March 15, 2016

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 542 BLUE JAY CREEK CULVERT, SITE 49-63/C
TOWNSHIP OF TEHKUMMAH, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5465-09-00, WP 5066-07-01

Submitted to:
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REPORT

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PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 542 BLUE JAY CREEK CULVERT, SITE 49-63/C

TOWNSHIP OF TEHKUMMAH, MANITOULIN ISLAND, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5090-13-00, WP 5066-07-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McIntosh Perry Consulting Engineers Ltd. (McIntosh Perry) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the Highway 542 Blue Jay Creek culvert at Station 11+597 (Site # 49-63/C), in the Township of Tehkummah on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 542 and the location of the investigated area are shown on Drawing 1. The orientation (i.e., north, south, east, and west) stated in the text of the report is referenced up-chainage along the existing Highway 542 alignment. For purposes of this report, Highway 542 is oriented north-south.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Blue Jay Creek culvert is located in the Township of Tehkummah on Highway 542, approximately 1.9 km north of Highway 6. The land use in the area is generally rural with a few residences and commercial buildings in the vicinity of the site.

In general, the topography in the area of the overall project limits is generally flat with gently rolling hills separated by the Blue Jay Creek which meanders along and below Highway 542 in this area. The creek banks are vegetated with grass and small trees. The creek flows from east to west and is approximately 4 m wide at the culvert location.

The existing highway grade at the culvert is at about Elevations 209.2 m. with the Blue Jay Creek located about 2.6 m below the existing highway grade. The existing culvert, which was constructed in 1985, is a 3.9 m span by 2.4 m high by 20 m long (on the skew with beveled ends) Structural Plate Corrugated Steel Pipe Arch (SPCSPA) under approximately 0.14 m of fill. The existing inlet and outlet inverts are at Elevation 206.6 m. A 2010 structural inspection indicated significant deterioration of the culvert barrel with bolt line cracking and breakdown of the structural steel coating. Photographs taken at the site are included following the text of the report.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out on September 20 and 21, 2012, during which time a total of three boreholes (BJW-1 to BJW-3) were advanced at the culvert location. The locations of the boreholes are shown on Drawing 1.

The field investigation was carried out using a track-mounted CME-850 drill rig supplied and operated by Landcore Drilling (Landcore) of Sudbury, Ontario. The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained at intervals of depth of about 0.75 m to 1.5 m, using a 50 mm outer diameter split-spoon sampler, operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Samples of the bedrock were obtained using NW casing and 'NQ' size rock core barrels in Boreholes BJW-1 and BJW-2. 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 with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The boreholes were advanced to depths ranging between 0.6 m and 6.0 m below existing ground surface. In Boreholes BJW-1 and BJW-2, a total of 3.0 m and 2.9 m of bedrock was cored, respectively. Borehole BJW-3 was advanced to split-spoon refusal (i.e., hammer bouncing) on the inferred bedrock surface. The pavement borehole advanced near the east end of the culvert in the vicinity of Borehole BJW-3 encountered refusal on inferred bedrock at a similar depth below ground surface and a copy of the pavement log is included in Appendix A. A Dynamic Cone Penetration Test (DCPT) was advanced adjacent to each borehole to refusal at depths ranging from 0.6 m to 2.9 m below the existing ground surface.

The fieldwork was supervised throughout by members of our technical staff who: located the boreholes; arranged for the clearance of underground services; supervised the drilling, sampling operations; logged the boreholes; and examined and cared for the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water contents and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included on the Record of Borehole Sheets in Appendix A and in Appendix B.

A sample of the creek water was obtained during the field investigation using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to stations on the highway. The MTM NAD 83 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 are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
BJW-1	5058819.2	344664.3	209.3	6.0
BJW-2	5058818.7	344654.3	207.2	3.7
BJW-3	5058827.9	344678.1	207.0	0.6

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on the Physiography of Southern Ontario (Ministry of Northern Development and Mines)[1], the site is located within clay plains, which are interrupted by drumlin formations of till and/or rock.

[1] Chapman, L.J. and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

Based on geological mapping in the area (Ministry of Northern Development and Mines)[2], the bedrock in the area consists typically of sandstone, shale, dolostone and siltstone from the Amabel Formation from the Silurian Period of the Paleozoic Era.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Drillhole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes is shown in profile on Drawing 1.

In general, the subsurface conditions encountered at the site generally consist of embankment fill overlying bedrock at the midpoint of the culvert and a surficial layer of sand or peat underlain by a relatively thin layer of clayey silt to silt overlying bedrock near the ends of the culvert. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Surface Treatment

A 50 mm thick layer of surface treatment was encountered at ground surface (Elevation 209.3 m) in Borehole BJW-1, which was advanced through the existing roadway.

4.2.2 Fill

Underlying the surface treatment in Borehole BJW-1, embankment fill material consisting of brown, moist sand and gravel to gravelly sand, trace to some silt, was encountered. The granular fill is about 2.9 m thick and extends to the bedrock surface. The augers were noted to be grinding likely on cobbles within the fill at depths of 2.4 m and 2.9 m below the existing ground surface.

Standard Penetration Test (SPT) 'N'-values in the granular fill are 14 blows and 25 blows per 0.3 m of penetration. One split-spoon drive at a depth of about 2.4 m, did not penetrate the full sampling depth indicative of the likely presence of cobbles.

A grain size distribution test was carried out on one sample of the gravely sand fill and the result is shown on Figure B1 in Appendix B.

The natural water content measured on one sample of the gravelly sand fill is 5 per cent.

[2] Ministry of Northern Development and Mines, 1991. *Bedrock Geology of Ontario*, Southern Sheet, Map 2544.

4.2.3 Peat

A 0.5 m thick deposit of black, wet amorphous peat, some sand and trace gravel was encountered from ground surface (Elevation 207.0 m) in Borehole BJW-3.

