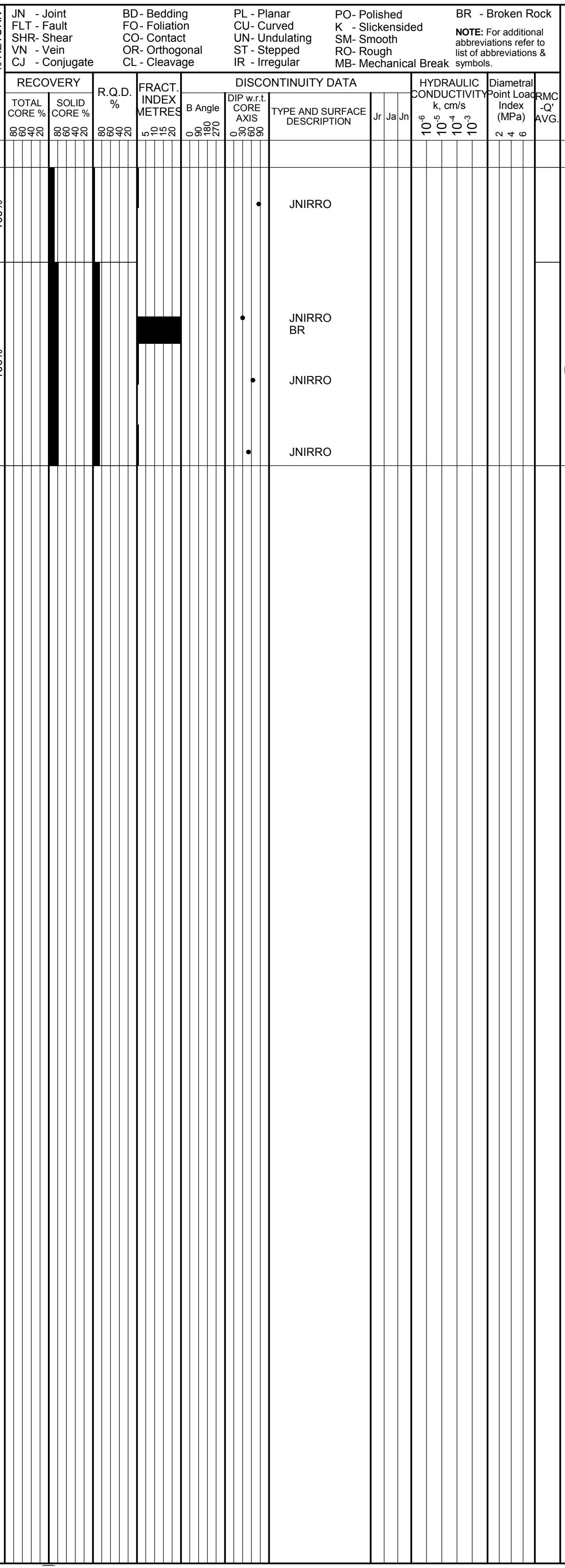
DRILL RIG: CME 55

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

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	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page						
	NW March 25, 2015 NQ Coring	GREYWACKE, minor metamorphic banding Fine grained Fresh Dark grey to brown Strong		403.2 2.4	1	GREY 100%	JNIRRO	
3								
		Broken rock between 3.5 m and 3.7 m depth.			2	GREY 100%	JNIRRO BR	
4							JNIRRO	UCS = 96 MPa
				401.0			JNIRRO	
		END OF DRILLHOLE		4.6				
5								
6								
7								
8								
9								
10								
11								
12								



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MR

CHECKED: DAM

RECORD OF BOREHOLE No SC-2

1 OF 2 **METRIC**

PROJECT 1411523
G.W.P. 6826-14-00
DIST
HWY 527
DATUM GEODETIC
LOCATION N 5398993.6; E 372370.7
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers, NW Casing and NQ Coring
DATE January 20, 2015 / March 24, 2015
ORIGINATED BY MR/JM
COMPILED BY AC
CHECKED BY DAM