The SPT ‘N’-value within the peat is 0 blows (i.e., weight of hammer) per 0.3 m penetration, suggesting a very soft consistency.

The natural moisture content measured on one sample of the peat is 94 per cent.

4.2.4 Sand

A 0.6 m thick deposit of grey, wet sand, trace gravel and trace to some organics, was encountered at ground surface (Elevation 207.2 m) in Borehole BJW-2.

The SPT ’N‘-value within the sand deposit is 2 blows per 0.3 m penetration, indicating a very loose relative density.

4.2.5 Clayey Silt to Silt

A 0.1 m to 0.2 m thick layer of grey, wet clayey silt to silt, some sand and some gravel, was encountered underlying the sand in Borehole BJW-2 and the peat in Borehole BJW-3 at Elevation 206.6 m and 206.5 m. The bottom of the deposit is defined by bedrock coring in Borehole BJW-2 and refusal to further auger advancement in Borehole BJW-3.

4.2.6 Bedrock/ Refusal

Bedrock was cored in Boreholes BJW-1 and BJW-2. Refusal to further auger penetration was encountered in Borehole BJW-3 with a generally consistent refusal depth in the adjacent pavement borehole. The bedrock surface/refusal depths and elevations are presented below.

Borehole No.	Depth to Bedrock/Refusal Surface (m)	Bedrock/Refusal Surface Elevation (m)	Refusal Type
BJW-1	3.0	206.3	Bedrock Cored (3.0m)
BJW-2	0.8	206.4	Bedrock Cored (2.9 m)
BJW-3	0.6	206.4	Auger Refusal
Pavement Borehole	0.5	N/A	NFP

The retrieved bedrock core is described as a fine to medium grained, slightly weathered, grey to brown, dolomitic limestone, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B2 in Appendix B.

The Total Core Recovery during bedrock coring was 100 per cent. The Rock Quality Designation measured on the core samples ranges from 67 per cent to 98 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

4.2.7 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized in the table below.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
BJW-1	3.6	205.7
BJW-2	1.7	205.5
BJW-3	Dry	Dry

Groundwater levels encountered in the boreholes shortly after drilling may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. The water in the creek at the time of the investigation in September 2012 was at about Elevation 206.7 m, just above the culvert invert. Groundwater levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field personnel supervising the drilling program was Mr. Ed Savard. This report was prepared by Ms. Michelle He and Mr. David Muldowney, P.Eng., and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.

Report Signature Page

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PART B

FOUNDATION DESIGN REPORT

HIGHWAY 542 – BLUE JAY CREEK CULVERT, SITE 49-63/C

TOWNSHIP OF TEHKUMMAH, MANITOULIN ISLAND, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5090-13-00, WP 5066-07-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation and conclusions and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as such interpretation may affect their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

The existing Blue Jay Creek culvert (Site 49-63/C) is an elliptical 3.8 m span by 2.4 m high by 20 m long Structural Plate Corrugated Steel Pipe Arch (SPCSPA) under about 0.14 m of fill. The existing culvert will be replaced with a 21 m long cast-in-place concrete culvert open footing culvert with a 5 m span and rise of 1.2 m. The inverts for the proposed culvert replacement will be similar to the existing inverts, which are at about Elevation 206.6 m at the inlet (east end) and the outlet (west end). The inverts are close to the bedrock surface as found in the boreholes. The existing embankment is constructed of granular fill material and is approximately 2.6 m high. The existing culvert was constructed in 1985.

The subsoils at the culvert midpoint generally consist of embankment fill materials (sand and gravel to gravelly sand) overlying bedrock. At the ends of the culvert, the native soils consist of sand or organics (peat) underlain by a deposit of clayey silt to silt overlying bedrock. Bedrock was encountered between Elevation 206.3 m and 206.4 m. Details of the subsurface conditions along this culvert are presented Section 4.2 and shown in profile on Drawing 1.

6.2 Culvert Types

The analysis and recommendations presented in this report are based on an open footing culvert. A CSP (circular or arch) or a concrete box culvert is also feasible at this site. Table 1 presents a comparison of the alternatives. The existing pipe arch provides more flow through capacity than a circular CSP of a similar height. Lining the existing pipe arch would also decrease the flow through capacity. CSPs also generally have a shorter design life than concrete culverts. From a foundations perspective, a precast concrete box culvert sufficiently wide to handle the flow is preferred, however, we understand that a box culvert is not preferred at this site in order to minimize the impact to the creek, which is environmentally sensitive due to the nearby fish hatchery.

6.3 Geotechnical Resistance

A factored geotechnical axial resistance at Ultimate Limit States (ULS) of 1,000 kPa may be used for design for the 1.6 m wide open footing culvert founded directly on bedrock. For an assumed 5 m wide box culvert bearing on granular bedding or a concrete working slab overlying bedrock, a factored axial resistance at ULS of 1,000 kPa may be assumed for design. Due to the shallow bedrock at this site, the geotechnical axial resistance at

Serviceability Limit States will be equal to or greater than the factored geotechnical resistances at ULS and, therefore, the ULS values will govern for design.

A working slab of 20 MPa concrete with a 100 mm thickness should be placed on the footing areas for the open footing culvert. For a box culvert, the bedrock should be levelled with 20 MPa concrete prior to placing the culvert or granular bedding could be placed below the culvert, as further discussed in Section 6.6.1.

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

Dewatering will be required to construct a cast-in-place culvert in the dry, as discussed further in Section 6.6.3.

6.3.1 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of a concrete box closed bottom culvert and the granular fill/bedding or footings for the CSP arch or open box culvert on the bedrock surface should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The following summarizes the coefficient of friction for the interface materials for a precast and cast-in-place concrete or footings.