SOIL PROFILE			SAMPLES			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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
408.2	GROUND SURFACE													
0.0	ASPHALT (75 mm)													
0.1	Silty sand to sand, trace to some coarse gravel, trace clay (FILL) Compact Brown Frozen* to moist Augers grinding from 0.6 m to 0.9 m depth on inferred cobbles / boulders. Gravel (up to 75 mm) recovered from core barrel between 1.9 m and 2.3 m depth. A 0.4 m boulder was encountered at 2.7 m depth.		1	AS	-		408							
			2	AS	-				○		3	64	29	4
			3	SS	130/0.1*	▽	407							
			-	RC	REC 50%		406							
			4	SS	13									
			5	RC	REC 60%		405							
404.8 3.4	SAND and GRAVEL, trace to some silt Dense Brown Wet A 100 mm cobble was encountered at 4.0 m depth and 4.3 m depth.		6	SS	40				○		43	51	(6)	
			7	RC	REC 70%		404							
			8	RC	REC 53%		403							
402.6 5.6	GREYWACKE (BEDROCK) Bedrock cored from 5.6 m depth to 7.2 m depth. For coring details see Record of Drillhole SC-2.		1	RC	REC 100%						RQD = 100%			
			2	RC	REC 100%		402				RQD = 78%			
401.0 7.2	END OF BOREHOLE Note: 1. Auger refusal encountered at 1.2 m depth on inferred cobbles / boulders. Advanced additional borehole 1 m north of Borehole SC-2 and continued sampling below 1.2 m depth. 2. Core barrel broke in borehole at 5.6 m depth. Advanced additional borehole on March 24, 2015 1 m west of Borehole SC-2 and cored below 5.6 m depth. 3. Water level at a depth of 1.3 m below ground surface (Elev. 406.9 m) upon completion of drilling.						401							

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

PROJECT: 1411523

RECORD OF DRILLHOLE: SC-2

SHEET 2 OF 2

LOCATION: N 5398993.6 ;E 372370.7

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 24, 2015

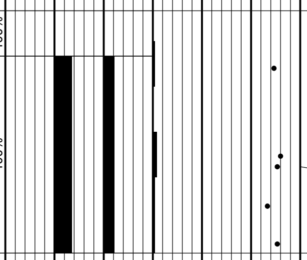
DRILL RIG: CME 55

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

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	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page		402.6				
	NW	GREYWACKE, minor metamorphic banding Fine grained Fresh Dark grey to brown Strong		5.6	1	GREY 100%		
6	March 24, 2015 NQ Coring				2	GREY 100%	JNIRRO	UCS = 68 MPa
							JNIRRO JNIRRO	
							JNIRRO	
7				401.0			JNIRRO	
		END OF DRILLHOLE		7.2				



8

9

10

11

12

13

14

15

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MR/JM

CHECKED: DAM

Golder Associates

RECORD OF BOREHOLE No SC-3

1 OF 2 **METRIC**

PROJECT 1411523

G.W.P. 6826-14-00

LOCATION N 5398982.4; E 372374.8

ORIGINATED BY JM

DIST

HWY 527

BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers, NW Casing and NQ Coring

COMPILED BY AC

DATUM GEODETIC

DATE January 17 and 18, 2015

CHECKED BY DAM

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 (%)

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
408.0	GROUND SURFACE										
0.0 0.1	ASPHALT (75 mm) Gravelly sand, some silt (FILL) Brown Frozen* to wet	1	AS	-							
		2	AS	-		407					
		3	SS	135*			○	24	55	19	2
					∇	406					
		4	SS	67							
	Inferred cobbles.	5	SS	150/0.1		405					
404.7 3.3	Amorphous PEAT, some sand, some gravel Stiff Dark brown Wet	6	SS	9		404	○				
403.7 4.3	SAND and GRAVEL, some silt, trace clay Very dense Grey Wet	7	SS	88		403					
		8	SS	69			○	40	45	13	2
402.4 5.6	GREYWACKE (BEDROCK) Bedrock cored from 5.6 m depth to 7.4 m depth. For coring details see Record of Drillhole SC-3.	1	RC	REC 100%		402		RQD = 100%			
		2	RC	REC 98%		401		RQD = 91%			
400.6 7.4	END OF BOREHOLE										

Note:

1. Auger refusal encountered at 2.7 m depth on inferred cobbles / boulders. Advanced additional borehole 1.2 m south of Borehole SC-3.

2. Auger refusal encountered at 1.5 m depth on inferred cobbles / boulders. Advanced additional borehole 2.9 m south of Borehole SC-3 and continued sampling below 2.9 m depth.

3. Water level at a depth of 1.9 m below ground surface (Elev. 406.1 m) upon completion of drilling.

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

PROJECT: 1411523

RECORD OF DRILLHOLE: SC-3

SHEET 2 OF 2

LOCATION: N 5398982.4 ;E 372374.8

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 18, 2015

DRILL RIG: CME 850

DRILLING CONTRACTOR: Cartwright Drilling Inc.