Interface Materials	Coefficient of Friction
Precast Concrete on Compacted Granular 'B' Type II	$\tan \delta = 0.45$
Cast-in-Place Concrete on Compacted Granular 'B' Type II	$\tan \phi = 0.58$
Cast-in-Place Concrete on Bedrock	$\tan \phi = 0.70$

The values are unfactored, in accordance with CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistances.

6.3.2 Frost Protection

The estimated frost penetration depth in the Tehkummah Township area is 1.6 m, as per OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario).

As the footings for the CSP arch or open bottom box culvert will be founded directly on bedrock, frost susceptibility is not an issue.

Closed bottom box culverts are typically not provided with the standard depth for frost protection as close bottom box culverts are tolerant to small magnitudes related to freeze-thaw cycles should these occur. The box culvert should, however, be founded below any existing fill and surficial organic materials. If granular bedding is provided, it should be of limited thickness to bring the grade above the bedrock to founding level and should consist of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II.

6.4 Stability, Settlement and Horizontal Strain

The following sections summarize stability, settlement horizontal strains along the culvert beneath the influence of the proposed embankment loading.

The recommendations provided below assume that all organics soils beneath the culvert alignment will be removed prior to construction as discussed in Section 6.6 and that granular fill (i.e., Granular 'B' Type II) will be used for replacement of sub-excavated material.

6.4.1 Stability

Granular fill embankments overlying the thin layer of cohesionless soils underlain by bedrock should be stable at side slopes not steeper than 2 Horizontal to 1 Vertical (2H:1V) provided all organics are excavated down to bedrock prior to embankment construction.

6.4.2 Settlement

As the proposed culvert will be founded directly on the bedrock surface or on granular bedding layer overlying the bedrock surface, settlements will be negligible.

It is recommended that consideration be given to the use of OPSS.PROV1010 (Aggregates) Granular 'B' Type I or II for embankment reconstruction at the culvert location. Where granular fill will be placed below the water level, Granular 'B' Type II should be used. The material placed below the water level will compress/settle under its self-weight as additional fill is placed over it. The material placed above the water level should be compacted in accordance with OPSS 501 (Compacting). Compression settlement of the fill placed below water and from properly compacted embankment fill above water is expected to occur during construction.

6.4.3 Horizontal Strain

Based on the limited vertical settlements at this site (less than 25 mm), horizontal strain along the culvert is not expected to occur. 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 (or head/wing walls if required) of the culverts 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.PROV1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II should be used as backfill behind the culverts. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with OPSD 3101.150 (Wall, Abutment, Backfill) and OPSD 3121.150 (Walls Retaining, Backfill).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culverts any retaining walls, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compaction). Other surcharge loadings should be accounted for in the design as required.
- Granular fill may be placed either in a zone with the width equal to at least 1.6 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 1.5 H: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*).
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 2.6 m behind the back of the wall (in accordance with Figure C6.20(a) of the Commentary to the CHBDC). For unrestrained walls, granular fill should be placed within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the Commentary to the CHBDC). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	**Unit Weight**	**Coefficients of Static Lateral Earth Pressure**	
		At-Rest, K_o	**Active, K_a**
Granular ‘A’	22 kN/m^3	0.43	0.27
Granular ‘B’ Type II	21 kN/m^3	0.43	0.27

If the wing/head walls and culvert structures allow for lateral yielding, active earth pressures may be used in the geotechnical design of the structures. If the wing/retaining walls and culvert structures do not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical 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*.

6.6 Culvert Construction Considerations

6.6.1 Excavations, Subgrade Preparation, Bedding and Backfill Above Base of Culvert

All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). We understand that the highway will be closed to traffic during culvert replacement such that traffic staging is not required. The culvert may be installed using open-cut excavations with a maximum temporary side slope of 1.5H:1V or flatter within the existing fill and/or native soils (short-term excavations).

Prior to placing any bedding material or fill for new construction, all organics and native soils should be excavated to expose the bedrock surface within the plan limits of the proposed culvert footprint.

The precast box culvert should be constructed in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) and could be installed in wet conditions depending on the season of construction and water level at the site of installation. The box culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material for bedding purposes, which will likely be placed in the wet and nominally compacted by the construction equipment or placed on a concrete levelling pad.

The bedding, levelling pad and backfill for a CSP circular or arch culvert should be in accordance with OPSD 802.010 (Flexible Pipe Embedment and Backfill) or OPSD 802.020 (Flexible Pipe Arch Embedment and Backfill), 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 CSP culvert should be constructed on a minimum 200 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material for bedding purposes.

The fill depth during placement should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 500 mm.

The culverts should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m^3 for Granular 'A' and 21 kN/m^3 for Granular 'B' Type II backfill above and surrounding the culvert. Inspection and field density testing should be carried out by qualified personnel during fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved.

6.6.2 Erosion Protection

If the culvert is placed on a granular blanket, provisions should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert location. In order to prevent surface water from flowing either beneath the 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 concrete cut-off wall or clay seal should be provided at the upstream end of the 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 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

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 for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should follow the standard presented in OPSD 810.010 similar to the outlet. Rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culvert.

6.6.3 Control of Groundwater and Surface Water

Excavation within the plan limits of the proposed Blue Jay Creek alignment will be required to remove organics, existing granular fill, and cohesionless soils (sand) and cohesive (clayey silt to silt) soils prior to construction of the footings, placement of backfill/embankment fill, bedding material and the actual culvert structures. The existing culvert flows will need to be diverted/piped during construction. Surficial water seepage into the excavation should be expected and will be heavier during periods of sustained precipitation. Seepage from the granular fills, near surface native granular materials and the bedrock should be expected, particularly after precipitation events. It is anticipated that this surficial seepage can be controlled by using properly filtered sumps within the excavation.

For a cast-in-place culvert, dewatering will be required for construction in-the-dry. The excavations will be advanced through or into water-bearing cohesionless soils and pervious bedrock and appropriate unwatering of the water-bearing granular soil deposits will be required to maintain the water level below the founding level for the culvert during excavation and construction. It is recommended that an NSSP (Non-Standard Special Provisions) be included in the Contract to address unwatering for the culvert site; a sample NSSP is included in Appendix C.

Based on discussions with others and our observations at the site, we understand that Blue Jay Creek is fed with underground springs. The Contractor should be alerted to these springs as it may impact dewatering during constructions, as referenced in the NSSP in Appendix C.

6.6.4 Analytical Testing for Construction Materials

The analytical test results on a sample of creek water taken adjacent to the culvert site are presented in Table B1. The suite of parameters tested is intended to allow the structural engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection.

7.0 CLOSURE

This report was prepared by Mr. David Muldowney, P.Eng and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact, carried out a quality control review and reviewed the technical aspects of the report.

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Ministry of Northern Development and Mines, 1991. Bedrock Geology of Ontario, Southern Sheet, Map 2544.

STANDARDS

ASTM International:

ASTM D1586-08a	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Contract Design Estimating and Documentation (CDED)

Special Provision 110S13	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Occupational Health and Safety Act

Ontario Regulation 213/91	Construction Projects
Ontario Regulation 443/09	Amendment to Ontario Regulation 213/91

Ontario Provincial Standard Drawing

OPSD 802.010	Flexible Pipe, Embedment and Backfill - Earth Excavation
OPSD 802.020	Flexible Pipe Arch, Embedment and Backfill - Earth Excavation
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penentration Depths for Southern Ontario
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement

Ontario Provincial Standard Specification

OPSS 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Precast Reinforced Concrete Box Culverts
OPSS 501	Construction Specification for Compacting
OPSS 1002	Material Specification for Aggregates – Concrete
OPSS 1205	Material Specification for Clay Seal

Ontario Water Resources Act

Ontario Regulation 372/97	Amendment to Ontario Regulation 903

Table 1: Evaluation of Culvert Types

Options	Rank	Advantages	Disadvantages	Relative Costs
Precast Concrete Culvert	1	■ Straightforward construction. ■ Dewatering/unwatering less for pre-cast option. ■ Open bottom culvert suitable for sites where reduced impact to creeks bed is required.	■ Bedding material may be required for a pre-cast closed bottom culvert. ■ Foundation support may not be adequate for open footing culvert.	■ Additional transportation costs for pre-cast option.
Cast-In-Place Concrete Culvert	2	■ Open bottom culvert suitable for sites where reduced impact to creeks bed is required.	■ Dewatering required for cast-in-place concrete. ■ Longer construction period. ■ Cast in place culverts may require longer duration for construction including dewatering and surface water pumping.	■ Additional cost for dewatering. ■ Additional cost for concrete form work for cast-in-place option.
CSP (circular or arch)	3	■ Straightforward construction.	■ Bedding material required for circular CSP. ■ Dewatering required for cast-in-place footings for CSP arch. ■ May not have sufficient hydraulic capacity. ■ Limited design life.	■ Additional costs for dewatering.

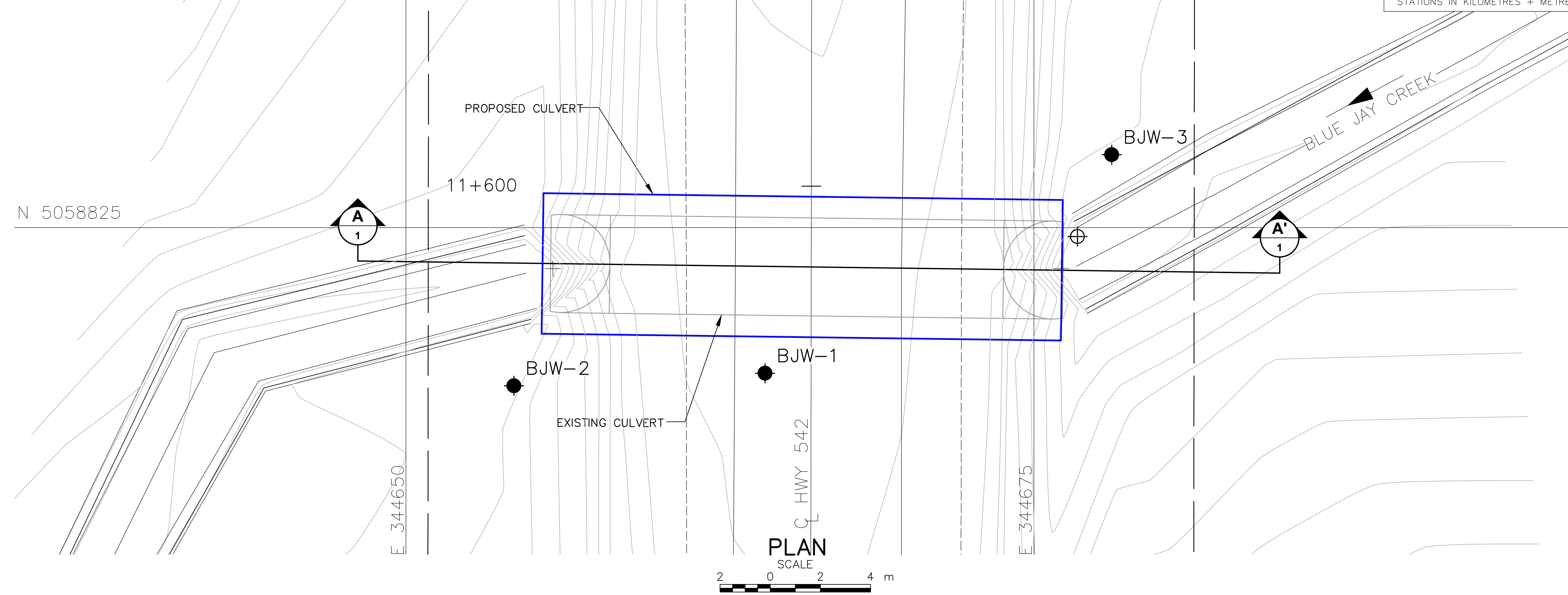
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5090-13-00