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	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX METRES 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	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.	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page		402.4																
6 7	MW January 18, 2015 NQ Coring	GREYWACKE, minor metamorphic banding Fine grained Fresh Dark grey to brown Very strong	▨	5.6	1	100%														
					2	100%														UCS = 158 MPa
				400.6 7.4																
8 9 10 11 12 13 14 15		END OF DRILLHOLE																		

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: JM

CHECKED: DAM

RECORD OF BOREHOLE No SC-4

1 OF 2 **METRIC**

PROJECT 1411523			
G.W.P. 6826-14-00	LOCATION N 5398999.7; E 372387.6	ORIGINATED BY MR
DIST HWY 527	BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers, NW Casing and NQ Coring	COMPILED BY AC
DATUM GEODETIC	DATE March 24, 2015	CHECKED BY DAM

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
405.0	GROUND SURFACE					▽					
0.0	Amorphous PEAT to Sandy PEAT, trace to some gravel Dark brown Frozen Augers grinding from 0.3 m to 1.5 m depth on inferred cobbles / boulders.		1	AS	-						
			2	SS	52/0.15		404				
403.2			3	SS	59/0.15				○		
1.8 402.7	BOULDER		-	RC	REC 100%		403				
2.3	GREYWACKE (BEDROCK) Bedrock cored from 2.3 m depth to 3.8 m depth. For coring details see Record of Drillhole SC-4.		1	RC	REC 100%		402				RQD = 69%
401.2			2	RC	REC 100%						RQD = 54%
3.8	END OF BOREHOLE Note: 1. Water level at ground surface (Elev. 405.0 m) upon completion of drilling.										

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

PROJECT: 1411523

RECORD OF DRILLHOLE: SC-4

SHEET 2 OF 2

LOCATION: N 5398999.7 ;E 372387.6

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 24, 2015

DRILL RIG: CME 55

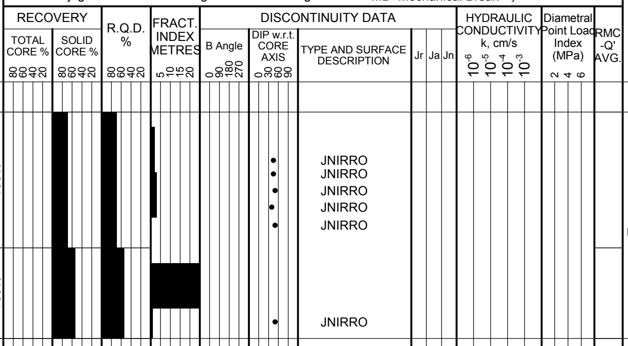
DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DATUM: GEODETIC

JN - Joint	BD - Bedding	PL - Planar	PO - Polished
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided
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

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)	TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page		402.7				
3	March 24, 2015 NW NQ Coring	GREYWACKE, minor metamorphic banding Fine grained Fresh Dark grey to brown Strong Broken rock between 3.4 m and 3.7 m depth.		2.3	1	GREY 100%	JNIRRO JNIRRO JNIRRO JNIRRO JNIRRO	UCS = 80 MPa
				401.2 3.8	2	GREY 100%	JNIRRO	
4		END OF DRILLHOLE						
5								
6								
7								
8								
9								
10								
11								
12								