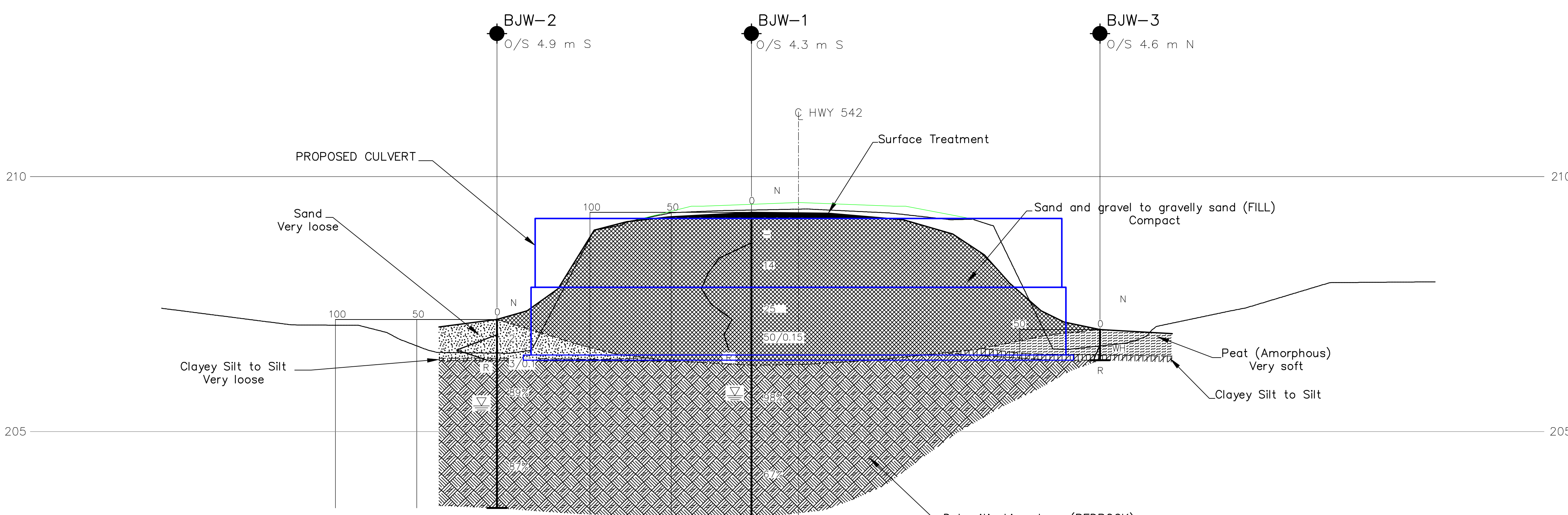
SHEET

HIGHWAY 542
BLUE JAY CREEK CULVERT STA. 11+597
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA

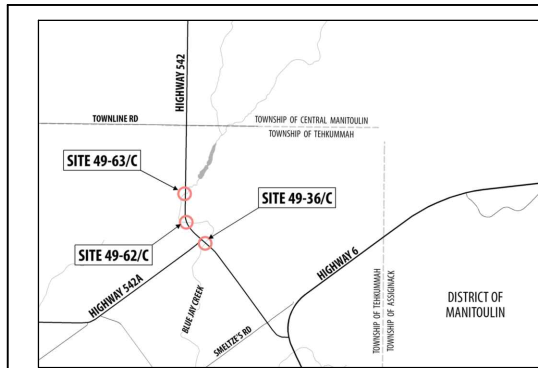


PLAN
SCALE
2 0 2 4 m



A-A' 1 CULVERT PROFILE STA. 11+597
HIGHWAY 542

HORIZONTAL SCALE
2 0 2 4 m
1 0 1 2 m
VERTICAL SCALE



KEY PLAN
N.T.S.

LEGEND

- ● Borehole – Current Investigation
- ⊕ Borehole – Pavement
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- R Refusal
- ▽ WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BJW-1	209.3	5058819.2	344664.3
BJW-2	207.2	5058818.7	344654.3
BJW-3	207.0	5058827.9	344678.1

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 McIntosh Perry, drawing file nos. 11-684-Bluejay (all 3) - XREF.dwg, received OCT 19, 2012. Cross-sections drawing file nos. Blue Jay and Jocko Cross-Sections.dwg, received NOV 22, 2012. Keyplan received August 24, 2012 file nos. KM11684-49-63,49-62 and 49-36 Location Map - June 26.2012.jpg. Proposed culvert drawing file nos. OKM-11-684-Blue Jay Creek Site 49-63 Plan and Profile.dwg and KM-11-684 BlueJay Site 62 & 63 Elevation.dwg, received MAR 2, 2016.

LICENSED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 MAR 11, 2016 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN MAR 11, 2016 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 41H-127

HWY. 542	PROJECT NO. 12-1191-0014		DIST.
SUBM'D. DAM	CHKD. AB	DATE: MAR 2016	SITE: 49-63/C
DRAWN: JJL	CHKD.	APPD. FJH	DWG. 1

Photograph 1: Looking northeast at culvert outlet (September 2012)

Photograph 2: Looking northeast from culvert inlet (November 2012)

APPENDIX A

Record of Boreholes and Drillholes

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

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		

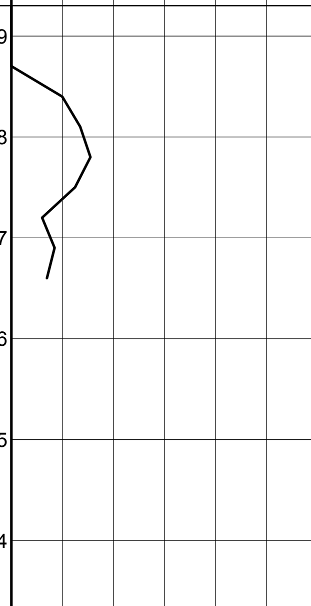
RECORD OF BOREHOLE No BJW-1

 METRIC

PROJECT 12-1191-0014
G.W.P. 5465-09-00
LOCATION N 5058819.2; E 344664.3
ORIGINATED BY EHS
DIST HWY 542
BOREHOLE TYPE 108 mm I.D. Continous Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY MH
DATUM GEODETIC
DATE September 20, 2012
CHECKED BY DAM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
209.3	GROUND SURFACE						
0.0 / 0.1	Surface Treatment (50 mm)						
	Sand and gravel to gravelly sand, trace to some silt (FILL) Compact to very dense Brown Moist	1	AS	-		209	
		2	SS	14			
		3	SS	25		208	23 66 (11)
	Augers grinding on cobbles at 2.4 m and 2.9 m depth.	4	SS	50/0.15		207	
206.3 / 3.0	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 3.0 m depth to 6.0 m depth. For coring details see Record of Drillhole BJW-1.	1	RC	REC 100%	∇	206 / 205	RQD = 98%
		2	RC	REC 100%		204	RQD = 67%
203.3 / 6.0	END OF BOREHOLE Note: 1. Water level at a depth of 3.6 m below ground surface (Elev. 205.7 m) upon completion of drilling. 2. Advanced DCPT 1.5 m south of Borehole BJW-1. Augered to 1.0 m depth prior to start of DCPT. DCPT refusal (hammer bouncing) at 2.9 m depth (Elev. 206.4 m).						

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

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

RECORD OF DRILLHOLE: BJW-1

PROJECT: 12-1191-0014
LOCATION: N 5058819.2 ;E 344664.3
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 20, 2012
DRILL RIG: CME 850
DRILLING CONTRACTOR: Landcore 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.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH COLOUR % RETURN | RECOVERY: TOTAL CORE % (80 60 40 20), 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

~SEE PREVIOUS PAGE~

Depth (m)	Elev.	Description	Drilling record	Run No.	Flush colour % return
3.0	206.3	DOLOMITIC LIMESTONE Fine grained Slightly weathered Brown to grey	September 20, 2012; NQ Coring; NW	1	GREY 100%
				2	GREY 100%
6.0	203.3	END OF DRILLHOLE			

Discontinuity type and surface description (run 1): JNPLRo, JNIRRo, JNPLRo, JNPLRo, JNPLRo, JNPLRo, JNPLRo

Discontinuity type and surface description (run 2): JNPLRo, JNPLRo, JNPLRo, JNPLRo, JNPLRo, JNPLRo, JNPLRo, JNPLRo, JNPLRo

Depth scale: 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: EHS
CHECKED: DAM

Golder Associates

RECORD OF BOREHOLE No BJW-2

 METRIC

PROJECT 12-1191-0014
G.W.P. 5465-09-00
LOCATION N 5058818.7; E 344654.3
ORIGINATED BY EHS
DIST HWY 542
BOREHOLE TYPE 108 mm I.D. Continous Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY MH
DATUM GEODETIC
DATE September 21, 2012
CHECKED BY DAM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
207.2	GROUND SURFACE						
0.0	SAND, trace gravel, trace to some organics Very loose Grey Wet	1	SS	2		207	
206.6 0.8	Augers grinding on cobbles at 0.5 m depth.	~~2~~	~~SS~~	~~3/0.1~~			
	CLAYEY SILT to SILT, some sand, some gravel Very loose Grey Wet	1	RC	REC 100%	∇	206	RQD = 89%
	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 0.8 m depth to 3.7 m depth. For coring details see Record of Drillhole BJW-2.	2	RC	REC 100%		205 204	RQD = 87%
203.5 3.7	END OF BOREHOLE						

Column headers also include: SOIL PROFILE; SAMPLES; STRAT PLOT; 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; GR SA SI CL.

Note:

1. Water level at a depth of 1.7 m below ground surface (Elev. 205.5 m) upon completion of drilling.

2. Advanced DCPT 1.0 m south of Borehole BJW-2. DCPT refusal (hammer bouncing) at 0.8 m depth (Elev. 206.4 m).

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

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: BJW-2

LOCATION: N 5058818.7 ;E 344654.3

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 21, 2012

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore 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.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % / SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25 m	B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		~SEE PREVIOUS PAGE~		206.4															
1–3	September 21 2012; NQ Coring; NW	DOLOMITIC LIMESTONE Fine to medium grained Slightly weathered Grey to brown		0.8	1	GREY 100%						JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo							∇
					2	GREY 100%						JNPLRo JNPLRo JNPLRo JNPLSM JNPLRo JNPLRo JNPLRo JNPLRo JNPLRo							
				203.5 3.7															
4–10		END OF DRILLHOLE																	

DEPTH SCALE

1 : 50

LOGGED: EHS

CHECKED: DAM

Golder Associates

Golder Associates

RECORD OF BOREHOLE No BJW-3

 METRIC

PROJECT 12-1191-0014
G.W.P. 5465-09-00
LOCATION N 5058827.9; E 344678.1
ORIGINATED BY EHS
DIST HWY 542
BOREHOLE TYPE 108 mm I.D. Continous Hollow Stem Augers
COMPILED BY MH
DATUM GEODETIC
DATE September 21, 2012
CHECKED BY DAM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
207.0	GROUND SURFACE										
0.0	PEAT, some sand, trace gravel (Amorphous) Very soft Black Wet		1	SS	WH				93.5		
206.5 0.6	CLAYEY SILT to SILT, some sand, some gravel Grey Wet										
	END OF BOREHOLE AUGER REFUSAL										

Notes:

1. Borehole dry upon completion of drilling.

2. Advanced DCPT 1.0 m north of Borehole BJW-3. DCPT refusal (hammer bouncing) at 0.6 m depth (Elev. 206.4 m).

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L.