DEPTH SCALE

1 : 50

LOGGED: MR

CHECKED: DAM

APPENDIX B

Laboratory Test Results

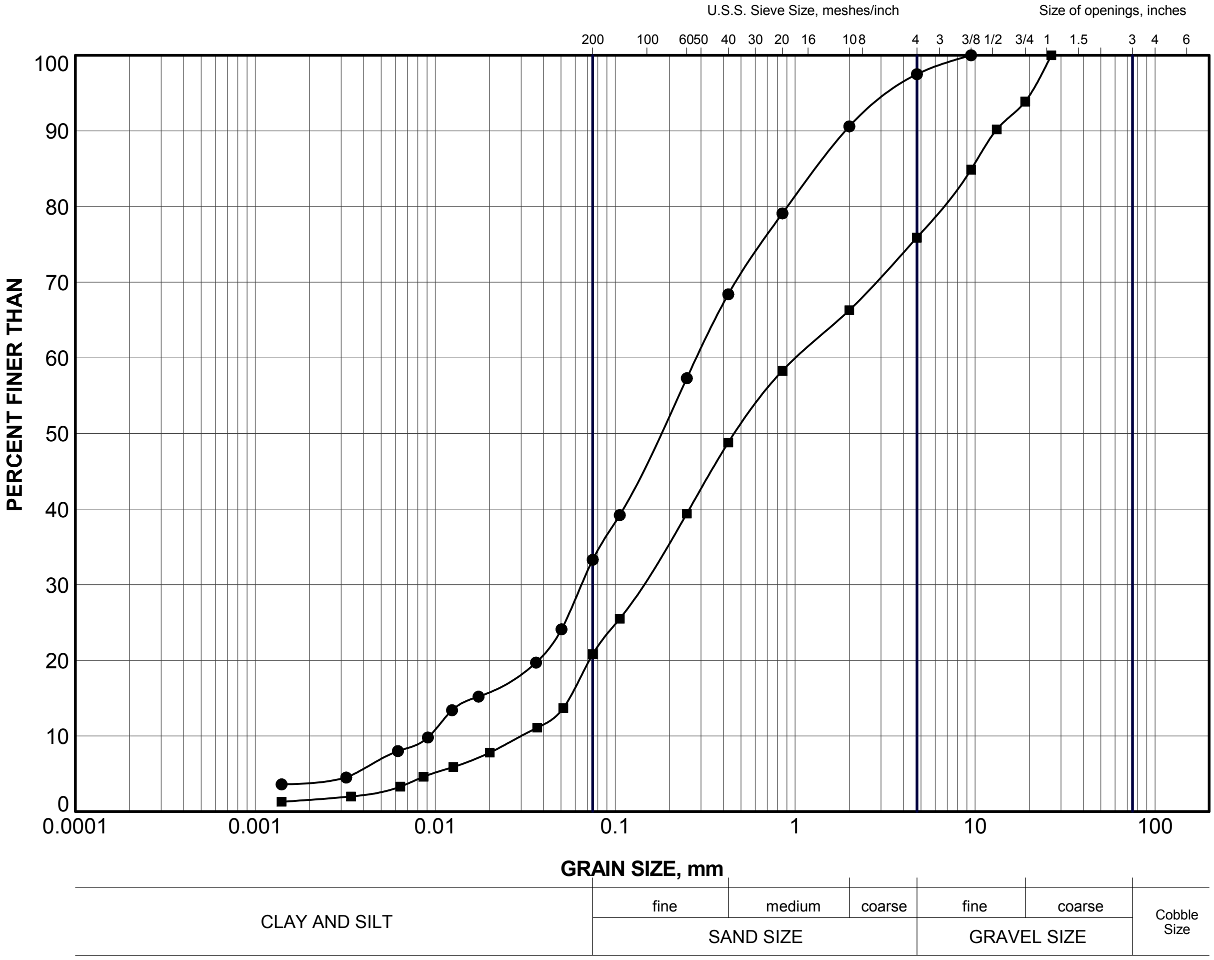
Table B1: Summary of Analytical Testing of South Current River Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	0.65
Sulphate (SO4)	mg/L	1.25
Conductivity (EC)	µS/cm	77.5
Resistivity	µohm-cm	<0.33
pH	n/a	7.29

Notes:

1. Sample obtained on January 18, 2015.
2. Analytical testing carried out by ALS Canada Ltd.

Prepared by: AC
Checked by: DAM
Reviewed by: JMAC



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	SC-2	2	407.2
■	SC-3	3	406.4