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

Culvert Replacement (Site 49-63C, on Hwy 542; W.P. 5066-07-01) 12-1184-0051
Station 11+575 to 11+625, Referenced to C/L March, 2013

11+598 10.60 Rt C/L D-2.00 HA

0	- 300	Wat
300	- 500	Gry Si Sa W Gr Occ Cob, Sat, Comp
	- 500	NFP BR

11+600 2.00 Rt C/L D-0 PA

0	- 090	PST
090	- 270	Br Cr Gran
270	- 2.90	Br Gr(y) Sa Tr Si Occ Cob Occ Blds, Moist, Wet @ 2.20, Comp
	- 2.90	NFP BR

11+601 4.40 Rt C/L D-0 PA

0	- 180	Br Cr Gran
180	- 1.30	Br F-Co Sa Tr Si Tr Gr Occ Cob Occ Blds, Moist, Comp
	- 1.30	NFP Blds

11+605 4.20 Lt C/L D-0 PA

0	- 200	Br Cr Gran
200	- 590	Br Gr(y) Sa W Si Occ Cob, Moist, Comp
590	- 1.50	Gry Sa Si Tr Cl Tr Gr, Wet, Comp
1.50	- 2.00	Gry Cl Si Tr Sa Tr Gr, Moist, Firm
2.00	- 2.90	Dk Gry-Blk Cl Si Tr Sa W Org M, Moist, Firm
	- 2.90	NFP BR

11+605 4.10 Rt C/L D-0 PA

0	- 270	Br Cr Gran
270	- 2.00	Br Gr(y) Sa W Si Occ Cob, Moist, Comp
	- 2.00	NFP BR

11+609 4.10 Lt C/L D-0 PA

0	- 180	Br Cr Gran
180	- 1.40	Br Gr(y) Sa Tr Si Occ Cob Occ Blds, Moist, Comp
1.40	- 1.60	Gry Si Sa W Gr Occ Cob Occ Blds, Moist, Comp
	- 1.60	NFP Blds

11+609 4.30 Rt C/L D-0 PA

0	- 320	Br Cr Gran
320	- 1.20	Br Gr(y) Sa W Si Occ Cob, Moist, Comp
1.20	- 1.80	Dk Br-Gry Cl Si W Sa Tr Gr Tr Org M, Wet, Firm
	- 1.80	NFP BR

11+625 9.00 Lt C/L D-1.40 HA

0	- 090	Dk Br Si Tps
090	- 1.80	Br Cl Si Tr Sa Tr Gr, Moist, Fr Wat @ 700, Sat, Firm
	- 1.80	NFP BR

APPENDIX B

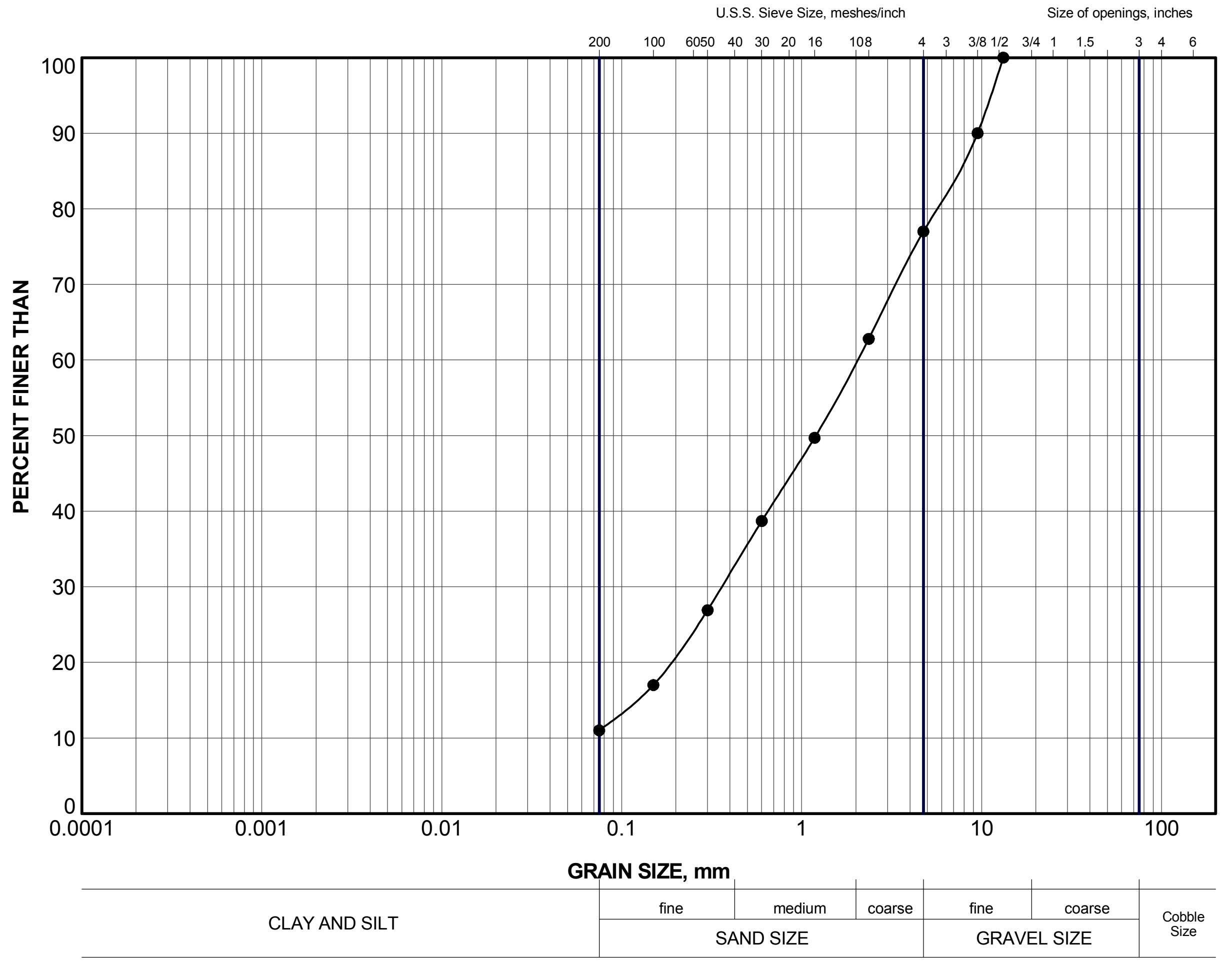
Laboratory Test Results

Table B1 - Summary of Analytical Testing of Creek Water

Parameter	Units	Method Detection Limit	Result
Resistivity	ohm-cm	n/a	3300
Conductivity	µmho/cm	1	300
pH	n/a	n/a	8.00
Sulphate	mg/L	1	14
Chloride	mg/L	1	4

Notes:
1. Sample obtained November 5, 2012.
2. Analytical testing carried out by Maxxam Analytics Inc.

Prepared by: DAM
Reviewed by: AB



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BJW-1	3	207.5

PROJECT

HIGHWAY 542
BLUE JAY CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

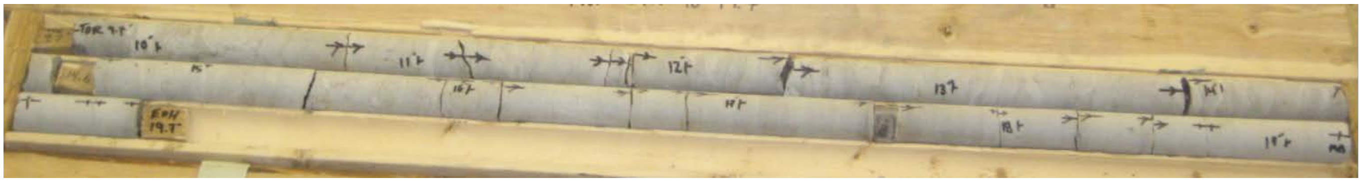
GRAVELLY SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	12-1191-0014		FILE No.	1211910014.GPJ
DRAWN	JJL	Sep 2013	SCALE N/A	REV.
CHECK	AB	Sep 2013		
APPR	FJH	Sep 2013	FIGURE B1	

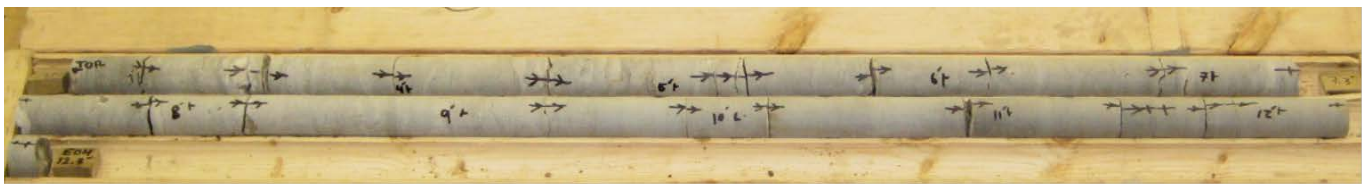
SUD-MTO GSD (NEW) GLDR_LDN.GDT

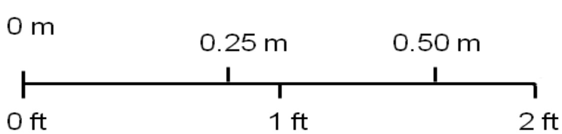
Borehole BJW-1
Elev. 206.3 m to 203.3 m



Borehole BJW-2

Elevation 206.4 m to 203.5 m





PROJECT	HWY 542 Blue Jay Creek Culvert Site # 49-63			
TITLE	BEDROCK CORE			
Golder Associates	PROJECT No. 12-1191-0014			FILE No. ----
	DESIGN	MH	Feb 2012	SCALE AS SHOWN REV.
	CADD	--		FIGURE B2
	CHECK	AB	Feb 2012	
	REVIEW			

APPENDIX C

Non-Standard Special Provisions and Operational Constraints

GROUNDWATER CONTROL - Item No.

Non-Standard Special Provision

Foundations for the new Blue Jay Creek culvert will require excavations to extend below the groundwater level at the site. Cohesionless soils (silty, sandy, gravelly) that are present below the groundwater table would slough, run, boil or cave into the excavation without appropriate groundwater controls. However, the excavation should be taken down to the bedrock surface. Further, the bedrock is fractured and springs (artesian conditions) are known to be present in the vicinity of the site and feed Blue Jay Creek. The Contractor is to design and install an appropriate dewatering system for the culvert site to enable construction in dry conditions.

Basis of Payment

Payment at the lump sum contract price for this Tender Item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

WORKING SLAB - Item No.

Non-Standard Special Provision

Scope of Work

This Special Provision covers the requirements for the supply and placement of a concrete working slab for the Blue Jay Creek culvert. The purpose of the working slab is to provide a level working surface above the bedrock.

Construction

Protection of Founding Soil

- Following inspection and approval of the prepared bedrock surface by the Quality Verification Engineer, a working slab, with a minimum thickness of 100 mm shall be placed on the foundation subgrade as per the contract drawings and documents. The concrete shall have a minimum 28 day compressive strength of 20 MPa.

Unwatering of the excavation for the culvert construction may be required, including the construction of the working slab.

Basis of Payment

Payment at the Contract Price for the above tender item includes full compensation for all labour, equipment and material to do the required work.

END OF SECTION

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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