PROJECT

HIGHWAY 527
SOUTH CURRENT RIVER CULVERT STA 16+956

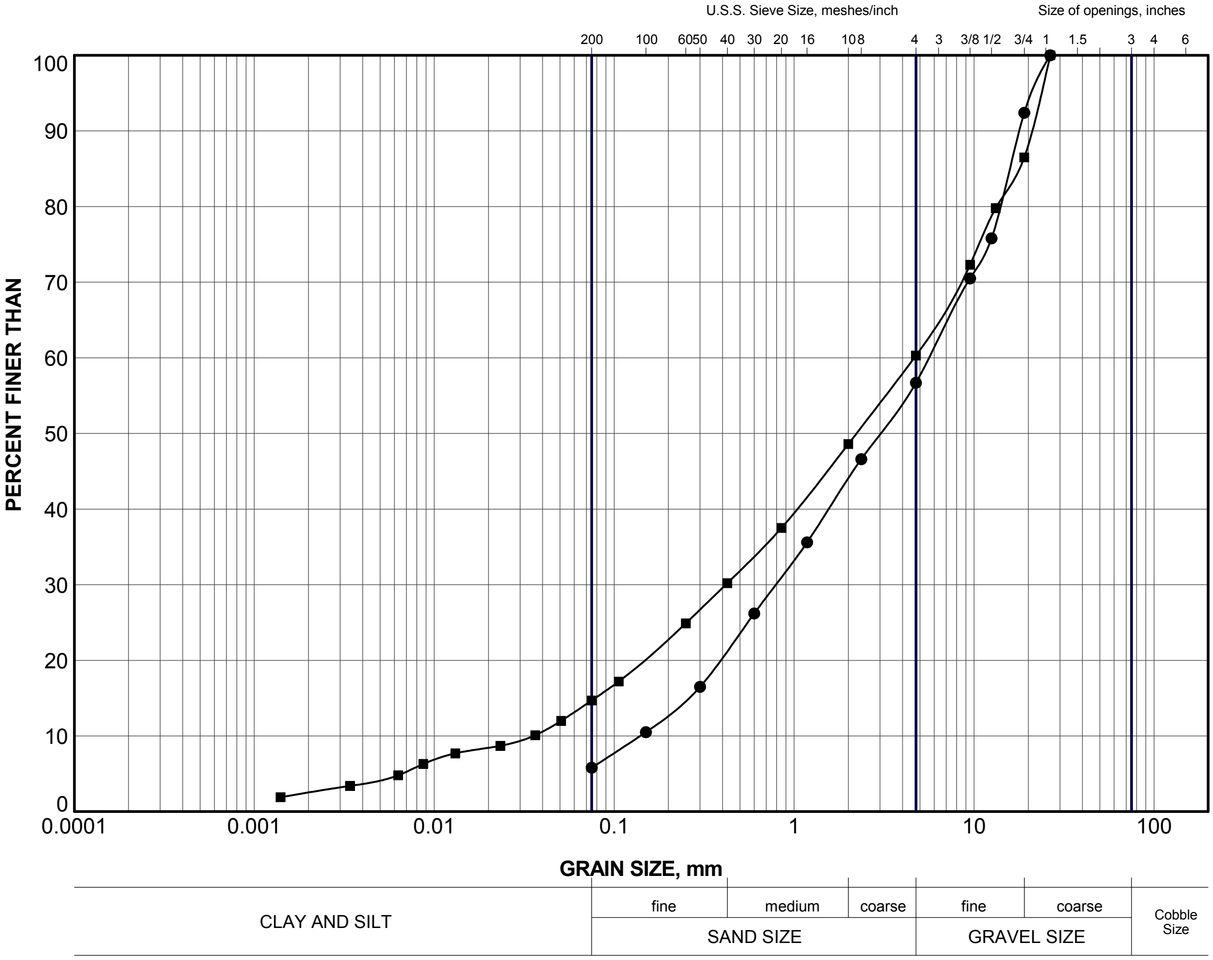
TITLE

GRAIN SIZE DISTRIBUTION

SILTY SAND to GRAVELLY SAND(FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	JJL	May 2015	SCALE N/A	REV.
CHECK	DAM	May 2015		
APPR	JMAC	May 2015	**FIGURE B1**	



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	SC-2	6	404.5
■	SC-3	8	402.6

PROJECT

HIGHWAY 527
SOUTH CURRENT RIVER CULVERT STA 16+956

TITLE

GRAIN SIZE DISTRIBUTION

SAND and GRAVEL

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	JJL	May 2015	SCALE N/A	REV.
CHECK	DAM	May 2015	**FIGURE B2**	
APPR	JMAC	May 2015		

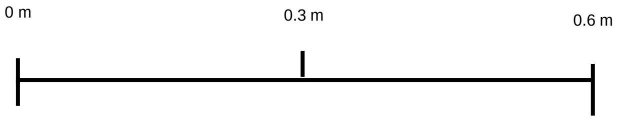
SUD-MTO GSD (NEW) GLDR_LDN.GDT

Borehole SC-1
Elevation 403.2 m to 401.0 m

Borehole SC-2
Elevation 402.6 m to 401.0 m

Borehole SC-3
Elevation 402.4 m to 400.6 m

Borehole SC-4
Elevation 402.7 m to 401.2 m



PROJECT
HIGHWAY 527
SOUTH CURRENT RIVER CULVERT STA 16+956

TITLE
BEDROCK CORE PHOTOGRAPHS

PROJECT No.	1411523		FILE No. ----
DESIGN			SCALE AS SHOWN | REV.
CADD	AC	Apr. 2015	**FIGURE B3**
CHECK	DAM	Apr. 2015	
REVIEW	JMAC	Apr. 2015	

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